Appendix E
Florida Department of Environmental Protection
Air Quality Permit Application

Attachment I-3

Detailed Description of Control Equipment / Vendor Data

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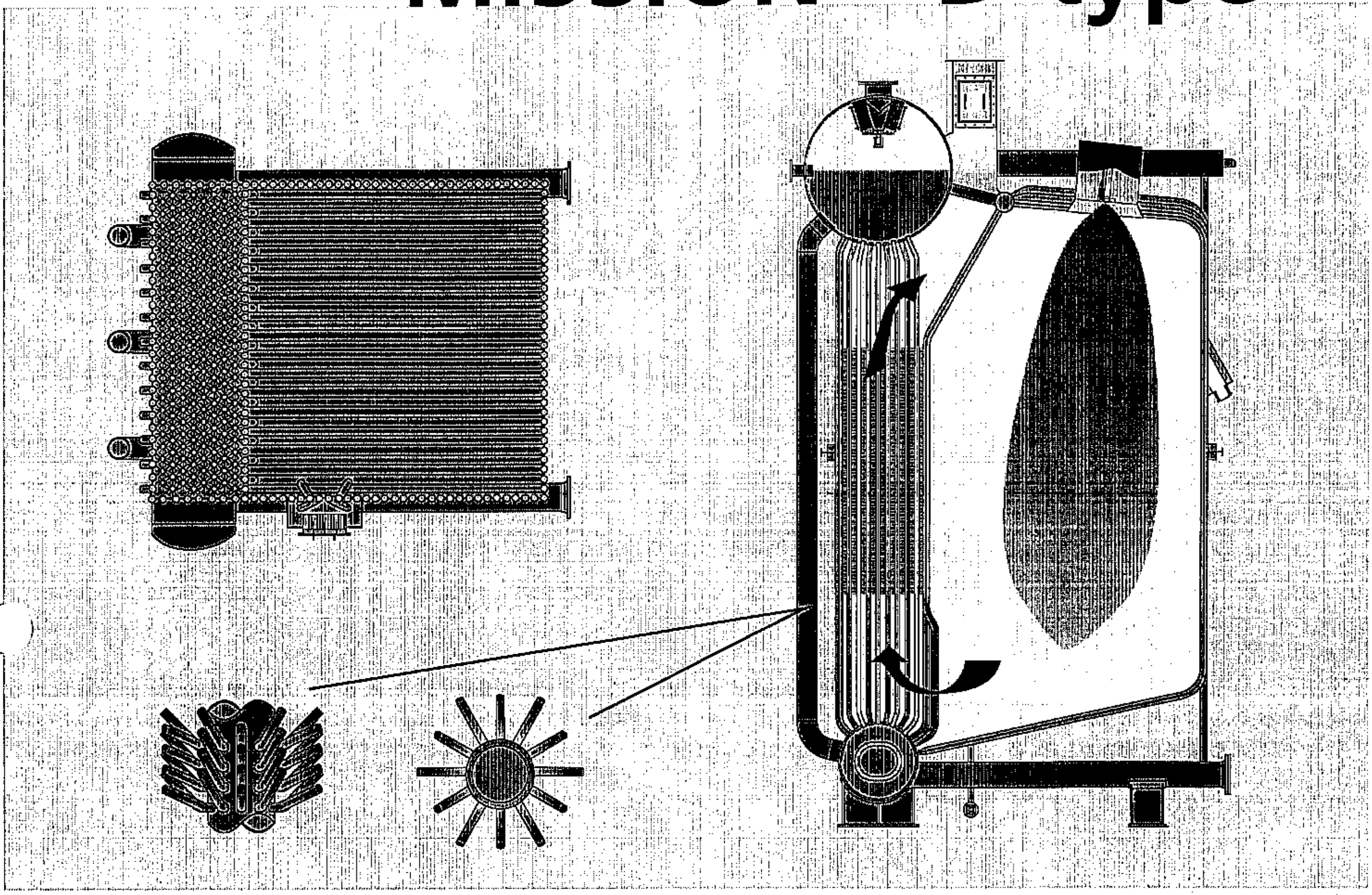
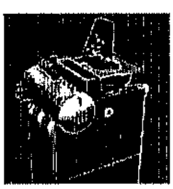
AALBORG BOILER DATA

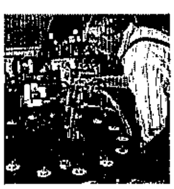
AALBORG INDUSTRIES

High performance D-type modular boiler plant

MISSION™ D-type





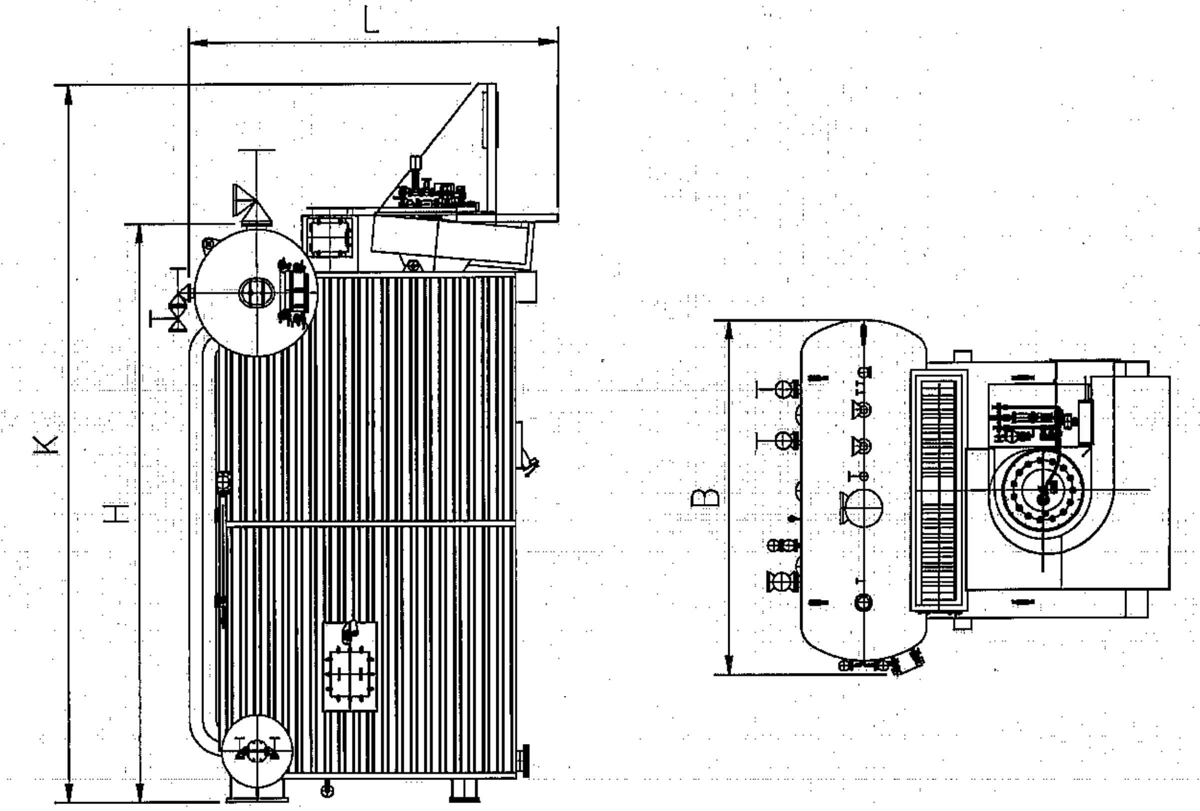


MISSION™ D-type is a standard vertical two-drum boiler. The furnace is built of membrane walls and contains a minimum of refractory.
The convection section consists of straight pin tubes with bent pins that provide a high heat transfer coefficient and low pressure loss. Circulation is ensured by downcomers arranged outside the furnace.

Capacity range: 25 – 120 t/h

AALBORG INDUSTRIES

MISSION™ D-type boiler



STANDARD PRODUCT RANGE

Capacity and dimensions

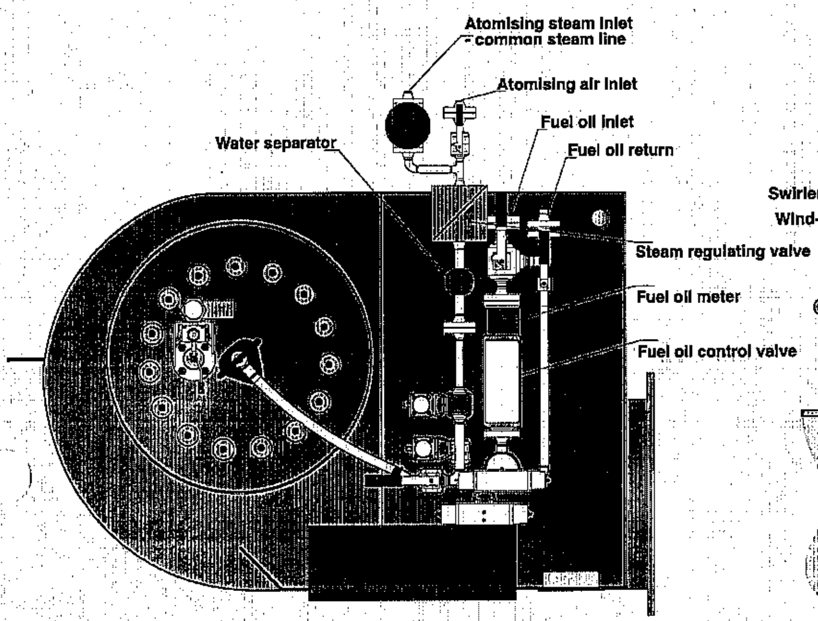
Steam capacity	Design pressure	Thermal output at 100% MCR	Height K (incl retraction of burner lance)	Total lenght L	Hight H	Width B (steam drum+200)	Boiler dry weight *)	Boiler operation weight
kg/h	bar (g)	kW	mm	mm	mm	mm	ton	ton
25,000	18	17,600	9,170	4,309	6,280	3,837	31.6	39.6
35,000	18	24,700	9,520	4,583	6,980	4,187	38.2	48.6
45,000	18	31,800	9,870	5,050	8,080	4,875	44.2	57.0
55,000	18	38,800	10,370	5,413	8,480	5,131	50.6	65.7
70,000	18	49,400	10,670	5,508	8,080	6,031	60.9	78.7
80,000	18	56,500	10,670	5,705	8,080	6,571	66.5	86.1
100,000	18	70,600	11,170	6,006	8,480	7,677	81.1	105.6
120,000	18	84,700	11,470	6,779	9,380	8,049	91.8	120.9

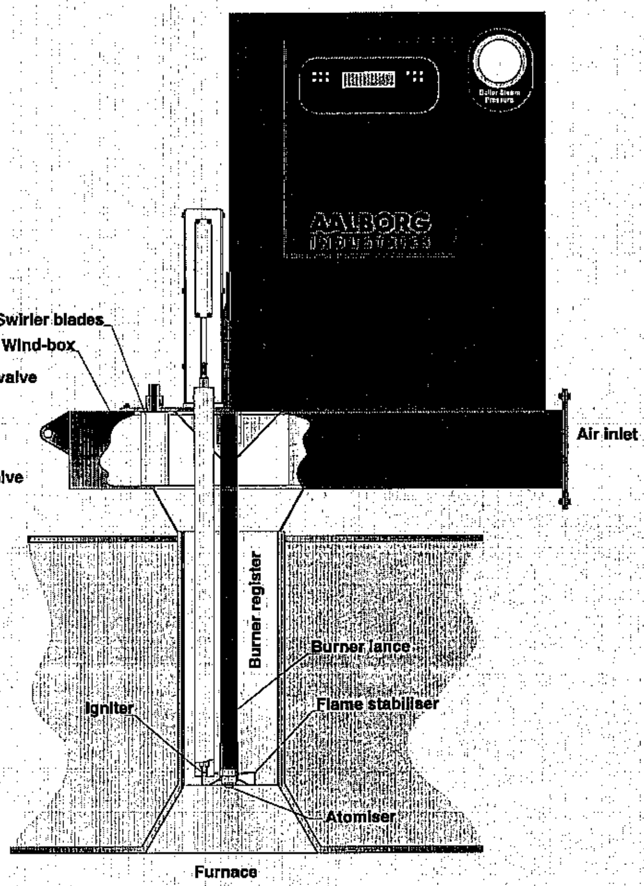
*) boiler dry weight incl. burner, insulation, valves, and refractory

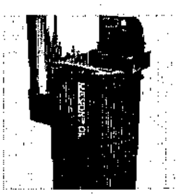
Your Preferred Partner

Steam atomising oil burner for diesel oil and heavy fuel oil KBSD 950 – KBSD 4150

KBSD







The KBSD steam atomising burner is designed for use on our top-fired boilers and is delivered pre-mounted.
A dynamic wind-box provides for low pressure loss and a stable combustion at low loads. All burner mountings are arranged to ensure easy installation and maintenance.

Capacity range: 1.7 – 46.6 MW

AALBORG INDUSTRIES

KBSD 950 – KBSD 4150 steam atomising burner

Description

The KBSD steam atomising burner has been designed to meet customer requirements such as high turn-down radio, minimum installation and operation costs, and the capability to produce inert gas at low loads.

Furthermore, the burner is a low-NO_X burner that will meet future marine environmental legislation regarding NO_X and particulate emissions.

Combustion processes are controlled by adjusting the swirl angle of the air flow, enchanced by very reliable system components controlling the fuel air flow. The KBSD burner has passed a rigorous and very extensive testing program, proving that the burner performs well on all grades of fuel oil. Additionally, the burner design has made it possible to achieve stable combustion with an excess air ratio of approx. 1.15.

Safe ignition of the burner is ensured by the fixed ignition burner which is equipped with its own ignition transformer, oil pump and nozzle. During operation of the main burner, the ignition burner is purged with air in order to prevent coke formation on the nozzle and the electrodes.

STANDARD PRODUCT RANGE

Capacity and dimensions

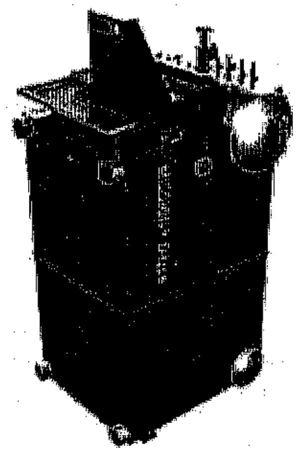
Burner type	Guideline boiler output	Capacity Min. - max.	Diesel oil consumption	Heavy fuel oil consumption min. - max.	Combustion air consumption max.	Combustion air consumption min.	Atomising steam consumption	Atomising air consumption
	kg/h	MW	kg/h	kg/h	Nm³/h	Nm³/h	kg/h	kg/h
KBSD 950	12,500	1.7–10.6	890	150–950	11,204	2,188	46	85
KBSD 1200	16,000	1.7–13.4	1,140	150–1,200	14,409	2,312	60	110
KBSD 1500	20,000	1.7–16.8	1,440	150–1,550	18,244	2,390	76	140
KBSD 1900	25,000	2.1–21.2	1,790	190–1,900	22,642	2,987	94	170
KBSD 2250	30,000	2.5–25.1	2,140	225–2,250	27,092	3,522	110	200
KBSD 2650	35,000	3.0–29.6	2,510	265–2,650	31,805	4,150	130	240
KBSD 3000	40,000	3.4–33.5	2,880	300–3,000	36,393	4,460	150	270
KBSD 3350	45,000	3.7–37.4	3,220	335–3,350	40,710	5,260	170	310
KBSD 4150	55,000	4.7–46.6	3,950	420–4,150	49,924	6,362	210	370

General burner data

Heavy fuel oil data			**General data**		
Max. viscosity at 50°C	700	cSt	Atomising steam/air pressure, min	6.5	bar (g)
Max. viscosity at burner inlet	15	cSt	Excess air ratio	1.15	–
Calorific value	40.2	MJ/kg	Combustion air temperature, design	45	°C
			Fuel oil delivery pressure	2.5	bar (g)
Diesel oil data (for ignition burner)					
Viscosity	1.3–12	cSt	NO_X emissions	0.6	g/kWh
Calorific value	42.2	MJ/kg	Particulate emissions	0.3	g/kWh

Product Range

MISSION™ D-type



General

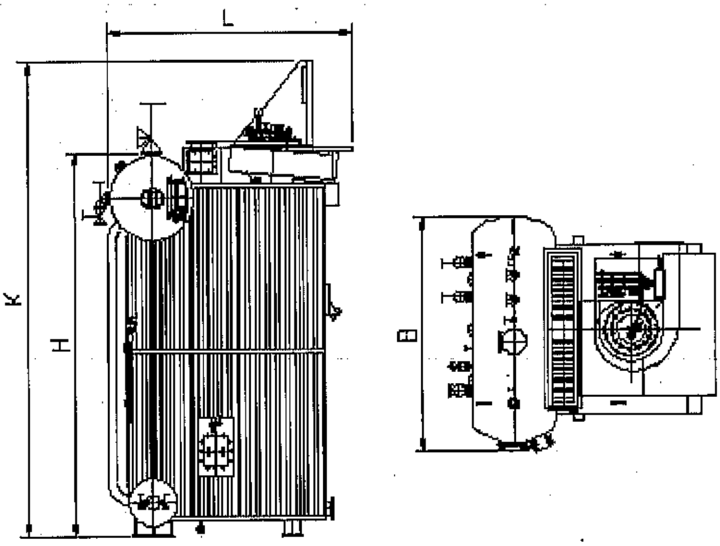
- Standard medium pressure water tube boiler
- Two-drum D-type configuration
- Horizontal flue gas pass
- Delivered as complete unit for easy installation
- Available with pin tubes or bare tubes

Design data

Steam capacity:	25 - 120 t/h / 18 - 90 MWe
Design pressure:	24 bar(g)
Steam pressure:	18 - 24 bar
Steam temperature:	Saturation - up to +40ºC

- Send Online inquiry
- Download datasheet (PDF - 750 kb - 267 sek/28k)
- Burner selection (PDF - 180 kb - 64 sek/28k)
- Download brochure (PDF - 800 kb -284 sek/28k)

Capacity, Fuel economy, Dimensions & Weight:



Steam capacity	Design pressure	Thermal output at 100% MCR	Height "K" (incl. retraction of burner lance)	Total length "L"	Height "H"	Width "B" (steam drum +200)	Boiler dry weight *)	Boiler operation weight
kg/h	bar (g)	kW	mm	mm	mm	mm	ton	ton
25,000	18	17,600	9,170	4,309	6,280	3,837	31.6	39.6
35,000	18	24,700	9,520	4,583	6,980	4,187	38.2	48.6

45,000	18	31,800	9,870	5,050	8,080	4,875	44.2	57.0
55,000	18	38,800	10,370	5,413	8,480	5,131	50.6	65.7
70,000	18	49,400	10,670	5,508	8,080	6,031	60.9	78.7
80,000	18	56,500	10,670	5,705	8,080	6,571	66.5	86.1
100,000	18	70,600	11,170	6,006	8,480	7,677	81.1	105.6
120,000	18	84,700	11,470	6,779	9,380	8,049	91.8	120.9

*) Boiler dry weight incl. burner, insulation, valves and refractory.

For 24 barg solution call you nearest sales office

DATA SHEET series

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EMISSIONS DATA (BOILERS)

AALBORG INDUSTRIES

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Fax +45 98 16 85 16
Telex 69705 albor dk
Giro No. 844-7756
VAT No. DK 17937677

Bankers: Danske Bank A/S, Copenhagen
IBAN: DK 73 3000 3201 669138
Nordea A/S, Copenhagen
IBAN: DK 30 2000 0270 344283

NOx Emission Data for Mission 100 and Mission 120

TABLE 1 - Predicted NOx values, calculated at 3% O_2.

70 t/h Boiler – Mission 100

Load (%)	FGR (%)	ppm	mg/Nm^3
100	0	44	90
100	15	25	49
60	0	43	88
60	15	25	49

100 t/h Boiler – Mission 120

Load (%)	FGR (%)	ppm	mg/Nm^3
100	0	48	98
100	15	27	55
60	0	41	84
60	15	25	49

These values have been calculated for Natural Gas.

TABLE 2 - Guaranteed NOx values, calculated at 3% O_2.

70 t/h Boiler – Mission 100

Load (%)	FGR (%)	ppm	mg/Nm^3
100	0	51	104
100	15	29	56
60	0	50	102
60	15	29	56

100 t/h Boiler – Mission 120

Load (%)	FGR (%)	Ppm	mg/Nm^3
100	0	55	113
100	15	31	64
60	0	47	97
60	15	29	56

Exhaust Emissions from MISSION™ D Boiler

Fuel

Produced fuel gas:
Molecular Weight: 18.87

Density:	0.844 kg/Nm^3
Higher Calorific Value:	54.34 MJ/kg
Elemental Analysis:	Carbon 76.63 %
	Hydrogen 23.37 %

The boilers are considered at the normal loads. The operating basis for the emission calculations is as follows:

Boiler Type		MISSION D 100
Boiler Capacity	t/h	90
Combustion Air Temperature	Deg-C	35
Furnace Volume	m^3	109
Fuel Gas Rate	kg/h	5485
Excess Oxygen (dry)	%	3.0

The exhaust composition main constituents are not a function of the boiler and burner design and operating conditions and hence do not change with boiler type. The exhaust gas compositions for the fuel oils and fuel gas are given below (Dry, 3% O_2 @ 273K and 101kPa).

Produced Fuel Gas

Component	% by Volume	% by Mass
Carbon Dioxide, CO_2	10.414	15.321
Water, H_2O	0.0	0.0
Sulphur Dioxide, SO_2	0.0	0.0
Oxygen, O_2	3.007	3.217

The amount of exhaust gas is 18.34 kg per kg of fuel gas fired.

The exhaust gas molecular weight is 29.908 and density is 1.334 kg/Nm^3

Nitrogen Oxides (NO_x)

Values are stated in mg/Nm^3 at 3% O_2 @ 273K and 101kPa.

Standard Burner	Low NOx Burner
125	79

Note: These values are predictions only, and not guarantee values.

Carbon Monoxide (CO)

Carbon Monoxide emissions for a boiler/burner combination operating at its design conditions (e.g. clean, etc.) will be extremely low and of the order of 10 –20 ppm (13 – 27 mg/Nm^3 @ 3% O_2, 273K and 101 kPa)

Carbon Monoxide emissions increase in the event of incomplete combustion due to factors, such as:

1. In-sufficient air supply
2. Poor fuel oil atomisation
3. Dirty, blocked air swirlers
4. Dirty, blocked fuel nozzles
5. Flame impingement on boiler tube surfaces

Correct operation and maintenance procedures will ensure Carbon Monoxide emissions are limited to the typical values given above.

Unburnt Hydrocarbons (UHC)

For the DF burner type burner the predicted stack solids (PM) emissions for the boiler are virtually zero for the produced fuel gas as the fuels are so clean and pure.

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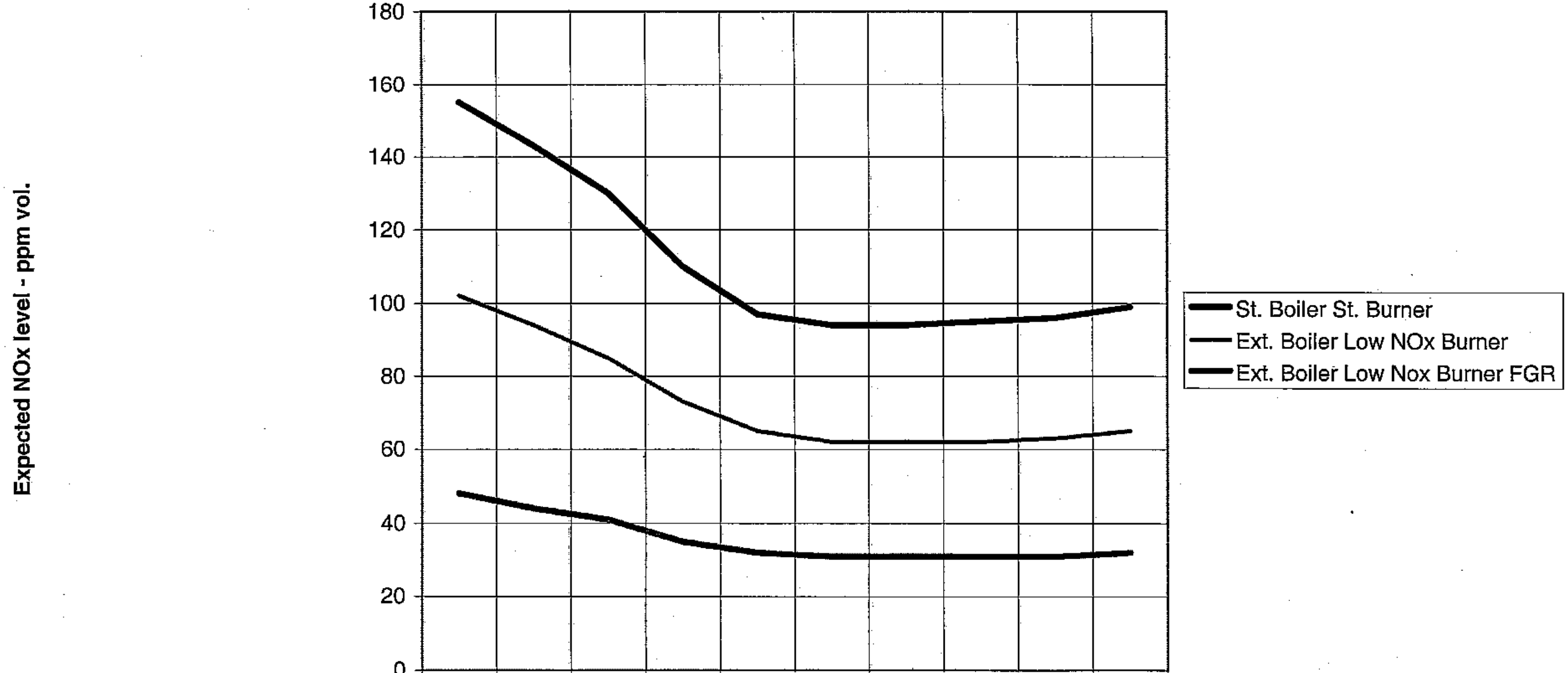
EMISSIONS CONTROL SYSTEMS DATA (BOILERS)

Basis for data:

Fuel Gas Composition	Range (Mole %):
Nitrogen	0.01 %
Methane (CH_4)	96.84 %
Ethane (C_2H_6)	2.73 %
Propane (C_3H_8)	0.35 %
Butane (C_5H_{10})	0.06 %
Pentanes and heavier	0.01 %
Sulphur and/or Sulphur compounds	0%
Ash and/or un-combustible solids	0%
Average Heat Value	HHV – 55.3 MJ/kg LHV – 49.9 MJ/kg
Supply press	3 barg
Supply Temp	0-30 C
Steam production	100 t/h
Steam press	28 barg
Feed water temp	60 C
Ambient temp	25 C

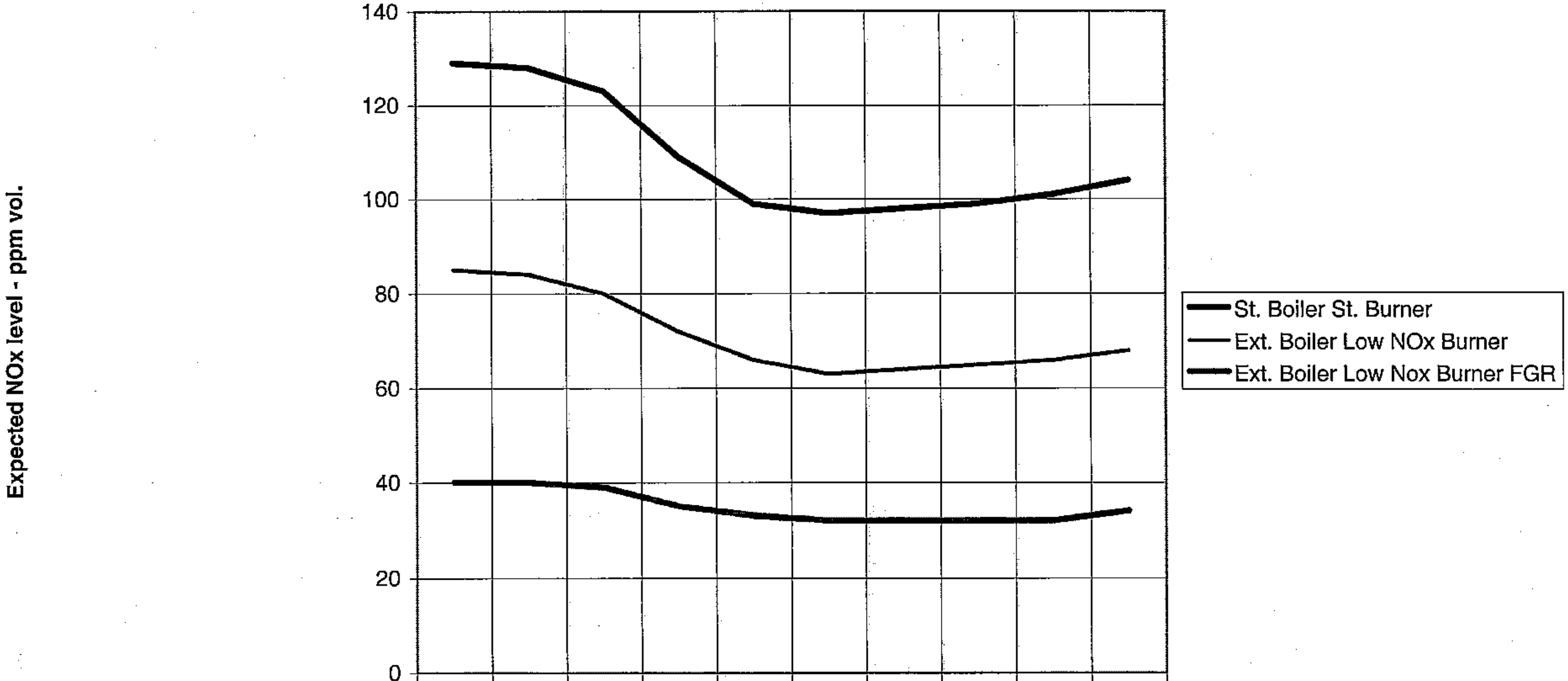
Boiler and Burner versus NOx Emisssion
(NOx converted to 3% Oxygen (dry) content in Flue Gas)



	15	20	30	40	50	60	70	80	90	100*
St. Boiler St. Burner	155	143	130	110	97	94	94	95	96	99
Ext. Boiler Low NOx Burner	102	94	85	73	65	62	62	62	63	65
Ext. Boiler Low Nox Burner FGR	48	44	41	35	32	31	31	31	31	32

% Load

Boiler and Burner versus NOx Emisssion
(NOx at expected Oxygen (dry) content in Flue Gas)



% Load	15	20	30	40	50	60	70	80	90	100*
St. Boiler St. Burner	129	128	123	109	99	97	98	99	101	104
Ext. Boiler Low NOx Burner	85	84	80	72	66	63	64	65	66	68
Ext. Boiler Low Nox Burner FGR	40	40	39	35	33	32	32	32	32	34

% Load

Standard Boiler and Standard Burner

Boiler	Flue Gas						
Load	Mass	Volume	Temp.	Oxygen	NOx	NOx	Recirculation
%	kg/h	Nm^3/h	°C	%	ppm	ppm	%
					@ stated O_2 dry	@ 3% O_2 dry	
15	19917	15028	244	6	129	155	0
20	24289	18290	252	4.84	128	143	0
30	34278	25774	268	3.96	123	130	0
40	43678	32796	286	3.15	109	110	0
50	53639	40241	297	2.65	99	97	0
60	63951	47960	327	2.44	97	94	0
70	74922	56176	350	2.32	98	94	0
80	85733	64271	374	2.22	99	95	0
90	97887	73374	378	2.15	101	96	0
100*	109538	82101	399	2.1	**104**	**99**	0

* Guarantee value for NOx, ppm - vol. +/-5%

Boiler with extended furnace and Low NOx Burner

Boiler	Flue Gas						
Load	Mass	Volume	Temp.	Oxygen	NOx	NOx	Recirculation
%	kg/h	Nm^3/h	°C	%	ppm	ppm	%
					@ stated O_2 dry	@ 3% O_2 dry	
15	19506	14717	244	6	85	102	0
20	23796	17919	250	4.84	84	94	0
30	33588	25255	261	3.96	80	85	0
40	42798	32135	273	3.15	72	73	0
50	52549	39423	286	2.65	66	65	0
60	62646	46981	299	2.44	63	62	0
70	73546	55144	314	2.32	64	62	0
80	83945	62931	329	2.22	65	62	0
90	95819	71824	344	2.15	66	63	0
100*	106949	80160	359	2.1	**68**	**65**	0

* Guarantee value for NOx, ppm - vol. +/-5%

Boiler with extended furnace, Low NOx Burner and Flue Gas Recirculation

Boiler	Flue Gas						
Load	Mass	Volume	Temp.	Oxygen	NOx	NOx	Recirculation
%	kg/h	Nm^3/h	°C	%	ppm	ppm	%
					@ stated O_2 dry	@ 3% O_2 dry	
15	19778	14923	247	6	40	48	15 - 20
20	24178	18207	253	4.84	40	44	15 - 20
30	34045	25598	266	3.96	39	41	15 - 20
40	43380	32573	280	3.15	35	35	15 - 20
50	53271	39965	295	2.65	33	32	15 - 20
60	63510	47629	311	2.44	32	31	15 - 20
70	74400	55785	328	2.32	32	31	15 - 20
80	85128	63818	346	2.22	32	31	15 - 20
90	97188	72850	363	2.15	32	31	15 - 20
100*	108618	81411	381	2.1	**34**	**32**	15 - 20

* Guarantee value for NOx, ppm - vol. +/-5%

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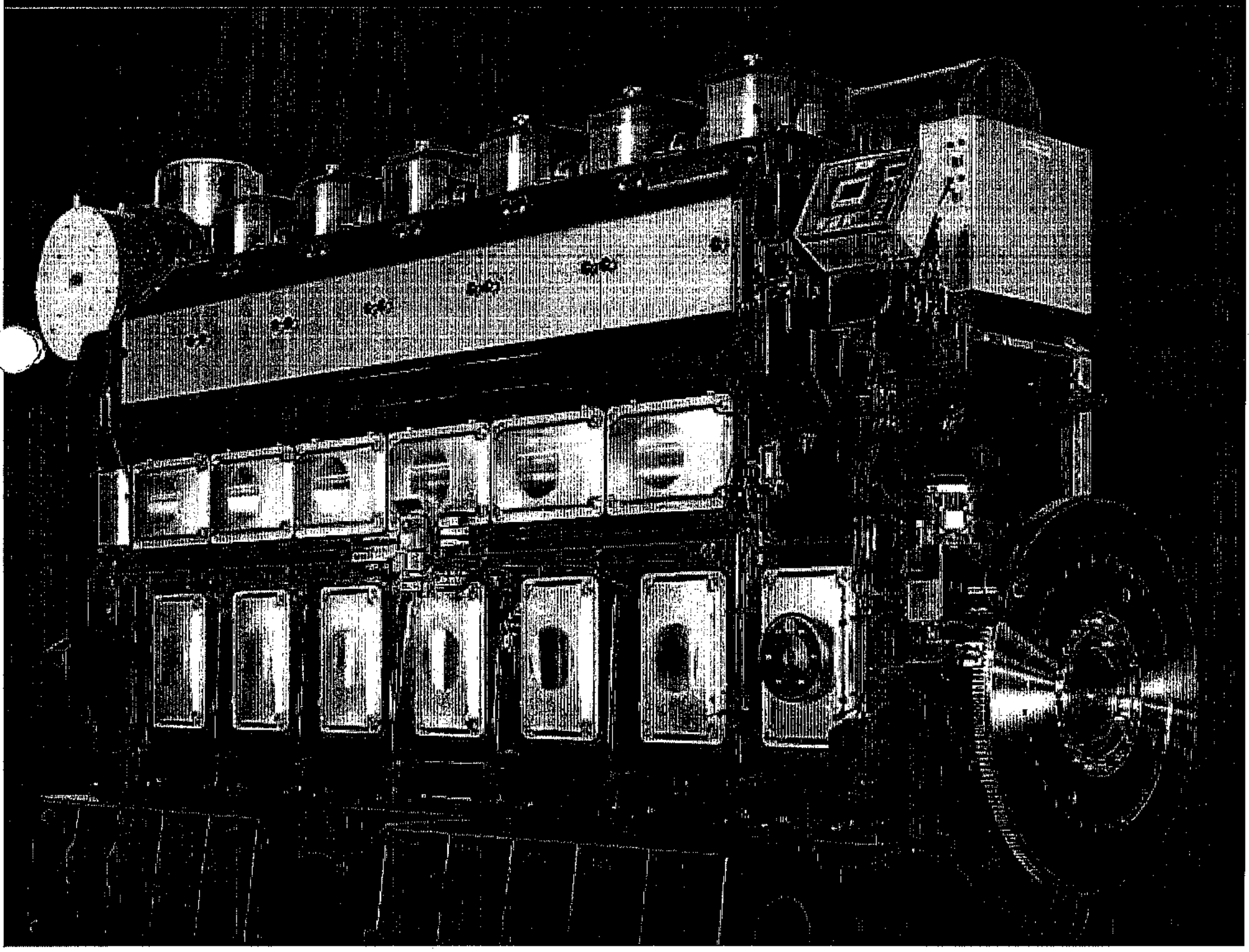
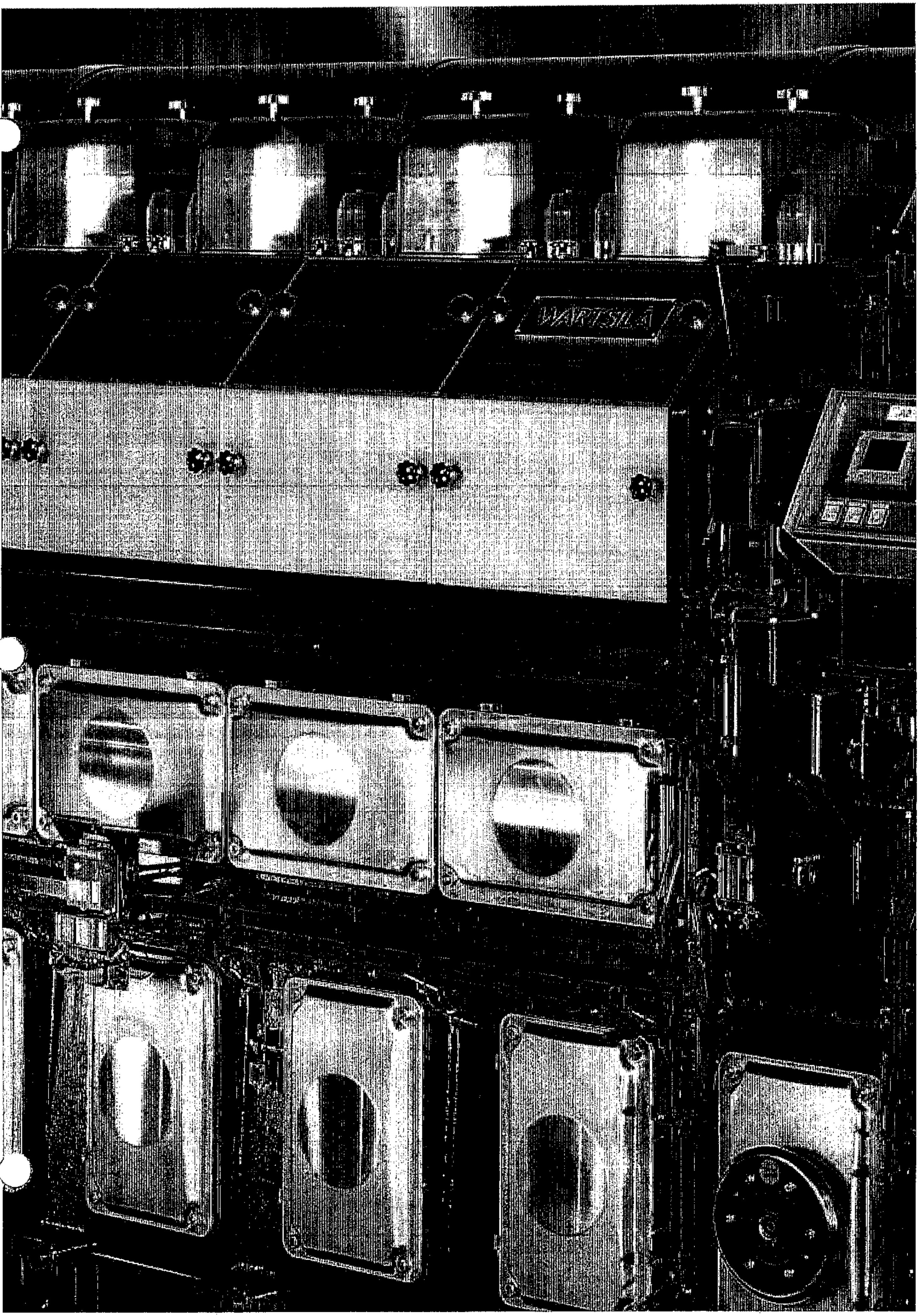
WARTSILA ENGINE DATA

WÄRTSILÄ **50DF**

Technology review



WÄRTSILÄ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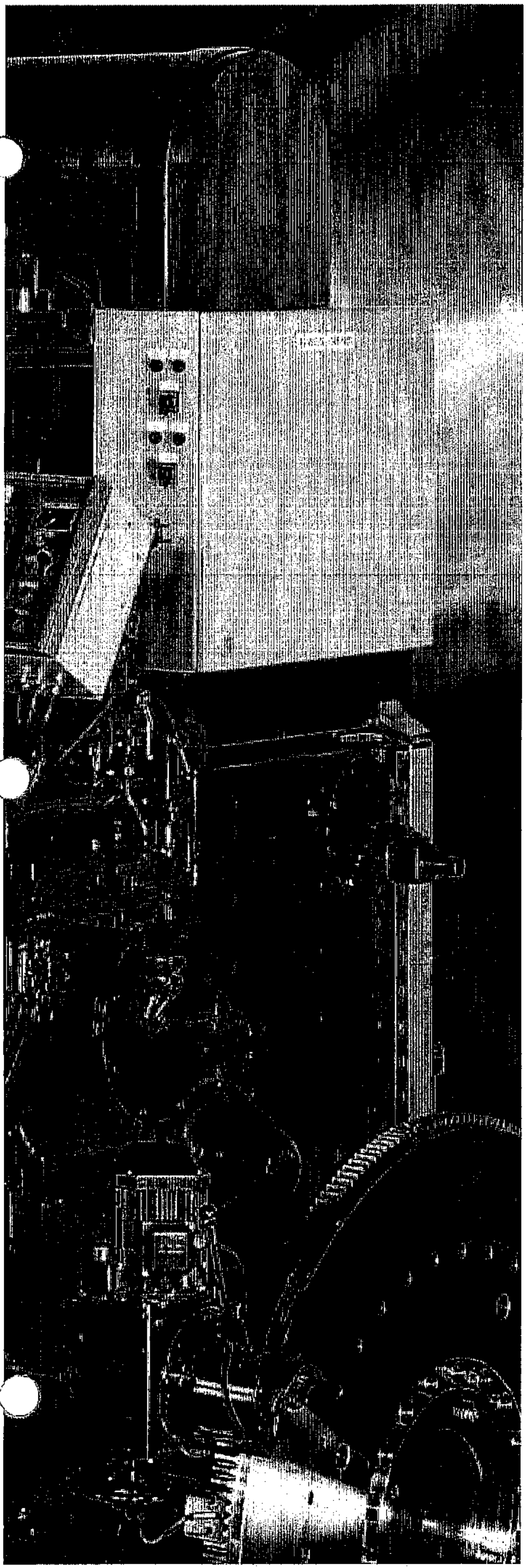
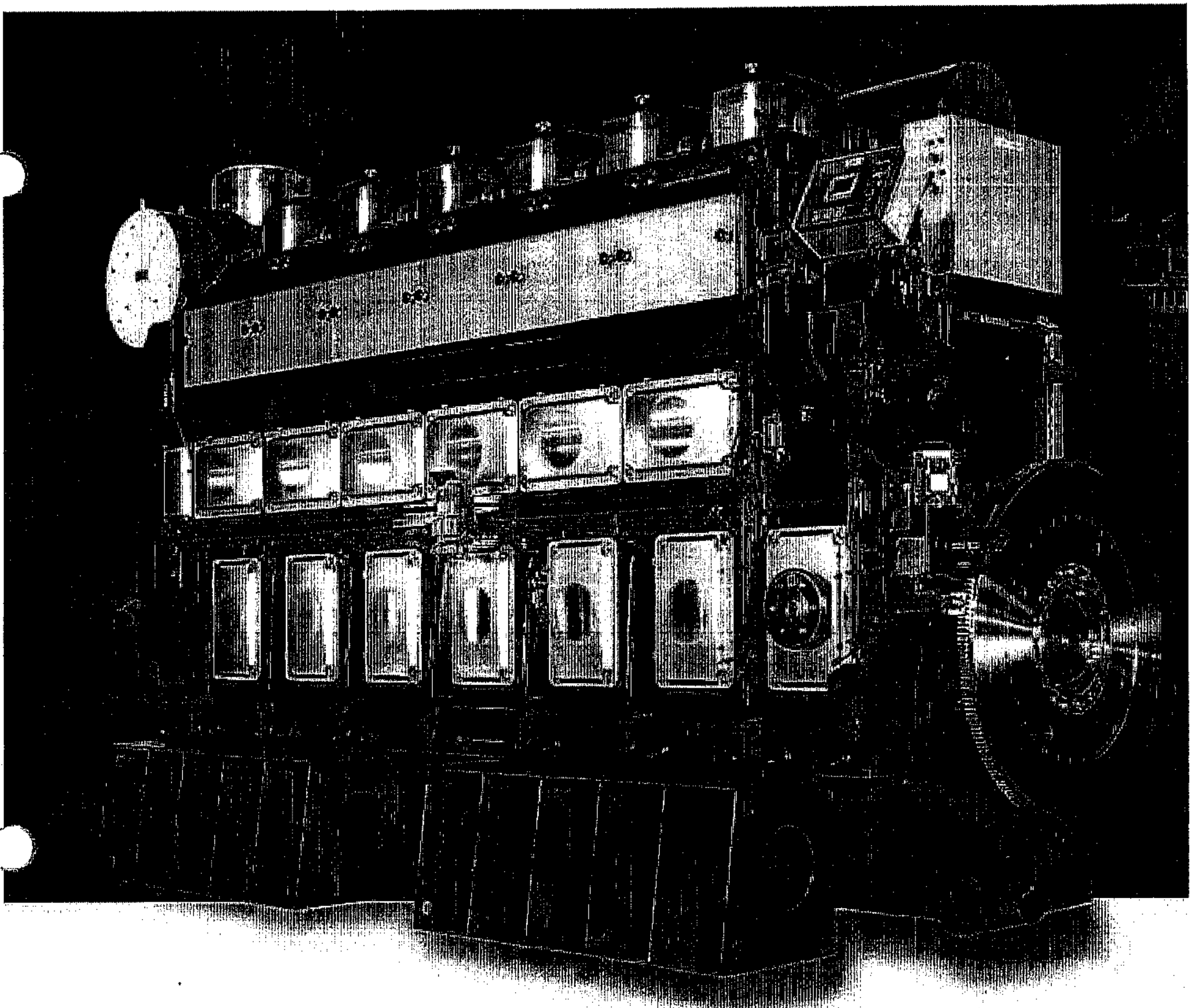


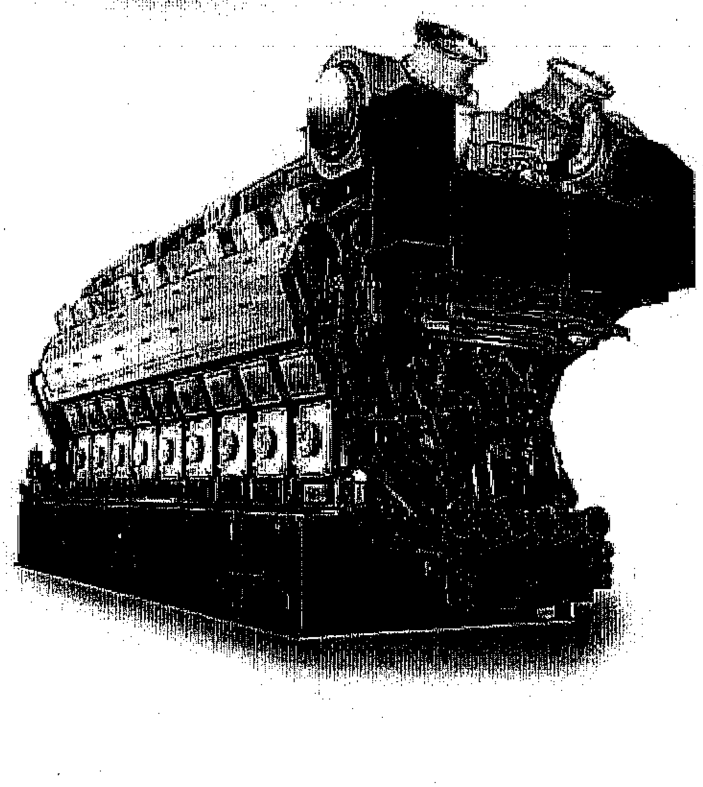
WÄRTSILÄ 50DF

Technology review

This is a brief guide to the technical features and performance of the Wärtsilä 50DF engine.



Introduction



The WÄRTSILÄ® 50DF dual-fuel engine gives new meaning to the words 'fuel flexibility' and 'high performance'.

The Wärtsilä 50DF is a four-stroke dual-fuel engine that can be run either on natural gas or light fuel oil (LFO) and also on heavy fuel oil (HFO). Moreover, the engine can switch over from gas to LFO/HFO and vice versa smoothly during engine operation. The Wärtsilä 50DF is manufactured in configurations from 6L up to 18V giving 950 kW per cylinder and a total maximum mechanical output of 17,100 kW. The engine speed is 500 or 514 rpm for use with 50 or 60 Hz applications. The engine has a maximum thermal efficiency of 47% (± 0% tolerance), higher than for any other gas engine.

Design philosophy

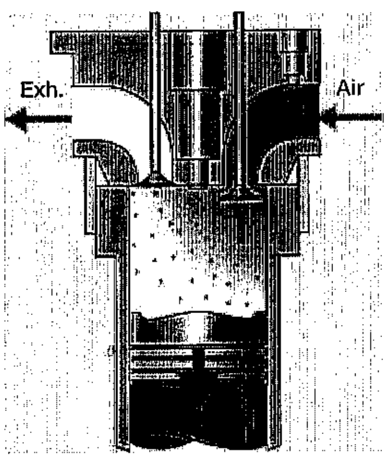
The Wärtsilä 50DF applies the sophisticated dual-fuel technology incorporated in the reliable and well-tried Wärtsilä 46 HFO engine.

The Wärtsilä 50DF is designed to provide high output with fuel flexibility, low emission rates, high efficiency and high reliability. The engine functions are controlled by an advanced automation system that allows optimum running conditions to be set independent of the ambient conditions or fuel.

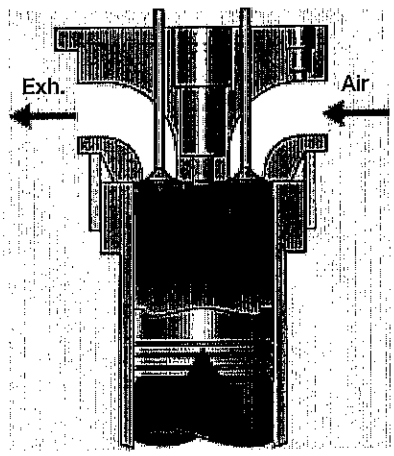
Both the gas admission and pilot fuel injection are electronically controlled. This ensures that the correct air-fuel ratio can be set for each cylinder individually and that the minimum amount of pilot fuel can be injected while ensuring safe and stable combustion. All parameters are controlled automatically during operation.

The Wärtsilä 50DF is designed to meet customer demands for a safe and fuel-flexible engine, running both on gas and on liquid fuel. The 50DF, like all Wärtsilä engines, has a simple and straightforward design. Its piping and external connections have been minimized, the safety margins are ample, maintenance is easy and rapid, and the electronic safety protection system is a built-in feature. The individually and electronically controlled valves ensure that all cylinders stay within the operating window, avoiding knocking and misfiring. This eliminates unnecessary load reductions and shutdowns.

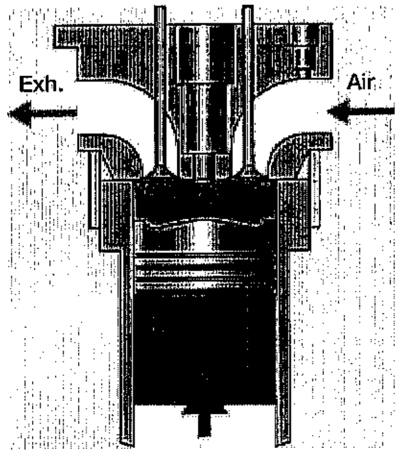
The Wärtsilä 50DF is designed to give the same output whether it is running on natural gas or on LFO/HFO. For the Wärtsilä 50DF operating on gas, NO_X and CO_2 emissions are substantially lower than for an HFO engine. The engine is optimized for NO_X emissions of 500 mg/Nm^3 at 5% O_2, dry, and fulfils the German TA-luft standard for operation on natural gas. This corresponds to 2g /kWh of NO_X. Back-up fuel: 970 ppm vol@15% O_2, dry, for World Bank NO_X or below 12.91 g/kWh following the marine requirements.



Air intake and gas injection



Compression of gas/air mixture



Pilot fuel injection and ignition

The lean-burn concept

The Wärtsilä 50DF operates on the lean-burn principle: the mixture of air and gas in the cylinder has more air than is needed for complete combustion. Lean combustion reduces peak temperatures and therefore NO_X emissions. Efficiency is increased and higher output is reached while avoiding knocking.

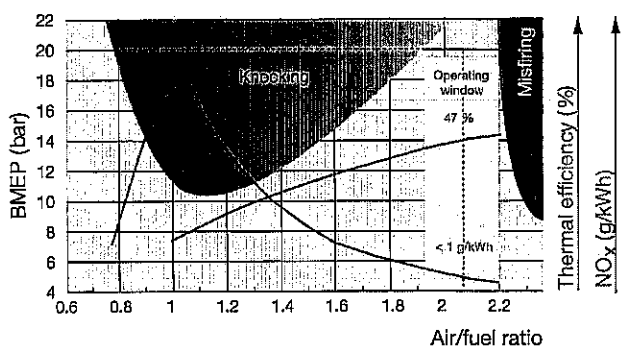
Combustion of the lean air-fuel mixture is initiated by injecting a small amount of LFO (pilot fuel) into the cylinder. The pilot fuel is ignited in a conventional diesel process, providing a high-energy ignition source for the main charge. To obtain the best efficiency and lowest emissions, every cylinder is individually controlled to ensure operation at the correct air-fuel ratio and with the correct amount and timing of pilot fuel injection.

Wärtsilä has developed a special electronic control system to cope with the demanding task of controlling the combustion in each cylinder, and to ensure optimal performance in terms of efficiency and emissions under all conditions by keeping each cylinder within the operating window. Stable and well-controlled combustion also contributes to less mechanical and thermal load on the engine components.

Emissions

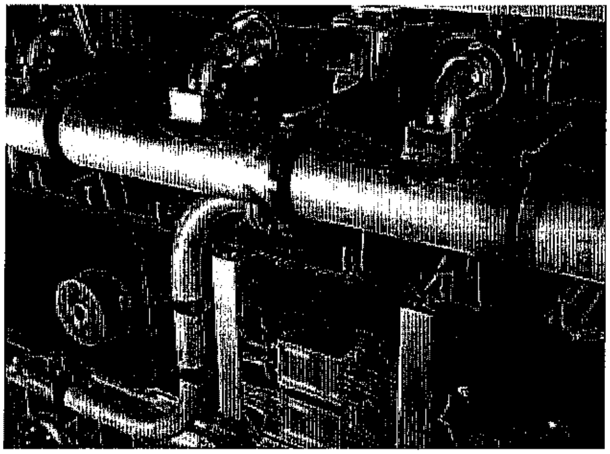
Current stringent emission regulations demand the reduction of NO_X emissions. In an internal combustion engine this means controlling peak temperature and residence time, which are the main parameters governing NO_X formation.

In the Wärtsilä 50DF engine, the air-fuel ratio is very high (typically 2.2). Since the same specific heat quantity released by combustion is used to heat up a larger mass of air, the maximum temperature and consequently NO_X formation are lower. The mixture is uniform throughout the cylinder since the fuel and air are premixed before introduction into the cylinders, which helps to avoid local NO_X formation points within the cylinder. Benefiting from this unique feature, NO_X emissions from the Wärtsilä 50DF are extremely low and comply with the most stringent existing legislation.



Fuel system

The fuel system of the Wärtsilä 50DF has been divided into two: one for gas and the other for fuel oil. The Wärtsilä 50DF is always started in diesel mode using both main diesel and pilot fuel. Gas admission is activated only when combustion is stable in all cylinders. This ensures safe and reliable starting. When running the engine in gas mode, the pilot fuel amounts to less than 1% of full-load



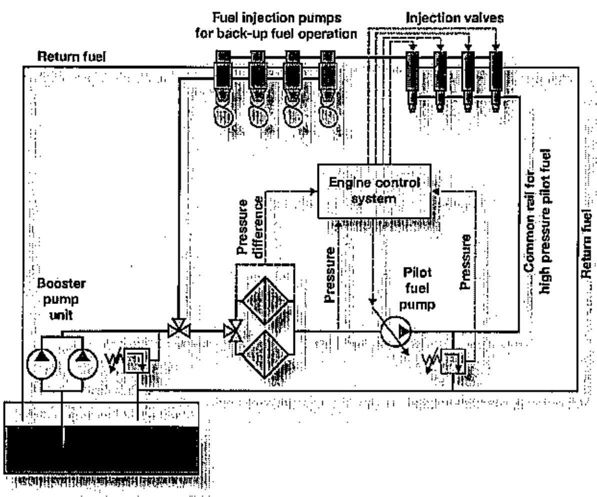
fuel consumption. The amount of pilot fuel is controlled by the engine control system.

Gas supply

The natural gas is supplied to the engine through a valve station. The gas is first filtered to ensure clean supply. The gas pressure is controlled by a valve located in the valve station. The gas pressure is dependent on engine load. At full load the pressure before the engine is 3.9 bar (g) for LHV 36 MJ/Nm3. For lower LHV the pressure has to be increased. The system includes the necessary shut-off and venting valves to ensure safe and trouble-free gas supply.

On the engine, the gas is supplied through large common-rail pipes running along the engine. Each cylinder then has an individual feed pipe to the gas admission valve on the cylinder head.

Gas pipes on the engine can be of double wall design on request.



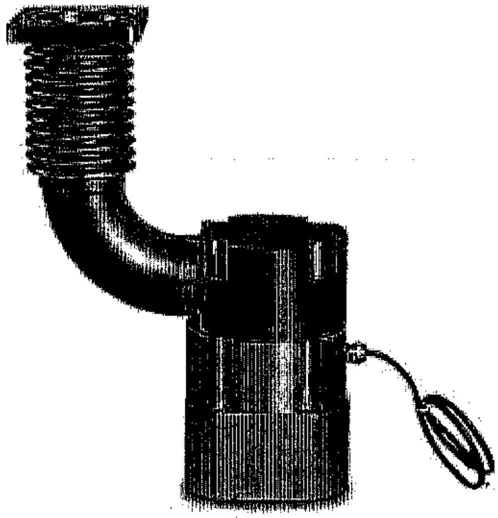
Diesel oil supply

The fuel oil supply on the engine is divided into two systems: one for the pilot fuel and the other for backup fuel.

The pilot fuel is elevated to the required pressure by a pump unit. This includes duplex filters, pressure regulator and an engine-driven radial piston-type pump. The high-pressure pilot fuel is then distributed through a common-rail pipe to the injection valves at each cylinder. Pilot fuel is injected at approximately 900 bar pressure and the timing and duration are electronically controlled. The backup fuel is fed to a normal camshaft-driven injection pump. From the injection pump, the high-pressure fuel goes to a spring-loaded injection valve of standard design for a diesel engine.

Injection valve

The Wärtsilä 50DF has a twin-needle injection valve. The larger needle is used in diesel mode and the smaller for pilot fuel oil when the engine is running in gas mode. Pilot injection is electronically controlled and the main diesel injection is hydromechanically controlled. The individually controlled solenoid valve allows optimum timing and duration of pilot fuel injection into every cylinder when the engine is running in gas mode. Since NO_X formation depends greatly on the pilot fuel amount, this design ensures very low NO_X formation while still employing a stable and reliable ignition source for the lean air-gas mixture in the combustion chamber.

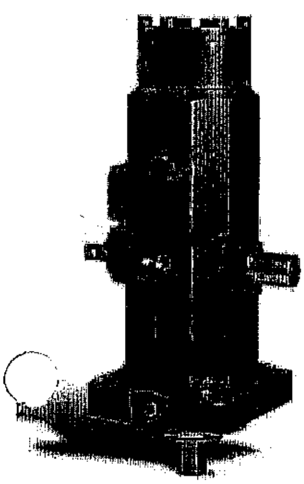


Gas admission valve

Gas is admitted to the cylinders just before the air inlet valve. The gas admission valves are electronically actuated and controlled by the engine control system to give exactly the correct amount of gas to each cylinder. This way the combustion in each cylinder can be fully and individually controlled. Since the valve can be timed independently of the inlet valves, the cylinder can be scavenged without risk of gas being fed directly to the exhaust system.

Independent gas admission ensures the correct air-fuel ratio and optimal operating point with respect to efficiency and emissions. It also enables reliable performance without shutdowns, knocking or misfiring. The gas admission valves have a short stroke and specially selected materials, thus providing low wear and long maintenance intervals.

Injection pump

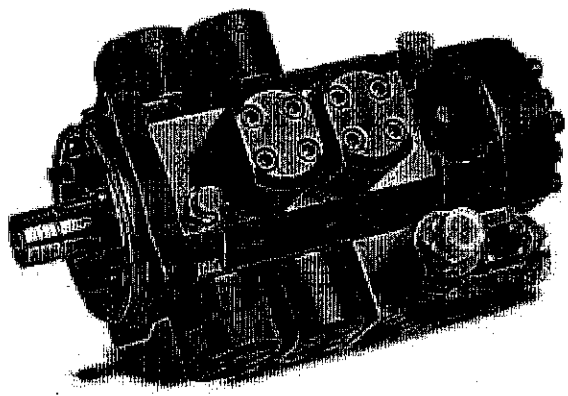


The Wärtsilä 50DF utilizes the well-proven monoblock injection pump developed by Wärtsilä. This pump withstands the high pressures involved in fuel injection and has a constant-pressure relief valve to avoid cavitation. The fuel pump is operating at all times and engine can switch over from gas to fuel oil operation if necessary. The plunger is equipped with a wear-resistant coating.

Pilot pump

The pilot fuel pump is engine-driven. It receives the signal for correct outgoing fuel pressure from the engine control unit and independently sets and maintains the pressure at the required level. It transmits the prevailing fuel pressure to the engine control system.

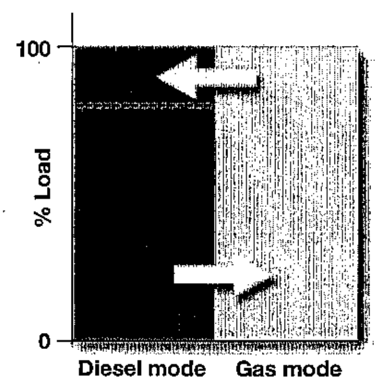
High-pressure fuel is delivered to each injection valve through a common-rail pipe, which acts as a pressure accumulator and damper against pressure pulses in the system. The fuel system has a double wall design with alarm for leakage.

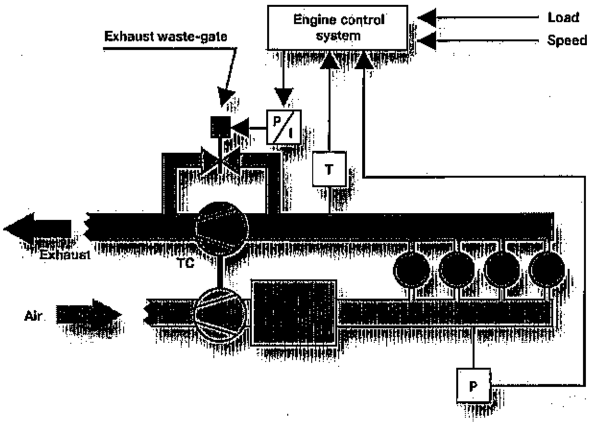


Operation mode transfer

The engine can be switched automatically from fuel oil to gas operation at loads below 80% of the full load. Transfer takes place automatically after the operator's command without load changes. During switchover, which lasts about one minute, the fuel oil is gradually substituted by gas.

The engine trips from gas to fuel oil operation at any load instantaneously and automatically in the event of gas supply interruption, for example.

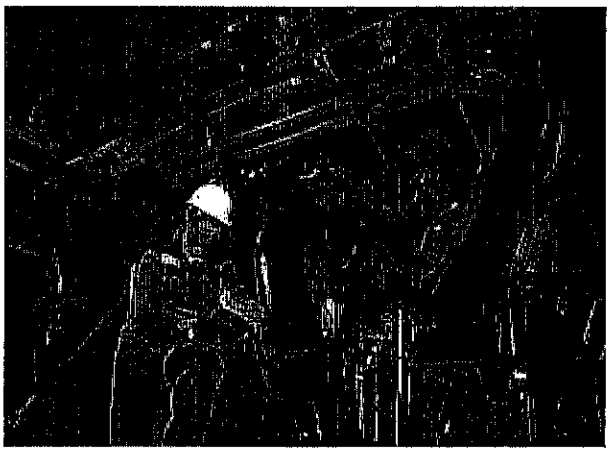




Air-fuel ratio control

Correct air-fuel ratio under any operating conditions is essential to optimum performance and emissions. For this function, Wärtsilä 50DF is equipped with an exhaust gas waste-gate valve.

Part of the exhaust gases bypasses the turbocharger through the waste-gate valve. The valve adjusts the air-fuel ratio to the correct value independent of the varying site conditions under high engine loads.



Engine cooling system

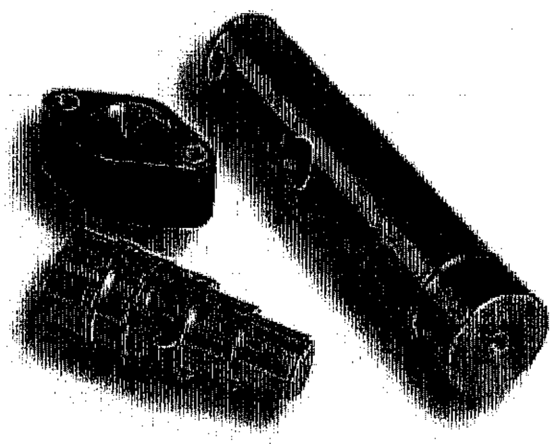
The 50DF engine has a flexible cooling system design optimized for different cooling applications. The cooling system has two separate circuits: high-temperature (HT) and low-temperature (LT). The HT circuit controls the cylinder liner and the cylinder head temperatures while the LT circuit serves the lubricating oil cooler. The circuits are also connected to the respective parts of the two-stage charge air cooler.

Both HT and LT water pumps are engine-driven as standard.

Engine lubrication system

The Wärtsilä 50DF has an engine-driven oil pump and can be provided with either a wet or dry sump oil system, where the oil is mainly treated outside the engine. Marine engines have a dry sump and power plant engines a wet sump. On the way to the engine, the oil passes through a full-flow automatic filter unit and a safety filter for final protection. Lubricating oil is filtered through a full-flow paper cartridge filter. A separate centrifugal filter acts as an indicator of excessive dirt in the lubricating oil. A separate pre-lubricating system is used before the engine is started to avoid engine part wear.

For running in, provision has been made for mounting special running-in filters in front of each main bearing.



Engine starting system

The Wärtsilä 50DF engine is provided with a conventional pneumatic in-cylinder starting system. Each cylinder head is equipped with a starting valve.

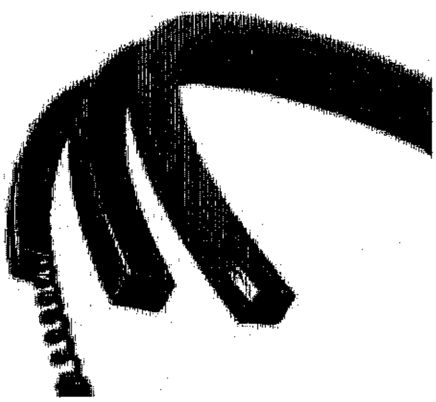
A starting limiter valve prevents the engine from starting if the turning gear is engaged.

Piston

Pistons are of the low-friction, composite type with forged steel top and nodular cast iron skirt. The design itself is tailored for an engine of this size and includes a number of innovative approaches. Long lifetime is obtained using Wärtsilä's patented skirt-lubricating system, a piston crown cooled by 'cocktail shaker' cooling, and box type stiff robust skirt design.

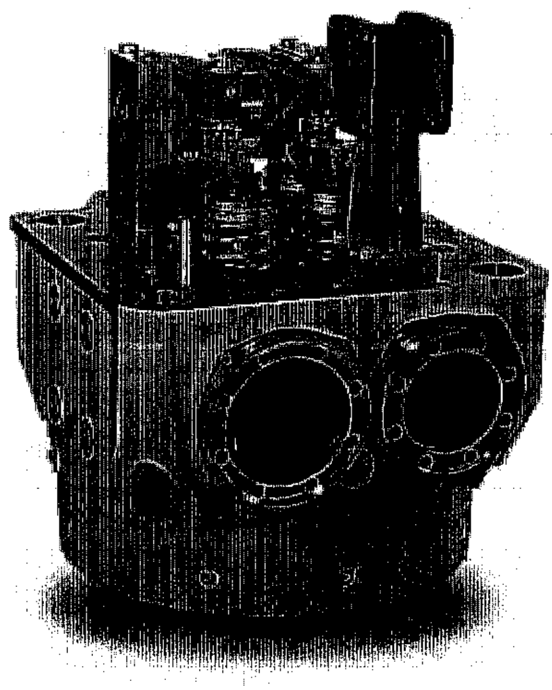
Piston ring set

Most of the frictional loss in a reciprocating combustion engine originates from the piston rings. The piston ring set in the Wärtsilä 50DF is optimal with respect to both functionality and efficiency. It is located in the piston crown and has two compression rings and an oil control ring. Every ring is dimensioned and profiled for its task. This three-ring concept has proved its efficiency in all Wärtsilä engines.



Cylinder head

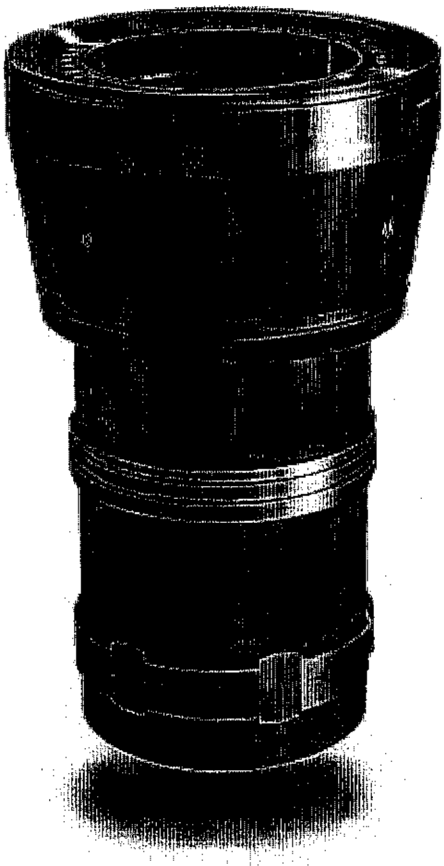
The cylinder head incorporates the four-screw technology introduced by Wärtsilä. At high cylinder pressures, it has proved its superiority, especially when liner roundness and dynamic behaviour are considered. It offers reliability and ease of maintenance. In addition, the most efficient air inlet and exhaust gas channels can be configured with this type of cylinder head. Cooling water flow has been optimized to provide proper cooling of the exhaust valves, cylinder head flame plate and the twin needle injection valve. 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.



Cylinder liner and anti-polishing ring

The cylinder liner and piston designs are based on extensive expertise in tribology and wear resistance acquired over many years of pioneering work in the design of heavy-duty diesel engines.

The liner's high bore-cooled collar ensures minimum deformation and efficient cooling. A material and surface honing structure has been selected for maximum wear resistance and strength. The anti-polishing ring is located at the upper part of the liner to minimize the risk of bore polishing and ensures low and stable lube oil consumption over the whole overhauling period.



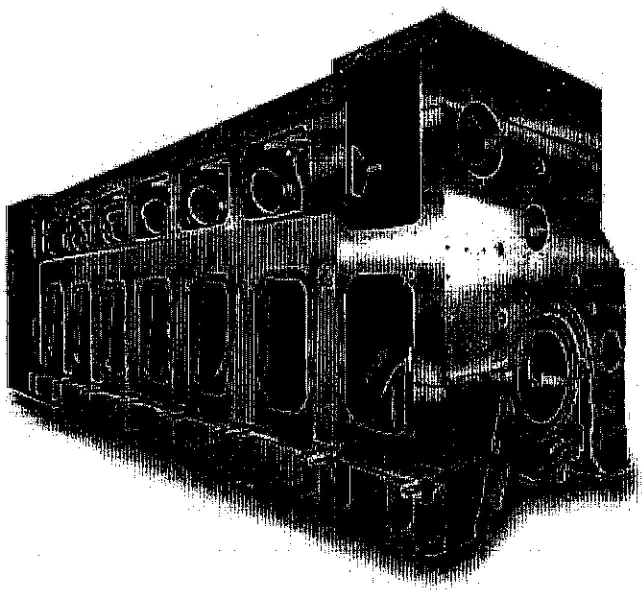
Connecting rod and big end bearings

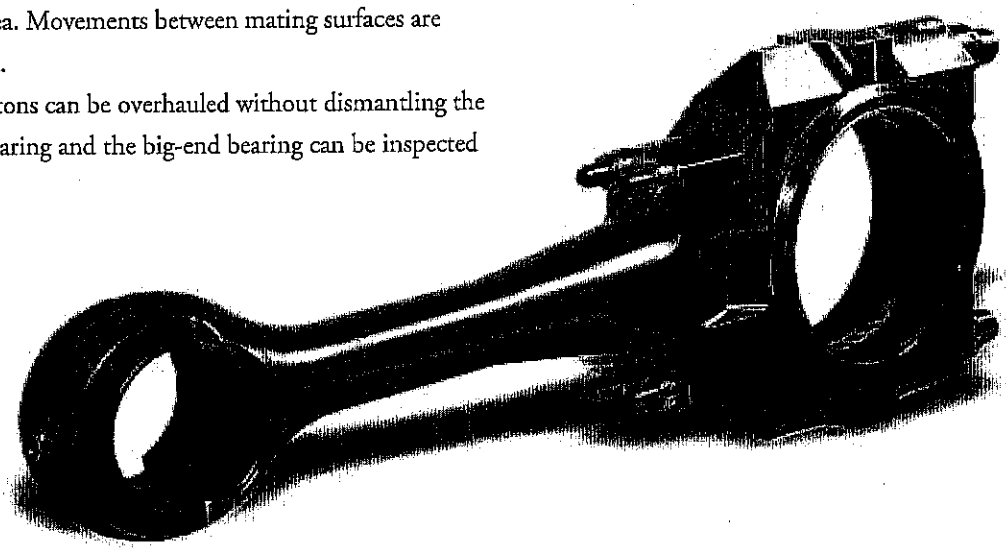
The connecting rod is a three-piece design and combustion forces are distributed over a maximum bearing area. Movements between mating surfaces are minimized.

The pistons can be overhauled without dismantling the big-end bearing and the big-end bearing can be inspected without removing the piston. The three-piece design also reduces the required height for piston overhaul. The big-end bearing housing is hydraulically tightened, resulting in a distortion-free bore for the corrosion-resistant precision bearing.

Engine block

The engine block is of nodular cast iron, cast in one piece. It features high rigidity, simplicity and cleanliness. The crankshaft is underslung and gives very high stiffness to the engine block. This provides excellent conditions for main bearing performance.

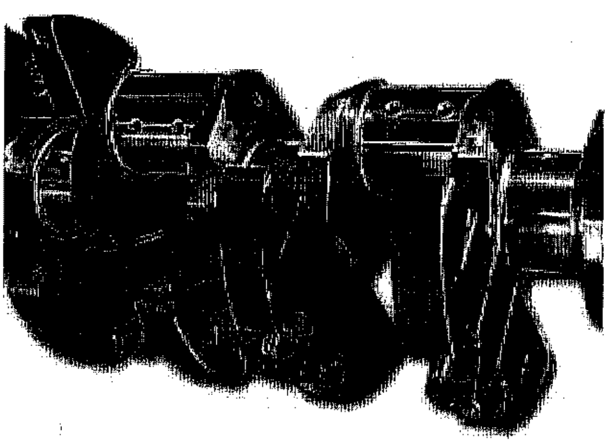




Crankshaft and bearings

The increasing cylinder pressures of the modern gas engines call for robustness and reliability of the crank gear. The bearing loads are kept conservative by using large pin and journal diameters, careful optimization of crank throw dimensions and fillets.

Ample oil film thickness is maintained in the main bearings by careful balancing of the rotational masses and by the use of an ungrooved bearing surface in the critical areas of the big-end bearings.



Turbocharger

The Wärtsilä 50DF is equipped with the modular-built Spex (single pipe exhaust) turbocharging system, which combines the advantages of both pulse and constant pressure charging. The interface between engine and turbocharger is streamlined with a minimum of flow resistance on both exhaust and air sides. High-efficiency turbochargers with inboard plain bearings are used, and the engine lubricating oil system is used for the turbocharger. The waste-gate is actuated electro-pneumatically.

Automation

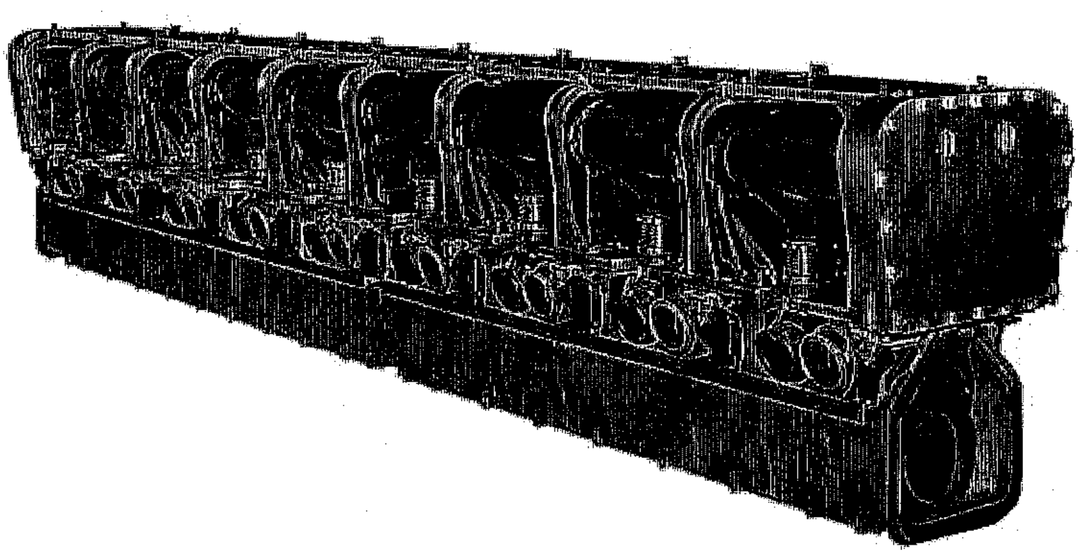
All engine functions are controlled by the engine control system, a microprocessor-based distributed control system mounted on the engine. The various electronic modules are dedicated and optimized for certain functions and they communicate with each other via a CAN databus.

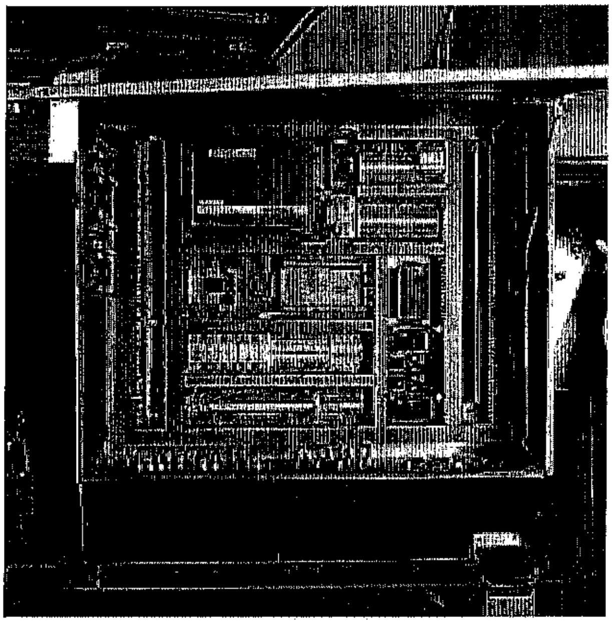
The engine control system offers the following advantages:

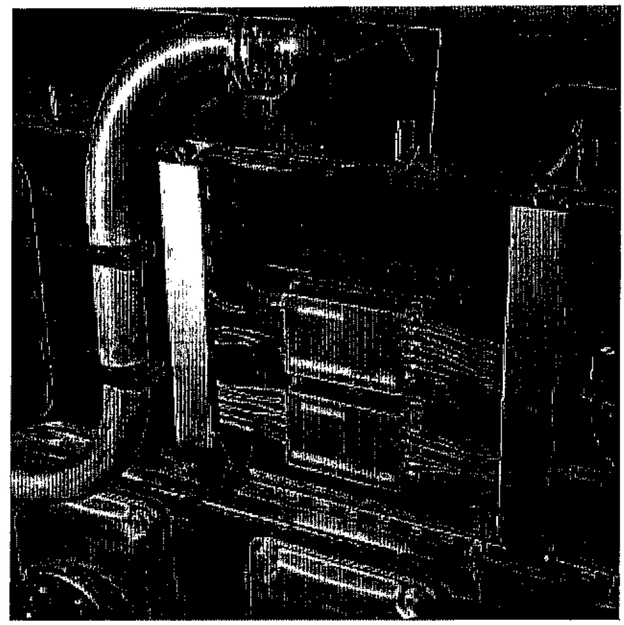
- Easy maintenance and high reliability thanks to rugged engine-dedicated connectors and prefabricated cable harness
- Easy interfacing with external systems via a databus
- Reduced cabling on and around the engine
- High flexibility and easy customizing
- Digitized signals - free from electromagnetic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

Main control module

The core of the engine control system is the main control module. This is responsible for ensuring the engine's reliable operation and for keeping the engine at optimum







performance in all operating conditions such as varying ambient temperature and gas quality. The main control module reads the information sent by all the other modules. Using this information it adjusts the engine's speed and load control by determining reference values for the main gas admission, air-fuel ratio and pilot fuel amount and timing. The main control module automatically controls the start and stop sequences of the engine and the safety system. The module also communicates with the plant control system (PLC).

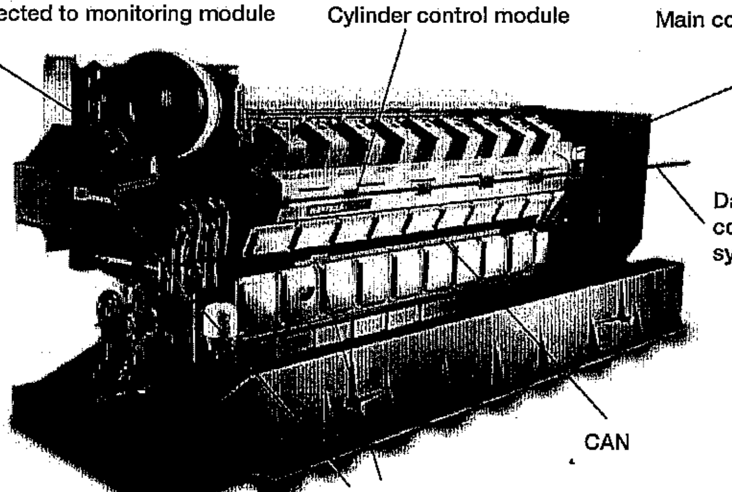
Cylinder control module

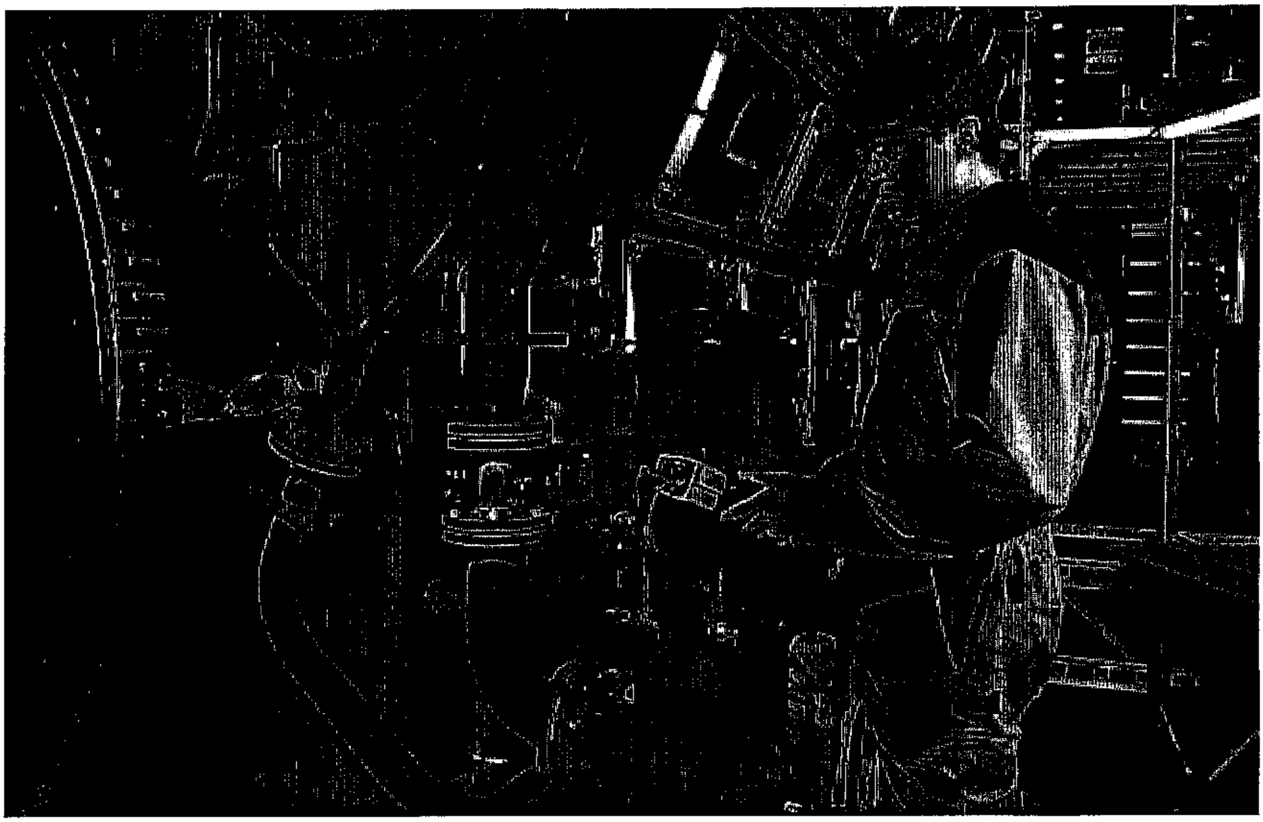
Each cylinder control module monitors and controls three cylinders. The cylinder control module controls the cylinder-specific air-fuel ratio by adjusting the gas admission individually for each cylinder.

The cylinder control module measures the knock intensity, i.e. uncontrolled combustion in the cylinder, information on which is used to adjust the cylinder specific pilot fuel timing and gas admission. Light knocking leads to automatic adjustment of the pilot fuel timing and cylinder specific air-fuel ratio. Heavy knocking leads to load reduction or a gas trip.

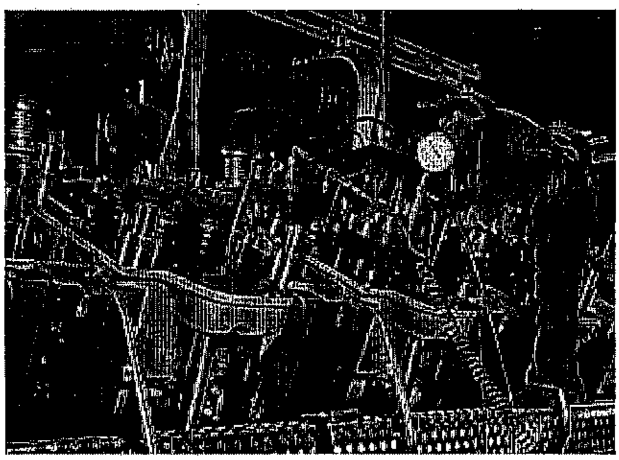
Monitoring modules

Monitoring modules are located close to groups of sensors, which shortens the cable harness on the engine. The monitored signals are transmitted to the main control module and used for the engine control and safety system. The monitored values are also transferred to the operator interface on the external control system.





Maintenance



Thanks to the purity of gas, the Wärtsilä 50DF offers long component lifetime and time between overhauls. Ease of maintenance, however, has been an essential element in the engine's design.

The engine has a large opening into the crankcase and camshaft to facilitate checking and maintenance. All high-tension bolts are tightened hydraulically and this approach is also widely used elsewhere where possible. 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. The following main features promote easy maintenance of the Wärtsilä 50DF:

- A resiliently mounted 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 on to intermediate bearing pieces.
- A wide range of special tools and measuring equipment specifically designed to facilitate service work are also available.
- The pilot pump is located in front of the engine, ensuring easy access and maintenance.
- Use of electrically controlled gas admission valves means few mechanical parts and no 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.

Gas fuel and diesel oil quality

The Wärtsilä 50DF can run on most natural gas qualities. The nominal design point is a Methane Number of 80. The engine can be operated on gases with lower Methane Numbers with a different performance.
The Wärtsilä 50DF is designed for continuous operation, without reduction in the rated output, on gas qualities that meet the following specification:

Lower heating value (LHV)	MJ/Nm³	> 28
Methane number for nominal output		≥ 80
Methane content, CH_4	% vol.	> 70
Hydrogen sulphide, H_2S	% vol.	< 0.05
Hydrogen, H_2	% vol.	< 3
Condensates	% vol.	0
Ammonia	mg/Nm³	< 25
Chlorine + fluorines	mg/Nm³	< 50
Particles or solids content	mg/Nm³	< 50
Particles or solids size	µm	< 5
Gas inlet temperature	°C	0-50
Gas inlet pressure	bar (g)	3.9 at LHV 36

The Wärtsilä 50DF is designed for continuous operation, without reduction in the rated output, on pilot and back-up fuels with the following properties:

Viscosity	cSt/40°C	≤ 11.0
Density at 15°C	g/ml	< 0.900
Water	% volume	< 0.3
Sulphur content	% mass	< 2.0
Ash content	% mass	≤ 0.01
Vanadium content	mg/kg	–
Sodium content	mg/kg	–
Conradson carbon residue	% mass	< 0.3
Asphaltenes	% mass	–
Flash point, PMCC	°C	> 60
Pour point	°C	≤ 6
Sediment	% mass	< 0.07
Cetane number		> 35

The Wärtsilä 50DF is designed for continuous operation, without reduction in the rated output, on back-up fuels with the following properties:

			HFO 1	HFO 2
ISO 8217		**DMC**		**RMK55**
Viscosity, max	cSt / 40°C	14	-	-
Viscosity, max	cSt / 100°C	-	55	55
Sulphur, max	%	2.0	2.0	5.0
Vanadium, max	mg/kg	100	100	600
Aluminium + Silicon*	mg/kg	25 (15)	30 (15)	80 (15)
Wärtsilä				
Sodium, max*	mg/kg	(30)	50 (30)	100 (30)

*Figures in brackets refer to values before engine

WÄRTSILÄ 50DF

Main technical data

Cylinder bore	500 mm
Piston stroke	580 mm
Cylinder output	950 kW/cyl
Engine speed	500, 514 rpm
Mean effective pressure	20.0, 19.5 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	
Natural gas	Methane Number: 80

Rated power: Generating sets

Engine type	500 rpm/50 Hz, 514 rpm/60 Hz	
	Engine kW	Gen. kW*
6L50DF	5 700	5500
8L50DF	7 600	7330
9L50DF	8 550	8250
12V50DF	11 400	11 000
16V50DF	15 200	14 670
18V50DF	17 100	16 500

*Generator efficiency 96.5%.

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

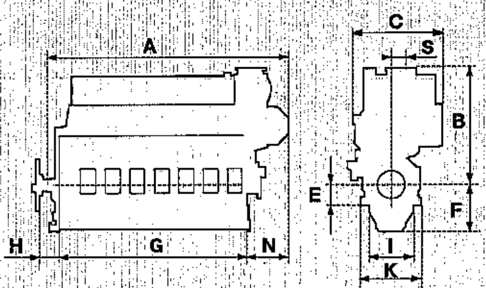
Engine type	H	I	K	N	S	Weight*
6L50DF	460	1 445	1 940	1 295	395	96
8L50DF	460	1 445	1 940	1 620	315	128
9L50DF	460	1 445	1 940	1 620	315	148
12V50DF	460	1 800	2 290	1 840	765	175
16V50DF	460	1 800	2 290	1 840	815	220
18V50DF	460	1 800	2 290	1 785	815	240

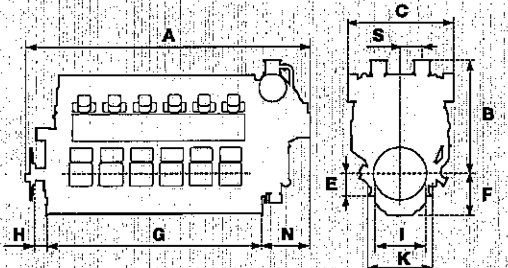
* Weights are dry weights (in Metric tons) of rigidly mounted engines without flywheel.

Principal generating set dimensions (mm) and weights (tonnes)

Engine type	Length	Width	Height	Weight
18V50DF	18 404	5 140	6 277	379

Weight with liquids. 150 mm high sring elements for common baseframe.





Wärtsilä enhances the business of its customers by providing them with complete lifecycle power solutions. When creating better and environmentally compatible technologies, Wärtsilä focuses on providing engines, related products and solutions as well as services for the shipping and power generation markets.

Through innovative products and services, Wärtsilä sets out to be the most valued business partner of every customer. This will be achieved by the dedication of more than 12,000 professionals manning 130 Wärtsilä offices in more than 60 countries around the world.

For more information visit www.wartsila.com

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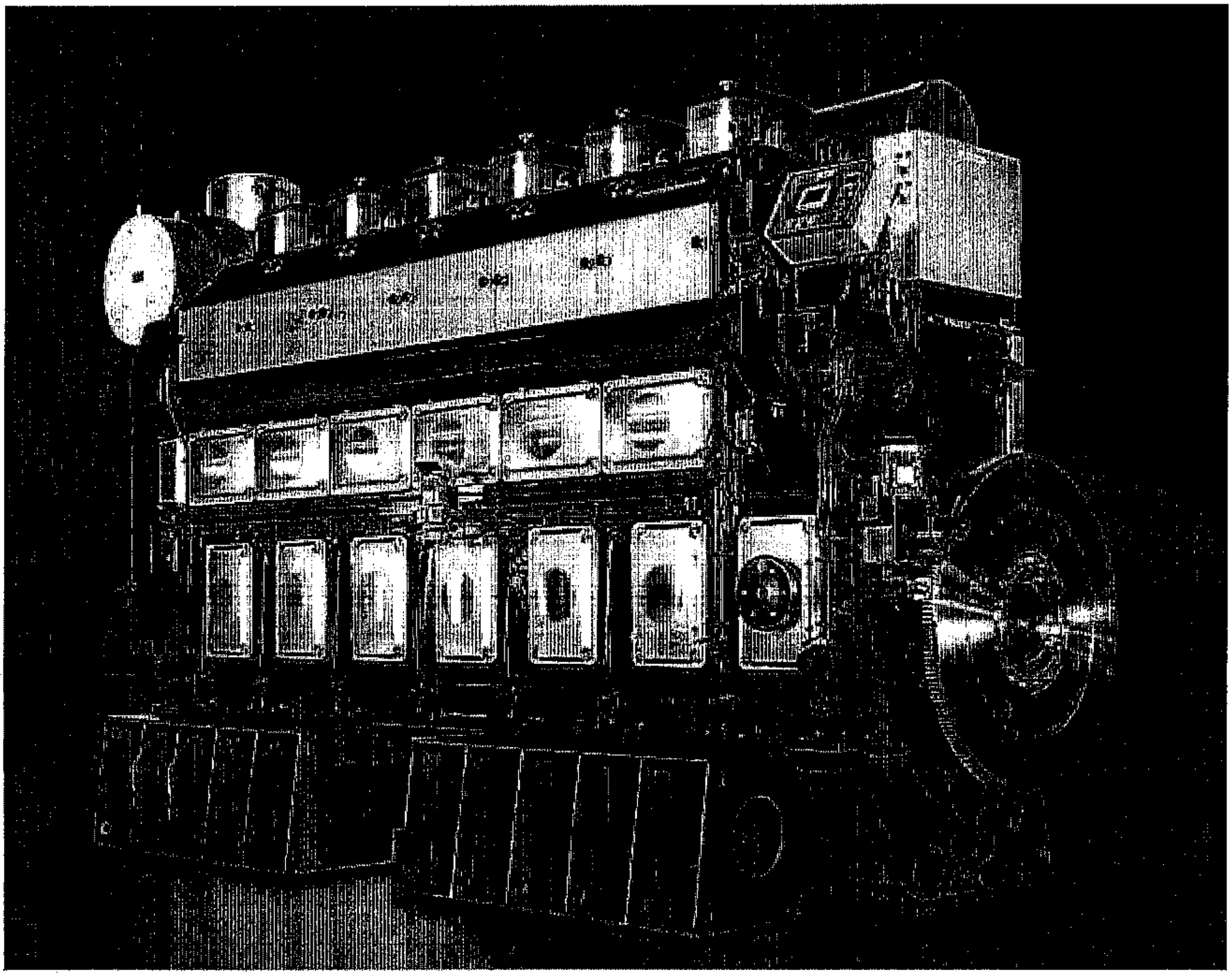
WÄRTSILÄ



Wärtsilä 50DF

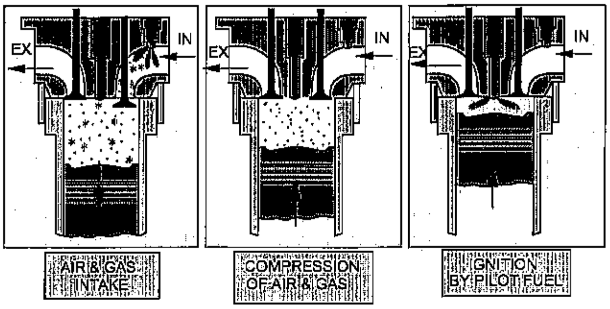
Design

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.

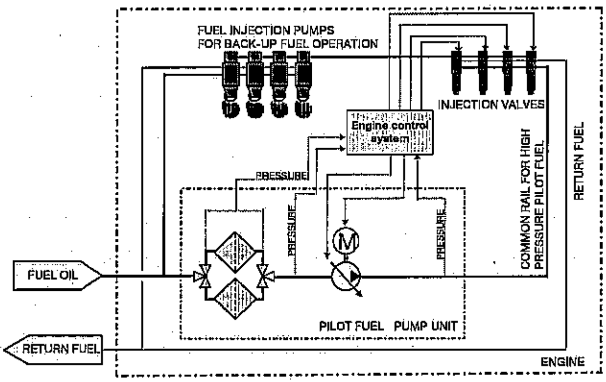
Combustion of the lean air-fuel mixture is initiated by injecting a small amount of MDF (pilot fuel) into the cylinder. The pilot fuel is ignited in a conventional diesel process, providing a high-efficiency ignition source for the main charge.

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.

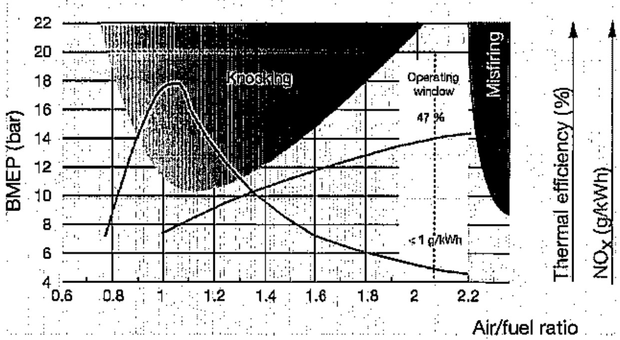
Operation

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.

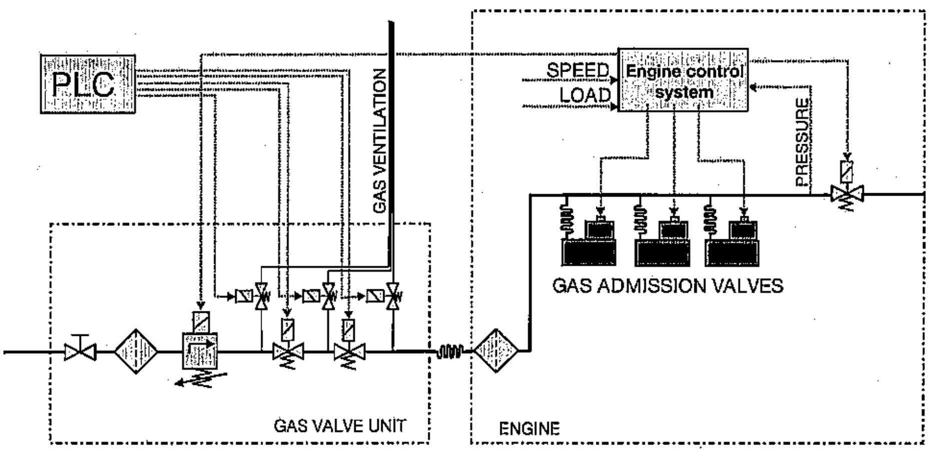
The engine is also capable of running on heavy fuel oil (HFO). The engine can be operated as a conventional diesel engine when running on HFO.

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

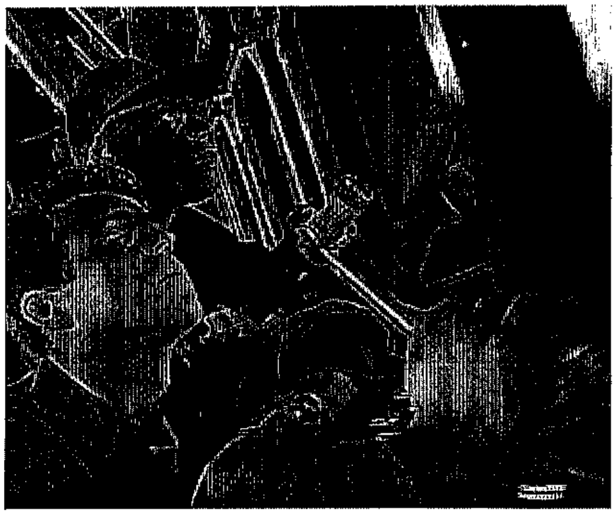
The engine is controlled by a sophisticated engine control system, a fully integrated engine management system designed for harsh environments. It ensures maximum engine performance and safety by monitoring and controlling vital engine functions. The engine control system is a modularized system consisting 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

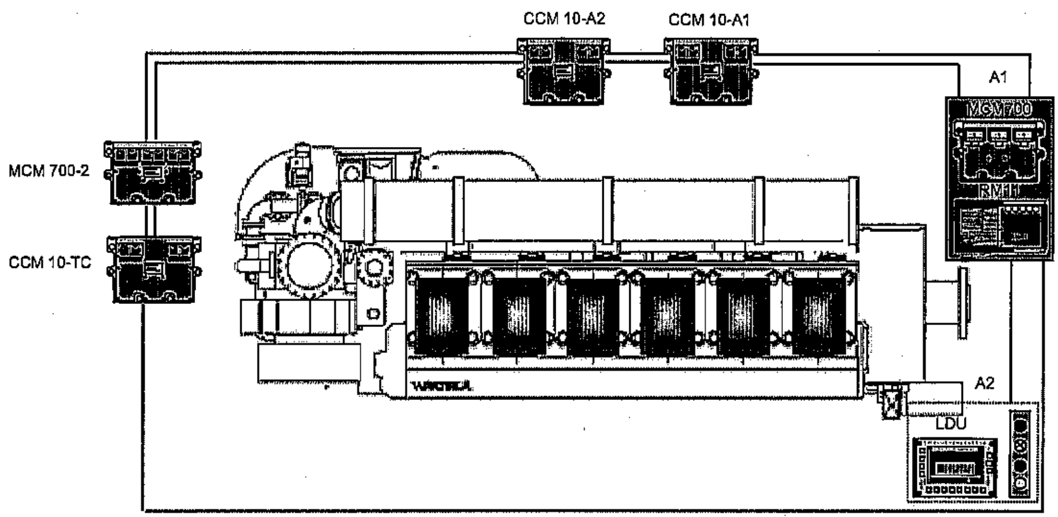
Thanks to the purity of gas, Wärtsilä 50DF offers long component lifetime and time between overhauls. The engine has a large opening into the crankcase and camshaft to facilitate checking and maintenance.



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

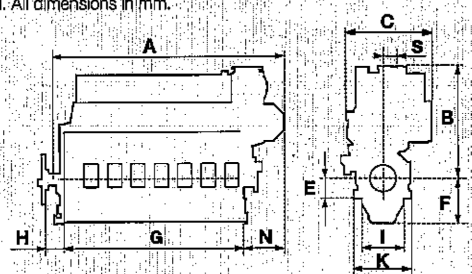
Engine type	500 rpm/50 Hz, 514 rpm/60 Hz	
	Engine kW	Gen. kW
6L50DF	5 700	5 500
8L50DF	7 600	7 330
9L50DF	8 550	8 250
12V50DF	11 400	11 000
16V50DF	15 200	14 670
18V50DF	17 100	16 500

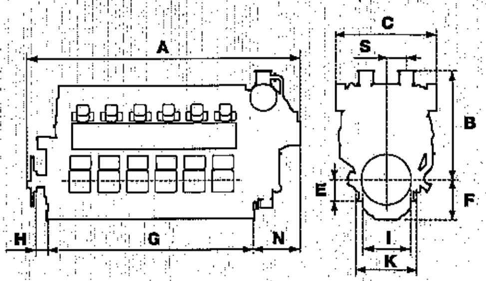
Principal engine dimensions (mm) and weights (tonnes)

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

Engine type	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 E
Florida Department of Environmental Protection
Air Quality Permit Application

Attachment I-3
Detailed Description of Control Equipment / Vendor Data

EMISSIONS DATA (ENGINES)

281.987.0800 (main)
281.987.3838
w.easton@intecengineering.com

From: Alexandre.Eykerman@wartsila.com [mailto:Alexandre.Eykerman@wartsila.com]
Sent: Monday, May 22, 2006 4:13 PM
To: Simon Reilly
Cc: Richie Keig; Andrew Easton; JTessitore@ene.com; Fred.Staible@suezenergyna.com; 11199502
Subject: RE: Wärtsilä Engines Calypso DWP Project

Dear Simon,

Our estimation is based on following assumption. Light gas (95% methane) / Heavy Gas (88% methane) / Fuel (MDO - 15 ppm). If you have other input (Gas and MDO specification), we would be please to re-calculate the given value.

Please look at the below table or the attached excel table.

	Light Gas	Heavy Gas	SCR & OXI reduction
NOx (g/kWh)	1.2	1.2	90%
CO	1.0	1.0	85%
SOx	0.002	0.002	
PM10*	0.065	0.065	70%
VOC	0.25	0.65	90%

Please note that the VOC emissions we have informed you are too high. Below you can find the calculated values. At least, you should not have any problems with VOC emissions as we additionally will get these VOC emissions reduced by approx 90% in the SCR/OXI unit.

Ligh s (at least 95% of methane)

Engine load	100%	90%	75%	50%	
VOC	0,25	0,25	0,3	0,55	g/kWh

Heavy gas (around 88% of methane)

VOC	0,6	0,65	0,75	1,5	g/kWh

Best regards,
Alexandre Eykerman

From: Simon Reilly [mailto:Simon.Reilly@intecengineering.com]
Sent: Monday, May 22, 2006 1:31 PM
To: Eykerman, Alexandre
Cc: Richie Keig; Andrew Easton; JTessitore@ene.com; Fred.Staible@suezenergyna.com; 11199502
Subject: RE: Wärtsilä Engines Calypso DWP Project

Alexandre,

One more time please....
Emission factors for NOx, CO, SO2, VOC,PMT and PM10 (g/Kwh)

- Case (1) Without SCR and without oxidation catalyst
- Case (2) With SCR and without oxidation catalyst
- se (3) With SCR and with oxidation catalyst

Regards and thanks

	Light Gas / Case 1	Heavy Gas / Case 1A	Case 2 / SCR	Case 3 / SCR & OXI
NOx	1.2	1.2	0.12	0.12
CO	1	1	1	0.15
SOx	0.002	0.002		
PM10	0.065	0.065	0.0195	0.0195
VOC	0.25	0.65	0.125	0.065

Tessitore, Joseph

Fi : Alexandre.Eykerman@wartsila.com
Sent: Thursday, August 17, 2006 6:24 AM
To: Menon, Annie
Cc: Tessitore, Joseph
Subject: RE: Information required for Wärtsilä Engines (Calypso DWP Project)
Attachments: 50DF- maintenance shedule 13-12-2005.pdf

Bonjour,

Please find below response to your questions....

1) Operation & Maintenance (see enclosure)

2) Natural Gas Input required (maximum) for 8L50DF and 9L50DF at maximum operating capacity (scf/minute)

8L50DF: 100%load
2000m^3N/h -> ~1178ft^3/min

Note this is at 32 degrees F (not 70F) so this is not SCF! if we use an ideal gas as an estimate we can conclude that the volume of the gas will increase about 7,6% for the 21 degrees C that is the temperature used for SCF.

Thus we can **estimate a worst case scenario with** a flow of **1270 SCF/min**

9L50DF: 100%load
225( )3N/h -> ~1326ft^3/min (at 32F) -> **1428 SCF/min (estimate)**

The values behind this estimate are:
- Heat value for gas: 28MJ/m^3N (minimum allowed)
- Gas consumption at 100% load (8L&9L): 7370 kJ/kWh

If a gas with a better heat value is used the flow will be less, this was the worst case. A better heat value will also reduce the gas pressure after the GVU.

Best regards,

Alexandre Eykerman
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Houston TEXAS 77032
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direct +1 281 233-6283
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Mobile +1 832 244-2909
alexandre.eykerman@wartsila.com

From: Menon, Annie [mailto:AMenon@ene.com]
Sent: Tuesday, August 15, 2006 9:39 AM
To: Eykerman, Alexandre
Cc: Tessitore, Joseph
Subject: Information required for Wartsila Engines (Calypso DWP Project)

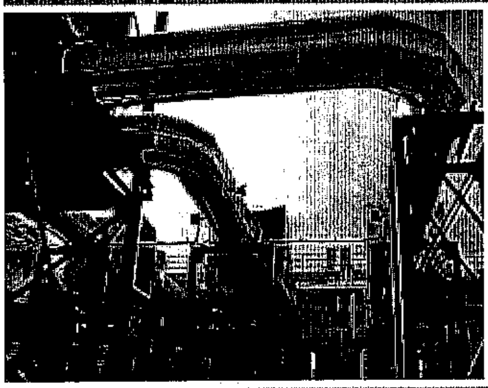
Alexandre,

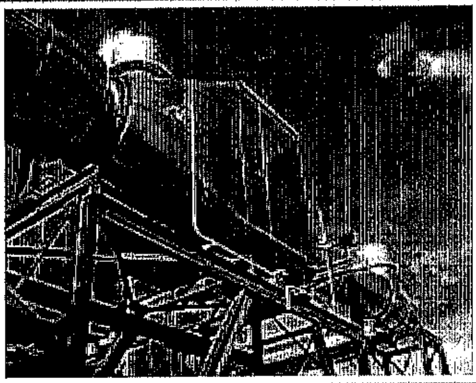
Appendix E
Florida Department of Environmental Protection
Air Quality Permit Application

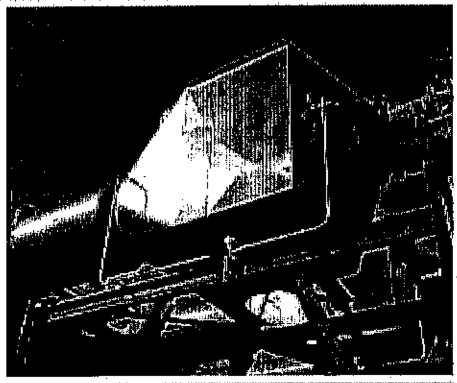
Attachment I-3
Detailed Description of Control Equipment / Vendor Data

EMISSIONS CONTROL SYSTEMS DATA (ENGINES)

Ultra Low Emissions Solution for gas power plants in the US market







by Hanna Strandberg, Senior Development Engineer Environment, Development & Technology, Power Plants

The Wärtsilä R&D project for ultra low air emissions with gas engines for the US market started early in 2000. As a result of this effort the first commercial project with this solution was in full operation at the beginning of 2002.

The Ultra Low Emissions (ULE) Solution is based on secondary emission reduction technologies, a selective catalytic reduction (SCR) system for control of nitrogen oxides (NO_X), and an efficient oxidation catalyst system for carbon monoxide (CO) and volatile organic compound (VOC) control. The system is specifically designed for Wärtsilä SG gas engines.

The first Wärtsilä dual-fuel (DF) engines applying a similar solution will be commissioned later this year. Feedback from the field is showing positive results, which gives us confidence in the future development of emission reduction technologies for gas engines.

Environmental impact of gas plants

All power plants have environmental impacts. The Wärtsilä lean-burn gas engine, however, is considered an environmentally sound alternative in the distributed power generation business.

The major environmental impacts of a gas power plant are the atmospheric emissions. The effective lean-burn combustion technology and the high thermal efficiency of the Wärtsilä gas engines ensure that the air emissions per kilowatt-hour of electricity produced are relatively low.

The Wärtsilä gas engine can be tuned for different NO_X emission levels to meet project-specific needs. Sulphur dioxide (SO_2) and particulate emissions are very low compared to operation on liquid fuels. The emissions of SO_2 are directly proportional to the sulphur content of the fuel being burned. In gaseous fuels sulphur can be present in the form of gas odorants and hydrogen sulphide (H_2S).

Gas suppliers usually remove H_2S from the gaseous fuels, resulting in negligible SO_2 emissions from gas engines. Abatement efficiencies up to 80% of CO can easily be achieved with a CO oxidation catalyst.

Moderate reduction of VOC, aldehyde and other hazardous air pollutant (HAP) compounds can also be achieved with this oxidation catalyst. Besides being dependent on engine optimization the VOC and aldehyde emissions from the gas engine are also strongly dependent on fuel quality, i.e. the composition of the natural gas.

Market demands

A gas engine as such or equipped with a CO oxidation catalyst can in most cases fulfil the emission limits. However, in some countries local authorities are applying stricter emission limits than the stipulated national or federal regulations, especially if the plant will be located in a sensitive area or degraded airshed.

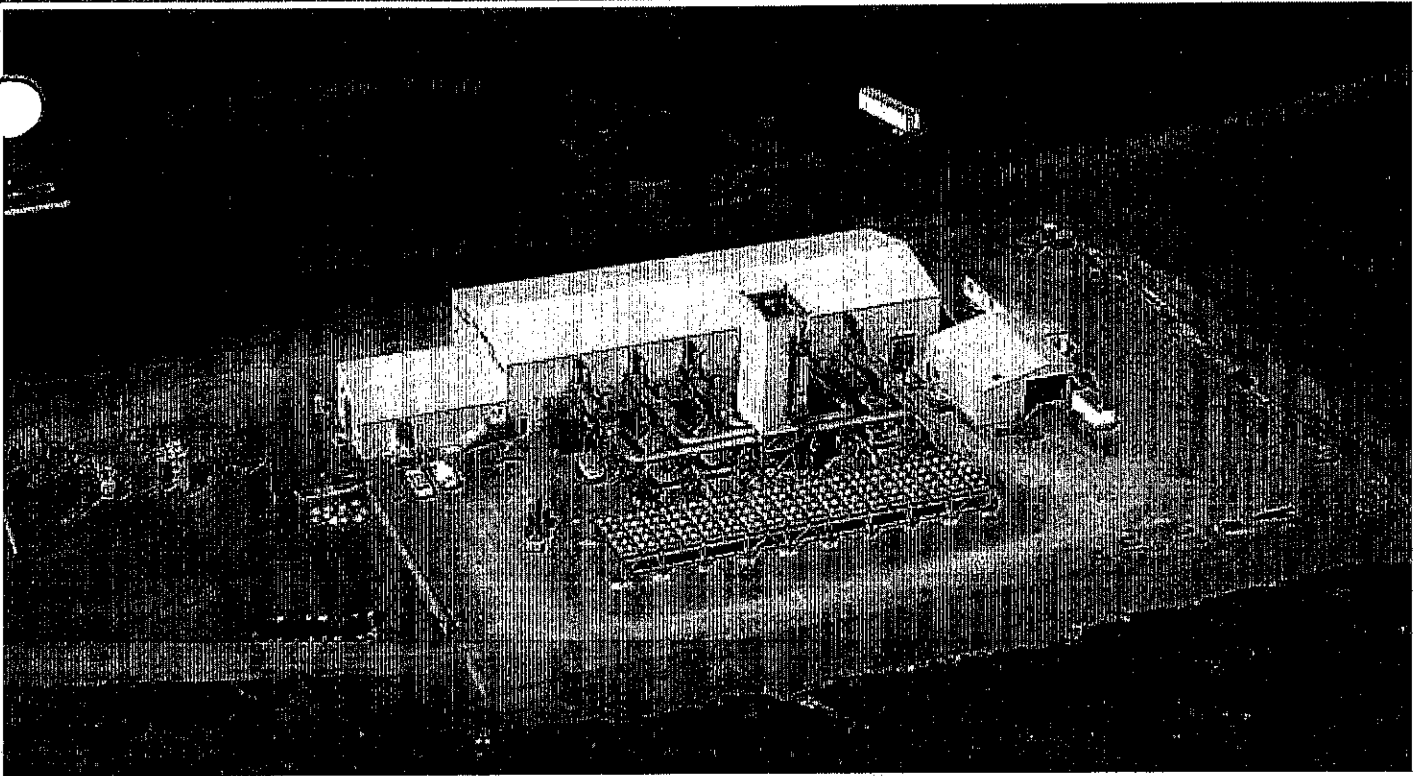
In the USA it is common practice to restrict the emission limits for maximum allowable emitted tonnes per year, which is stipulated in the plant operation permit. In practice this means that the higher the capacity of the plant and requested annual running hours, the stricter the actual emission limits in g/kWh will be. This makes the majority of projects in the US unique. It is essential that all environmental regulations are identified early and taken into consideration at the planning and design phase of the project.

The Ultra Low Emissions Solution

The Ultra Low Emissions (ULE) Solution is based on secondary emission reduction technologies.

A conventional platinum-based oxidation catalyst for CO and moderate hydrocarbon emission control have been installed on Wärtsilä gas engines (~700 MW) worldwide since the mid-1990s. The control method uses catalyst active metals to accelerate the oxidation reactions between combustible components and flue gas residual oxygen to carbon dioxide and water.

In order to reach very low emission



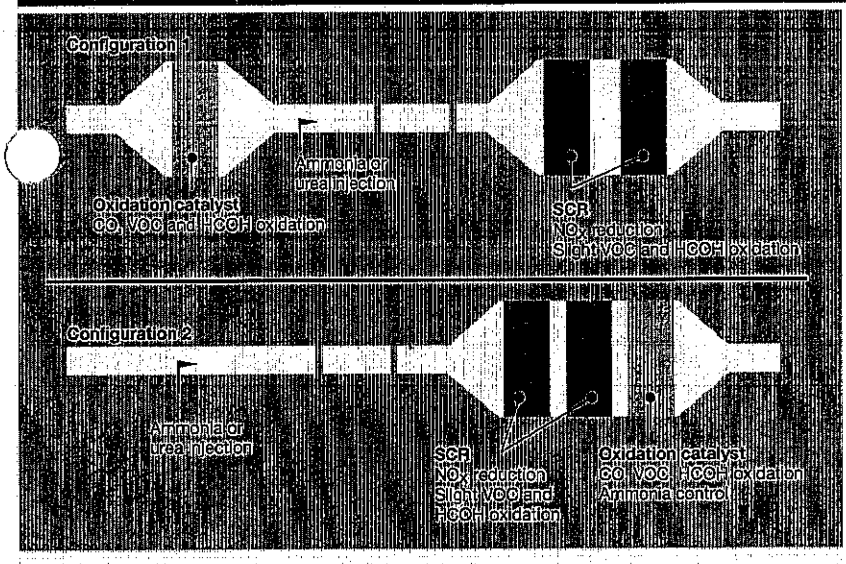


Figure 1. Alternative catalyst configurations for ULE design.

Unit	NO_X	CO	VOC	CH_2O
g/kWh *	0.082-0.125	0.10-0.30	0.125-0.25	0.018
ppm (15 %-vol O_2, dry gas)	5-9	12-35	20-40	1.5

* Calculated based on generator terminal output

Table 1. Emission limits in commercial projects in the USA.

levels (ULE) the plant has to be equipped with a more efficient oxidation catalyst. The active materials in such an oxidation catalyst are usually based on both platinum and palladium.

The use of Selective Catalytic Reduction (SCR) for removing NO_X emissions is a well known technology within Wärtsilä. SCR units have been installed on a few Wärtsilä gas engines and on many Wärtsilä diesel engines (500 MW) since early 1990.

In the SCR process, nitrogen oxides are reduced by injection of an ammonium-based compound to nitrogen (N_2, the major component of air) and water (H_2O). The system can be designed to apply either an aqueous urea (32-40%-wt) solution or aqueous ammonia (25%-wt) as the reduction agent.

The main components of the Ultra Low Emissions Solution consist of the reactor(s) with catalyst, reagent storage, injection and a control system. Figure 1 shows two different types of catalyst configurations based on the Ultra Low Emissions Solutions that are installed with Wärtsilä gas engines. The configuration is optimized for project-specific requirements and the technical solution of the catalyst vendor.

Important factors in the SCR design are the mixing stage, flue gas distribution, the amount of catalytic material and the control system. Unless there is a perfect mixing of the reagent and exhaust gas in combination with a perfect reactor design, the last ammonia (NH_3) molecules will not 'find' and convert the last few NO_X molecules. This will lead to excessive ammonia injection (NH_3/NO_X ratio larger than 1.0), which will eventually cause ammonia slip in the exhaust gas.

Many different compounds fall under the collective term VOC. The VOC components are oxidized at different rates. Saturated VOC, especially propane, react the slowest. Unsaturated, oxygen-containing organic compounds and polycyclic aromatics react considerably faster. The performance of the oxidation catalyst depends on exhaust gas temperature, the quantity of noble metals (tailor-made

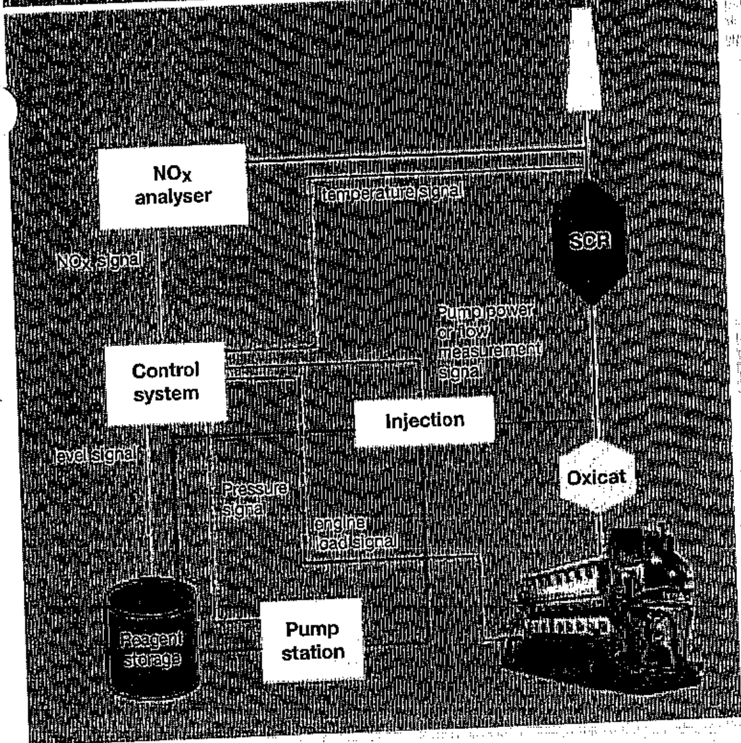


Figure 2. Schematic of control system

Investment cost (incl. installation)[Euro]	NO_x [g/kWh*]	VOC [g/kWh*]	% NO_x reduction	% VOC reduction
998,000	0.33	0.20 **	75	65
1,357,000	0.13	0.16 ***	90	78

* Based on generator terminal output
** Based on natural gas with methane number 90
*** Based on natural gas with methane number 85

Table 2. ULE system investment cost for a 23 MW gas engine plant.

Cost		74% NO_x reduction	90% NO_x reduction
Urea consumption	(4000 h/year) (8000 h/year)	69,000 138,000	83,000 165,000
Catalyst replacement *		56,000	69,000
Other O&M cost **		15,000	21,000
Total yearly cost	(8000 h/year)	209,000	255,000
Total O&M cost	(euro/MWh)	1.2	1.4

* Based on a 5-year average.
** Assuming 1.5% of investment cost

Table 3. O&M cost for a 23 MW power plant.

for ULE), the catalyst volume and the design (space velocity).

As mentioned earlier the Wärtsilä gas engine can be optimized either for optimal heat rate or for low NO_x emissions. The latter alternative has a small negative effect on heat rate and also on emissions of incomplete combustion products, such as CO and VOC emissions. Calculations show that the high efficiency engine setting is favourable for the ultra low emissions solution design.

Table 1 presents the emission guarantees in the commercial projects in the USA that were used as a design basis for the Ultra Low Emissions Solution.

The ammonia slip requirements were 0.028-0.047 g/kWh, which corresponds to 5-8 ppm (in wet gas, 15%-vol O_2)

A main limitation for the SCR technology to reach very low ppm NO_x values originates from the NH_3 slip requirement. In order to achieve very low NO_x and ammonia emissions simultaneously, the catalyst and control system must be designed with care.

The SCR control system is based on the engine load signal and a feedback signal from the NO_x analyser. The urea injection rate versus engine load curve is set during commissioning of the SCR system. The analyser is continuously (or semi-continuously if the analyser is time-shared between several engines) analysing the NO_x concentration at the reactor outlet in order to adjust the reagent injection rate. This way the system corrects for engine NO_x fluctuation due to variations in ambient conditions and consequently the guarantee values can be achieved at all times during normal stable load operation.

The exhaust temperature from the engine is optimal for SCR operation and does not require heat recovery prior or parallel to the mixing ducting of the SCR system as is the case in gas turbine installations. Both from a mechanical and operational point of view this is a simple and integrated system.

Good experience from the field

Feedback from the ULE solution installations is showing positive results. The measured emission values during commissioning have all been well below the guarantee levels (Table 1) at all installations.

Comprehensive pilot testing and successful commissioning is important in order to develop ULE further. It is also essential to follow up the long-term experience on such installations in order to optimize and develop the performance and reliability of this solution.

What does it cost?

The ULE solution has significant operation and maintenance costs in addition to the initial investment cost.

The investment, operation and maintenance costs for a catalyst system depend on the capacity of the engine, the uncontrolled emission concentration, the desired emission abatement and the annual operating hours of the engine. The prices of the catalytic materials also follow the world market prices of the catalytic active metals, such as platinum, palladium and vanadium.

Table 2 shows typical investment cost for different catalyst abatement efficiency systems. Prices are based on a 23 MW power plant operating on natural gas. Note that the VOC limit and corresponding percent reduction is heavily dependent on the natural gas specification. Values for the VOC are therefore only indicative.

Table 3 presents typical catalyst operating costs for different operation scenarios. The reagent price is dependent on specific site delivery cost, though 370 euros per ton of urea solution (40%-wt) has been used in these calculations. In the calculation it was assumed that the catalyst material has to be changed over a 5-year period. The catalyst replacement intervals are dependent on plant-specific operation conditions and will therefore vary from case to case.

It is a challenge for the regulatory

ULE:	**Ultra Low Emissions**	
Technology:	Secondary emission control technique Combined SCR and VOC catalyst system	
Application:	Wärtsilä gas engines	
ULE today:	NO_x	5 ppm (dry gas, 15 vol-% O_2)
	CO	12 ppm (dry gas, 15 vol-% O_2)
	VOC	20 ppm* (dry gas, 15 vol-% O_2)
	HCOH	1,5 ppm (dry gas, 15 vol-% O_2)
	Ammonia	5 ppm (wet gas, 15 vol-% O_2)

* dependent on fuel gas quality

Plains End

authority to focus on the total environmental impact. The total environmental impact includes production of the catalyst (containing heavy metals) and reagent (ammonia or urea), transportation of the catalyst and reagent to the site, disposal or recycling of the used catalyst, as well as added ammonia emissions to the atmosphere rather than the last few NO_x molecules in the exhaust gas.

The cost of secondary emission controls to achieve very low emission levels, mainly considering NO_x, might become excessive, i.e. the overall environmental impact may actually become worse. It might not be worth the price to attempt to reach zero level.

Wärtsilä offers reliable environmental solutions

Besides the ongoing development of primary emission reduction technologies for engines, i.e. increasing engine efficiency and optimizing the combustion processes, the secondary cleaning techniques for ultra low emission levels are here to stay. It is an inspiring task for Wärtsilä to develop secondary emission reduction techniques together with our sub-suppliers and to utilize these techniques in combination with our engines as successful solutions. ■

Sarayacu crude oil pump station chooses Wärtsilä 12V32LN

The Ecuadorian oil sector is divided into 32 blocks. Foreign oil companies have signed agreements with the government in order to receive the rights to explore and develop the different blocks.

Perenco, with headquarters in Paris, London and the Bahamas, bought the rights to explore Blocks 7 and 21 located in the Oriente region in 2002. To get the crude oil to the market, Perenco needed to construct a pipeline about 50 km long to connect to an existing pipeline owned by AGIP. To keep the oil flowing, a new pumping station will be built at Sarayacu.

1300 m above sea level

The Sarayacu pumping station is located in the Ecuadorian jungle 1300m above sea level at the borderline of Block 21. The pumping station will start to feed the new pipeline with heavy crude oil during 2003.

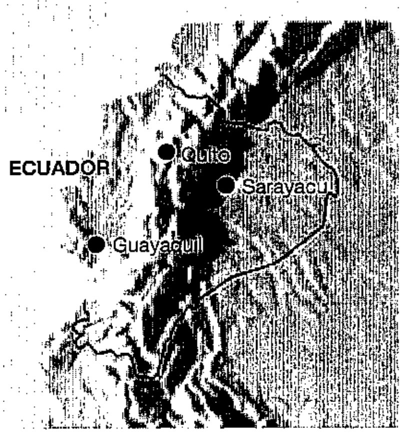
The site belongs to AGIP, who have been the forerunner in using crude-oil-fired Wärtsilä engines at their AGIP Villano oil field in the neighbouring Block 10. With 3 x 16V32LN (21.5 MW) in operation at the Villano field since 1998, AGIP has proven the technical and economic reliability of this new power production concept in Ecuador. They are at this moment installing the fourth 16V32LN for the expansion of the Villano field.

Technology of choice

With this pumping station in operation, Perenco will be able to increase their production capacity in Ecuador to 20,000 bpd and fill their initial quota established for the OCP pipeline.

The Sarayacu pump station will be equipped with two Wärtsilä 12V32LN generating sets burning crude oil. This order is a follow-up to the three Wärtsilä 12V32LN units Perenco bought last year for the power plant facility at the Yuralpa field in Block 21. The gensets will be delivered four months from order.

Wärtsilä 32LN engines have become the technology of choice for oil companies needing crude-oil-burning engines to generate power efficiently. With more than 3000 MW in operation, onshore and offshore, Wärtsilä has an abundance of experience in a number of different oil and gas field applications. ■



WÄRTSILÄ

Description of SCR

Document ID:
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Author:
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Date:
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1. INTRODUCTION

In order to meet the most stringent Nitrogen oxide emission levels Wärtsilä engines can be supplied with a Selective Catalytic Reduction system. The compact SCR is able to reduce the NO_x levels >90%. The SCR unit is developed for gas/diesel engines and characterised by low complexity, high efficiency, long service life and a compact design.

NO_x is reduced by SCR in which a small amount of a solution of urea and water is injected into the hot exhaust gas, where it is vaporised and contacted with NO_x in a heterogeneous catalysis over the SCR catalysts. Urea, (NH2)2CO, is a common chemical commodity used for NO_x reduction in various types of combustion processes and as a raw material in a wide range of products.

There are no waste products involved with the SCR process and the NO_x reduction rate can easily be varied to meet different air pollution regulations by adjusting the urea injection rate between 0-100%.

2. SCR SYSTEM

The main components in a SCR system are detailed described in this chapter. The exhaust gas silencer can be integrated into the SCR or placed after the SCR unit. If the overall plant efficiency is increased by installing a Waste heat recovery unit it will always be installed after the SCR unit in the exhaust gas funnel.

The main components in the NO_x reduction equipment are the storage tank, service pump, injection nozzles, SCR converter, NO_x analyser and control system.

2.1 UREA STORAGE

Urea is used as agent to reduce the NO_x level in the exhaust gas. Urea is generally supplied and bunkered as a ready solution with specific weight of about 1112 kg/m³ at 20°C and 40% Urea / water solution.

Steel tanks should be internally coated with epoxy or similar. Pipes and fittings should be made of stainless steel or plastic material (Urea is corrosive on Copper and its alloys).

The consumption of urea solution is generally within 5-8% (wt) of the fuel consumption depending on the desired NO_x reduction versus the base line emission.

2.2 SERVICE PUMP UNIT

The service pump transfers the liquid urea solution from the storage tank to the injection nozzles. The Urea Service Pump to be installed at urea tank bottom level. Service Pump System consists of 2 x 100 % capacity pump, filters, instrumentation, valves and fittings, starters, remote and local control.

2.3 INJECTION OF UREA/AIR

The urea solution is injected to the exhaust gas before the SCR converter. Urea is supplied by the service pump system via a control valve to respective injector. The injector is fitted in the injection section located before the SCR Converter. The injection of urea into the exhaust duct is augmented by pressurised injection air, supplied by a compressor system, in order to atomise the urea solution and to purge the injector from urea solution after injection shut off.

Downstream the injection section, static mixers are fitted into the exhaust piping. The mixers make sure that the exhausts and the vaporised urea are mixed to a homogenous gas flow before entering the SCR Converter.

2.4 SCR CONVERTER

The SCR converter is installed vertically in the casing, before any exhaust gas boiler. A drain should be arranged between exhaust gas boiler and SCR Converter, to avoid wash water entering the catalytic elements.

The SCR Converter comprises:

- Converter casing in high temperature steel.
- Gas distributors.
- Layers of SCR catalyst.

- Catalyst fixation and support system.
- Dust blower system can be supplied if necessary, see 2.4.1.
- Hatches for service and catalyst charging.
- Temperature and differential pressure instrumentation.

The lances are mounted under each catalyst layer covering the complete surface for efficient dust removal.

The SCR layers consist of ceramic monoliths/blocks packed side by side in multiple layers inside the converter casing. The catalyst blocks have narrow channels and are coated with catalytic active materials such as metals or their oxides. The open area is typically >65% thus providing an extremely large contact surface.

Depending on the operating conditions, type of catalyst, and the design safety margin, the performance of the catalysts is reduced over time. The SCR converter system can be operated up to 100,000 h before used catalyst is replaced or fresh catalyst is added

2.4.1 Dust blowing system

The SCR converters supplied by Wärtsilä can be equipped with a well-proven dust blowing system that is automatically operated on the starting or service air system. The system is designed for low air consumption and relies on air jets from a series of fixed lances inside the converters. Dust blowing duration and intervals are adjustable via the control panel.

If the fuel used for the power plant is unclean a dust blowing system is recommended. The automatic dust blowing system also adds extra safety in situations like engine combustion malfunction or poor / uneven fuel oil quality.

2.5 CONTROL/METERING UNIT

The Control / Metering Unit are installed in the engine room. Separate Control/Metering Units are supplied for each SCR Converter/diesel engine

The Control/Metering Unit consists of:

- Urea Control valve, fast responding.
- Urea Flow meters.
- Instrumentation.
- Valves and fittings.
- Control Cabinet containing electronics and PLC.

The Control/Metering Unit receives load signal from the diesel/gas engine and controls the urea injector, the service pump unit, the converter dust blower system and the atomisation air to the injection nozzle.

The Control Metering Unit receives load and RPM signal from respective diesel engine. T signals are used for controlling the urea injection flow to suit the different engine load conditions according to the pre-set injection curve. For gas engines with NO_x reduction rates about 90% (and other applications with strict reduction rates) a signal from a NO_x

The control system makes sure that the desired NO_x reduction is maintained throughout the load range of the engine. The control system supervises the SCR converter system and controls the injection of urea solution by a feed forward proxy NO_x function, which matches the stoichiometric proportions between urea and NO_x. This fast responding method guarantees a high NO_x reduction during transient load conditions.

2.6 NO_X ANALYSER

A NO_x analyser can be integrated to the SCR system. The samples to the NO_x analyser are taken after the SCR converter to measure the NO_x concentration in the exhaust gas. If a steady load is continuously achieved with the gas engines one NO_x analyser might be enough for a multiple engine installation. However; if the load will change during the operation one NO_x analyser is necessary for each engine.

3. DIMENSIONS AND WEIGHT

An exhaust gas silencer need to be installed after the SCR in order to achieve a noise attenuation of 25 or 35 dB(A).

Table 1. Typical technical information for one selective catalytic reactor (1 (2

Engine type	6L50DF	9L50DF
Length	1.5 m	2.0 m
Width	1.8 m	2.1 m
Height	3.2 m	3.7 m
Weight (loaded with catalyst)	Abt. 2400 kg	Abt. 4100 kg
Pressure drop at 100% MCR	1.9 kPa	1.6 kPa
Temperature increase over SCR system	Max 10 °C	Max 10 °C

1) Values are dependent of the type of installation

2) Dimensions without insulation

4. PERFORMANCE

- The urea solution is typically injected using one pump for several engines. One stand by pump is installed to achieve full redundancy.
- The injection air consumption is feed continuously in to the exhaust gas in combination with urea solution.
- The compressed air is feed from ships compressed air system. Dust blowing is only performed occasionally to clean the SCR converter.

Table 2. Typical consumption of one SCR unit[1]

ENGINE TYPE	6L50DF (in gas mode)	9L50DF (in gas mode)
Urea cons.(40 wt%)[2]	11-14 l/h	16-21 l/h
Injection air (7 bar)	10-15 Nm^3/h	15-25 Nm^3/h
Dust blowing air (7 bar)[3]	0.3–1.3 Nm^3/h	0.5-2 Nm^3/h
NO_x level after SCR[4][5]	0.2 g/kWh	0.2 g/kWh

1) Only typical, not for a specific project

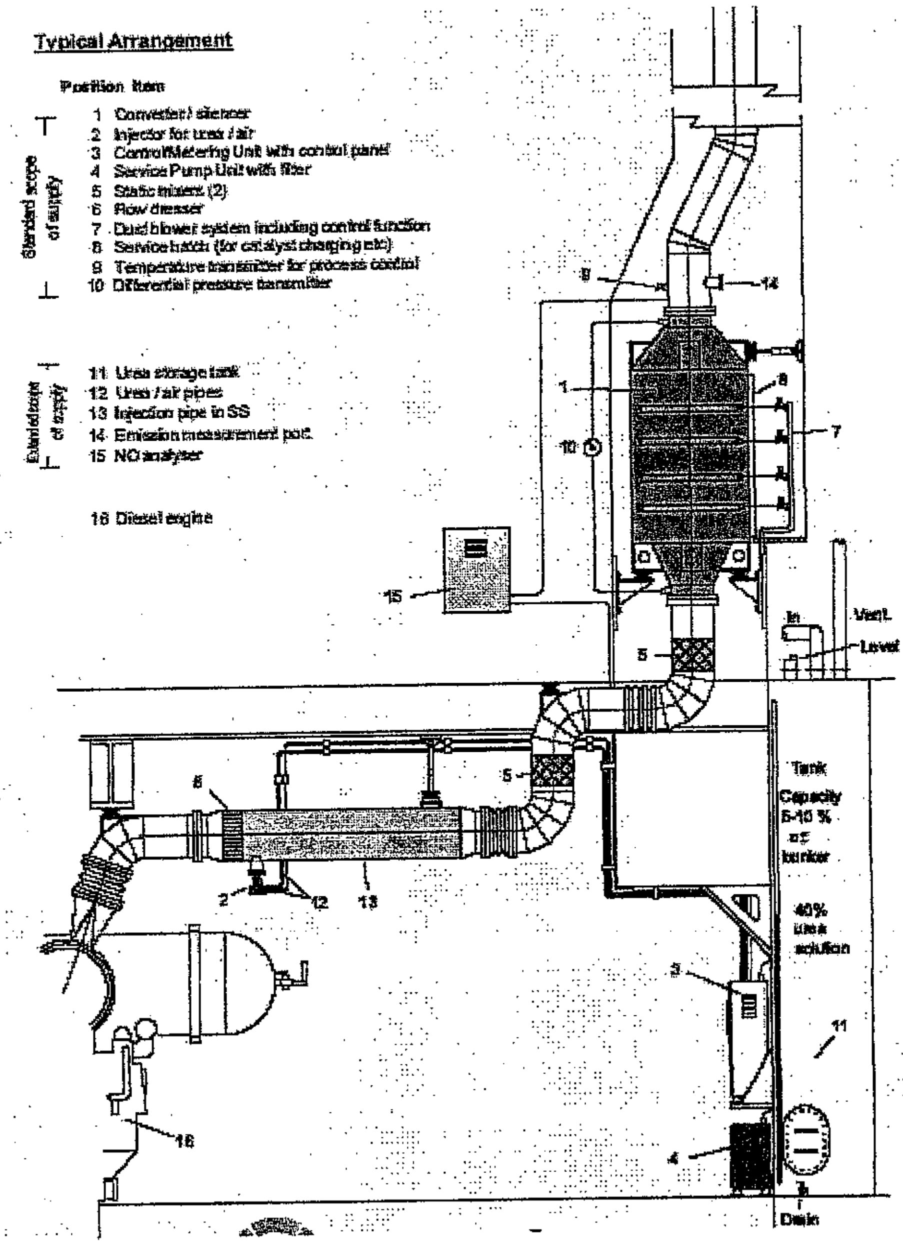
2) Consumption on 100% load

3) Occasionally used

4) Estimated O_2 content in ex. gas 12%

5) Based on measurement method: USA EPA 7E: Determination of nitrogen oxides from stationary sources (instrumental analyzer method)

5. TYPICAL ARRANGEMENT



Note! Gas engines to have constant upward slope to prevent gas to accumulate in the system.

Appendix E
Florida Department of Environmental Protection
Air Quality Permit Application

Attachment I-3
Detailed Description of Control Equipment / Vendor Data

EXHAUST GAS FLOW DATA (ENGINES)

WÄRTSILÄ

Project:				Doc.ID:	DAAB047605
Title:	Wärtsilä 50DF			Status:	Finalised
Subject:	Exhaust gas data 50DF			Rev:	c
Created:	Christian Westerlund	Date:	14.Feb.2006	Pages:	1/3
Checked:	Britt-Mari Kullas-Nyman	Date:	14.Feb.2006		

TYPICAL VALUES FOR EXHAUST GAS DATA FOR WÄRTSILÄ50DF

Engine: Wärtsilä 50DF
Rated engine output. 950 kW/cylinder

ISO Conditions [1)]
ISO 3046/1 conditions
LT-water temperature 35°C

GAS MODE OPERATION							
		6L50DF	8L50DF	9L50DF	12V50DF	16V50DF	18V50DF
Engine load	Exhaust gas temperature	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow
%	°C	kg/s	kg/s	kg/s	kg/s	kg/s	kg/s
100	400	9.0	12.0	13.5	17.9	23.9	26.9
95	406	8.6	11.5	12.9	17.2	22.9	25.8
90	412	8.2	11.0	12.3	16.4	21.9	24.6
85	418	7.9	10.4	11.8	15.7	20.9	23.5
80	424	7.5	9.9	11.2	14.9	19.9	22.3
75	430	7.1	9.4	10.6	14.2	18.9	21.2
70	434	6.7	8.8	10.0	13.3	17.7	19.9
65	438	6.2	8.2	9.3	12.4	16.6	18.6
60	442	5.8	7.7	8.7	11.6	15.4	17.3
55	446	5.3	7.1	8.0	10.7	14.3	16.0
50	450	4.9	6.5	7.4	9.8	13.1	14.7

DIESEL MODE OPERATION							
		6L50DF	8L50DF	9L50DF	12V50DF	16V50DF	18V50DF
Engine load	Exhaust gas temperature	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow
%	°C	kg/s	kg/s	kg/s	kg/s	kg/s	kg/s
100	348	11.9	15.9	17.8	23.8	31.7	35.7
95	347	11.4	15.2	17.1	22.8	30.4	34.2
90	346	10.9	14.5	16.3	21.8	29.1	32.7
85	346	10.4	13.9	15.6	20.8	27.7	31.2
80	345	9.9	13.2	14.8	19.8	26.4	29.7
75	344	9.4	12.5	14.1	18.8	25.1	28.2
70	349	8.9	11.8	13.3	17.7	23.7	26.6
65	354	8.3	11.1	12.5	16.7	22.3	25.0
60	360	7.8	10.4	11.7	15.6	20.8	23.4
55	365	7.3	9.7	10.9	14.6	19.4	21.8
50	370	6.7	9.0	10.1	13.5	18.0	20.2

Winter Conditions [1)]
Ambient 0°C, suction air temperature 10°C

GAS MODE OPERATION

Minor changes from exhaust gas data at ISO conditions.

DIESEL MODE OPERATION							
		6L50DF	**8L50DF**	**9L50DF**	**12V50DF**	**16V50DF**	**18V50DF**
Engine load	Exhaust gas temperature	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow
%	°C	kg/s	kg/s	kg/s	kg/s	kg/s	kg/s
100	320	12.4	16.6	18.5	24.8	33.0	37.2
95	319	11.9	15.9	17.8	23.8	31.7	35.6
90	318	11.4	15.2	17.0	22.7	30.3	34.1
85	318	10.8	14.4	16.2	21.7	28.9	32.5
80	317	10.3	13.7	15.5	20.6	27.5	30.9
75	316	9.8	13.0	14.7	19.6	26.2	29.4
70	321	9.2	12.3	13.9	18.5	24.7	27.7
65	326	8.7	11.6	13.0	17.4	23.2	26.1
60	330	8.1	10.8	12.2	16.3	21.7	24.4
55	335	7.6	10.1	11.4	15.2	20.2	22.7
50	340	7.0	9.4	10.5	14.1	18.8	21.0

Tropical Conditions[1)]
Suction air temperature 35°C
LT-water temperature 35°C

GAS MODE OPERATION

		6L50DF	8L50DF	9L50DF	12V50DF	16V50DF	18V50DF
Engine load	Exhaust gas temperature	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow
%	°C	kg/s	kg/s	kg/s	kg/s	kg/s	kg/s
100	398	9.0	12.0	13.5	17.9	23.9	26.9
95	404	8.6	11.5	12.9	17.2	22.9	25.8
90	410	8.2	11.0	12.3	16.4	21.9	24.6
85	416	7.9	10.4	11.8	15.7	20.9	23.5
80	422	7.5	9.9	11.2	14.9	19.9	22.3
75	428	7.1	9.4	10.6	14.2	18.9	21.2
70	432	6.7	8.8	10.0	13.3	17.7	19.9
65	436	6.2	8.2	9.3	12.4	16.6	18.6
60	440	5.8	7.7	8.7	11.6	15.4	17.3
55	444	5.3	7.1	8.0	10.7	14.3	16.0
50	448	4.9	6.5	7.4	9.8	13.1	14.7

DIESEL MODE OPERATION

		6L50DF	8L50DF	9L50DF	12V50DF	16V50DF	18V50DF
Engine load	Exhaust gas temperature	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow	Exhaust gas flow
%	°C	kg/s	kg/s	kg/s	kg/s	kg/s	kg/s
100	367	11.6	15.5	17.3	23.1	30.8	34.7
95	366	11.1	14.8	16.6	22.2	29.5	33.2
90	365	10.6	14.1	15.9	21.2	28.2	31.8
85	364	10.1	13.5	15.1	20.2	27.0	30.3
80	363	9.6	12.8	14.4	19.2	25.7	28.9
75	363	9.1	12.2	13.7	18.3	24.4	27.4
70	368	8.6	11.5	12.9	17.2	23.0	25.9
65	374	8.1	10.8	12.2	16.2	21.6	24.3
60	379	7.6	10.1	11.4	15.2	20.3	22.7
55	384	7.1	9.4	10.6	14.2	18.9	21.2
50	390	6.5	8.7	9.8	13.1	17.5	19.6

(Note 1) Flowrates given with 5% tolerance and temperatures with 10 °C tolerance.

Appendix E
Florida Department of Environmental Protection
Air Quality Permit Application

Attachment I-3
Detailed Description of Control Equipment / Vendor Data

MISCELLANEOUS BOILERS / NATURAL GAS & FUEL OIL EMISSIONS

TABLE 1.4-2. EMISSION FACTORS FOR CRITERIA POLLUTANTS AND GREENHOUSE GASES FROM NATURAL GAS COMBUSTION[a]

Pollutant	Emission Factor ($lb/10^6$ scf)	Emission Factor Rating
CO_2[b]	120,000	A
Lead	0.0005	D
N_2O (Uncontrolled)	2.2	E
N_2O (Controlled-low-NO_X burner)	0.64	E
PM (Total)[c]	7.6	D
PM (Condensable)[c]	5.7	D
PM (Filterable)[c]	1.9	B
SO_2[d]	0.6	A
TOC	11	B
Methane	2.3	B
VOC	5.5	C

[a] Reference 11. Units are in pounds of pollutant per million standard cubic feet of natural gas fired. Data are for all natural gas combustion sources. To convert from $lb/10^6$ scf to $kg/10^6$ m^3, multiply by 16. To convert from $lb/10^6$ scf to lb/MMBtu, divide by 1,020. The emission factors in this table may be converted to other natural gas heating values by multiplying the given emission factor by the ratio of the specified heating value to this average heating value. TOC = Total Organic Compounds. VOC = Volatile Organic Compounds.

[b] Based on approximately 100% conversion of fuel carbon to CO_2. CO_2[$lb/10^6$ scf] = (3.67) (CON) (C)(D), where CON = fractional conversion of fuel carbon to CO_2, C = carbon content of fuel by weight (0.76), and D = density of fuel, 4.2×10^4 $lb/10^6$ scf.

[c] All PM (total, condensible, and filterable) is assumed to be less than 1.0 micrometer in diameter. Therefore, the PM emission factors presented here may be used to estimate PM_{10}, $PM_{2.5}$ or PM_1 emissions. Total PM is the sum of the filterable PM and condensible PM. Condensible PM is the particulate matter collected using EPA Method 202 (or equivalent). Filterable PM is the particulate matter collected on, or prior to, the filter of an EPA Method 5 (or equivalent) sampling train.

[d] Based on 100% conversion of fuel sulfur to SO_2.
Assumes sulfur content is natural gas of 2,000 grains/10^6 scf. The SO_2 emission factor in this table can be converted to other natural gas sulfur contents by multiplying the SO_2 emission factor by the ratio of the site-specific sulfur content (grains/10^6 scf) to 2,000 grains/10^6 scf.

Table 1.3-1. CRITERIA POLLUTANT EMISSION FACTORS FOR FUEL OIL COMBUSTION[a]

Firing Configuration (SCC)[a]	SO_2[b]		SO_3[c]		NO_x[d]		CO[e]		Filterable PM[f]	
	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING	Emission Factor (lb/10^3 gal)	EMISSION FACTOR RATING
Boilers > 100 Million Btu/hr										
No. 6 oil fired, normal firing (1-01-004-01), (1-02-004-01), (1-03-004-01)	157S	A	5.7S	C	47	A	5	A	9.19(S)+3.22	A
No. 6 oil fired, normal firing, low NO_x burner (1-01-004-01), (1-02-004-01)	157S	A	5.7S	C	40	B	5	A	9.19(S)+3.22	A
No. 6 oil fired, tangential firing, (1-01-004-04)	157S	A	5.7S	C	32	A	5	A	9.19(S)+3.22	A
No. 6 oil fired, tangential firing, low NO_x burner (1-01-004-04)	157S	A	5.7S	C	26	E	5	A	9.19(S)+3.22	A
No. 5 oil fired, normal firing (1-01-004-05), (1-02-004-04)	157S	A	5.7S	C	47	B	5	A	10	B
No. 5 oil fired, tangential firing (1-01-004-06)	157S	A	5.7S	C	32	B	5	A	10	B
No. 4 oil fired, normal firing (1-01-005-04), (1-02-005-04)	150S	A	5.7S	C	47	B	5	A	7	B
No. 4 oil fired, tangential firing (1-01-005-05)	150S	A	5.7S	C	32	B	5	A	7	B
No. 2 oil fired (1-01-005-01), (1-02-005-01), (1-03-005-01)	157S	A	5.7S	C	24	D	5	A	2	A
No.2 oil fired, LNB/FGR, (1-01-005-01), (1-02-005-01), (1-03-005-01)	157S	A	5.7S	A	10	D	5	A	2	A

Table 1.3-1. (cont.)

Firing Configuration (SCC)[a]	SO_2[b]		SO_3[c]		NO_x[d]		CO[e]		Filterable PM[f]	
	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING	Emission Factor ($lb/10^3$ gal)	EMISSION FACTOR RATING
Boilers < 100 Million Btu/hr										
No. 6 oil fired (1-02-004-02/03) (1-03-004-02/03)	157S	A	2S	A	55	A	5	A	10	B
No. 5 oil fired (1-03-004-04)	157S	A	2S	A	55	A	5	A	9.19(S)+3.22	A
No. 4 oil fired (1-03-005-04)	150S	A	2S	A	20	A	5	A	7	B
Distillate oil fired (1-02-005-02/03) (1-03-005-02/03)	142S	A	2S	A	20	A	5	A	2	A
Residential furnace (A2104004/A2104011)	142S	A	2S	A	18	A	5	A	0.4[g]	B

[a] To convert from $lb/10^3$ gal to $kg/10^3$ L, multiply by 0.120. SCC = Source Classification Code.
[b] References 1-2,6-9,14,56-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.
[c] References 1-2,6-8,16,57-60. S indicates that the weight % of sulfur in the oil should be multiplied by the value given. For example, if the fuel is 1% sulfur, then S = 1.
[d] References 6-7,15,19,22,56-62. Expressed as NO_2. Test results indicate that at least 95% by weight of NO_x is NO for all boiler types except residential furnaces, where about 75% is NO. For utility vertical fired boilers use 105 $lb/10^3$ gal at full load and normal (>15%) excess air. Nitrogen oxides emissions from residual oil combustion in industrial and commercial boilers are related to fuel nitrogen content, estimated by the following empirical relationship: lb $NO_2/10^3$ gal = 20.54 + 104.39(N), where N is the weight % of nitrogen in the oil. For example, if the fuel is 1% nitrogen, then N = 1.
[e] References 6-8,14,17-19,56-61. CO emissions may increase by factors of 10 to 100 if the unit is improperly operated or not well maintained.
[f] References 6-8,10,13-15,56-60,62-63. Filterable PM is that particulate collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. Particulate emission factors for residual oil combustion are, on average, a function of fuel oil sulfur content where S is the weight % of sulfur in oil. For example, if fuel oil is 1% sulfur, then S = 1.
[g] Based on data from new burner designs. Pre-1970's burner designs may emit filterable PM as high as 3.0 $lb/10^3$ gal.

Table 1.3-3. EMISSION FACTORS FOR TOTAL ORGANIC COMPOUNDS (TOC), METHANE, AND NONMETHANE TOC (NMTOC) FROM UNCONTROLLED FUEL OIL COMBUSTION[a]

EMISSION FACTOR RATING: A

Firing Configuration (SCC)	TOC[b] Emission Factor ($lb/10^3$ gal)	Methane[b] Emission Factor ($lb/10^3$ gal)	NMTOC[b] Emission Factor ($lb/10^3$ gal)
Utility boilers			
No. 6 oil fired, normal firing (1-01-004-01)	1.04	0.28	0.76
No. 6 oil fired, tangential firing (1-01-004-04)	1.04	0.28	0.76
No. 5 oil fired, normal firing (1-01-004-05)	1.04	0.28	0.76
No. 5 oil fired, tangential firing (1-01-004-06)	1.04	0.28	0.76
No. 4 oil fired, normal firing (1-01-005-04)	1.04	0.28	0.76
No. 4 oil fired, tangential firing (1-01-005-05)	1.04	0.28	0.76
Industrial boilers			
No. 6 oil fired (1-02-004-01/02/03)	1.28	1.00	0.28
No. 5 oil fired (1-02-004-04)	1.28	1.00	0.28
Distillate oil fired (1-02-005-01/02/03)	0.252	0.052	0.2
No. 4 oil fired (1-02-005-04)	0.252	0.052	0.2
Commercial/institutional/residential combustors			
No. 6 oil fired (1-03-004-01/02/03)	1.605	0.475	1.13
No. 5 oil fired (1-03-004-04)	1.605	0.475	1.13
Distillate oil fired (1-03-005-01/02/03)	0.556	0.216	0.34
No. 4 oil fired (1-03-005-04)	0.556	0.216	0.34
Residential furnace (A2104004/A2104011)	2.493	1.78	0.713

[a] To convert from $lb/10^3$ gal to $kg/10^3$ L, multiply by 0.12. SCC = Source Classification Code.
[b] References 29-32. Volatile organic compound emissions can increase by several orders of magnitude if the boiler is improperly operated or is not well maintained.

Appendix E
Florida Department of Environmental Protection
Air Quality Permit Application

Attachment I-3
Detailed Description of Control Equipment / Vendor Data

MISCELLANEOUS DUAL FUEL AND DIESEL ENGINE EMISSIONS

Table 3.4-1. GASEOUS EMISSION FACTORS FOR LARGE STATIONARY DIESEL AND ALL STATIONARY DUAL-FUEL ENGINES[a]

Pollutant	Diesel Fuel (SCC 2-02-004-01)			Dual Fuel[b] (SCC 2-02-004-02)		
	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	EMISSION FACTOR RATING	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	EMISSION FACTOR RATING
NO_x						
Uncontrolled	0.024	3.2	B	0.018	2.7	D
Controlled	0.013[c]	1.9[c]	B	ND	ND	NA
CO	5.5 E-03	0.85	C	7.5 E-03	1.16	D
SO_x[d]	8.09 E-03S_1	1.01S_1	B	4.06 E-04S_1 + 9.57 E-03S_2	0.05S_1 + 0.895S_2	B
CO_2[e]	1.16	165	B	0.772	110	B
PM	0.0007[c]	0.1[c]	B	ND	ND	NA
TOC (as CH_4)	7.05 E-04	0.09	C	5.29 E-03	0.8	D
Methane	f	f	E	3.97 E-03	0.6	E
Nonmethane	f	f	E	1.32 E-03	0.2[g]	E

[a] Based on uncontrolled levels for each fuel, from References 2,6-7. When necessary, the average heating value of diesel was assumed to be 19,300 Btu/lb with a density of 7.1 lb/gallon. The power output and fuel input values were averaged independently from each other, because of the use of actual brake-specific fuel consumption (BSFC) values for each data point and of the use of data possibly sufficient to calculate only 1 of the 2 emission factors (e. g., enough information to calculate lb/MMBtu, but not lb/hp-hr). Factors are based on averages across all manufacturers and duty cycles. The actual emissions from a particular engine or manufacturer could vary considerably from these levels. To convert from lb/hp-hr to kg/kw-hr, multiply by 0.608. To convert from lb/MMBtu to ng/J, multiply by 430. SCC = Source Classification Code.

[b] Dual fuel assumes 95% natural gas and 5% diesel fuel.

[c] References 8-26. Controlled NO_x is by ignition timing retard.

[d] Assumes that all sulfur in the fuel is converted to SO_2. S_1 = % sulfur in fuel oil; S_2 = % sulfur in natural gas. For example, if sulfer content is 1.5%, then S = 1.5.

[e] Assumes 100% conversion of carbon in fuel to CO_2 with 87 weight % carbon in diesel, 70 weight % carbon in natural gas, dual-fuel mixture of 5% diesel with 95% natural gas, average BSFC of 7,000 Btu/hp-hr, diesel heating value of 19,300 Btu/lb, and natural gas heating value of 1050 Btu/scf.

[f] Based on data from 1 engine, TOC is by weight 9% methane and 91% nonmethane.

[g] Assumes that nonmethane organic compounds are 25% of TOC emissions from dual-fuel engines. Molecular weight of nonmethane gas stream is assumed to be that of methane.

Table 3.4-2. PARTICULATE AND PARTICLE-SIZING EMISSION FACTORS FOR LARGE UNCONTROLLED STATIONARY DIESEL ENGINES[a]

EMISSION FACTOR RATING: E

Pollutant	Emission Factor (lb/MMBtu) (fuel input)
Filterable particulate[b]	
< 1 μm	0.0478
< 3 μm	0.0479
< 10 μm	0.0496
Total filterable particulate	0.0620
Condensable particulate	0.0077
Total PM-10[c]	0.0573
Total particulate[d]	0.0697

[a] Based on 1 uncontrolled diesel engine from Reference 6. Source Classification Code 2-02-004-01. The data for the particulate emissions were collected using Method 5, and the particle size distributions were collected using a Source Assessment Sampling System. To convert from lb/MMBtu to ng/J, multiply by 430. PM-10 = particulate matter ≤ 10 micrometers (μm) aerometric diameter.

[b] Particle size is expressed as aerodynamic diameter.

[c] Total PM-10 is the sum of filterable particulate less than 10 μm aerodynamic diameter and condensable particulate.

[d] Total particulate is the sum of the total filterable particulate and condensable particulate.