WÄRTSILÄ

WÄRTSILÄ **Engines**

WÄRTSILÄ 50DF ENGINE TECHNOLOGY

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

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INTRODUCTION

The WÄRTSILÄ® 50DF tri-fuel engine is the ultimate 'fuel flexibility' engine.

The Wärtsilä 50DF is a four-stroke dual-fuel engine that can be run on natural gas, light fuel oil (LFO) or 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 950/975 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%, higher than for any other gas engine.

DESIGN PHILOSOPHY

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

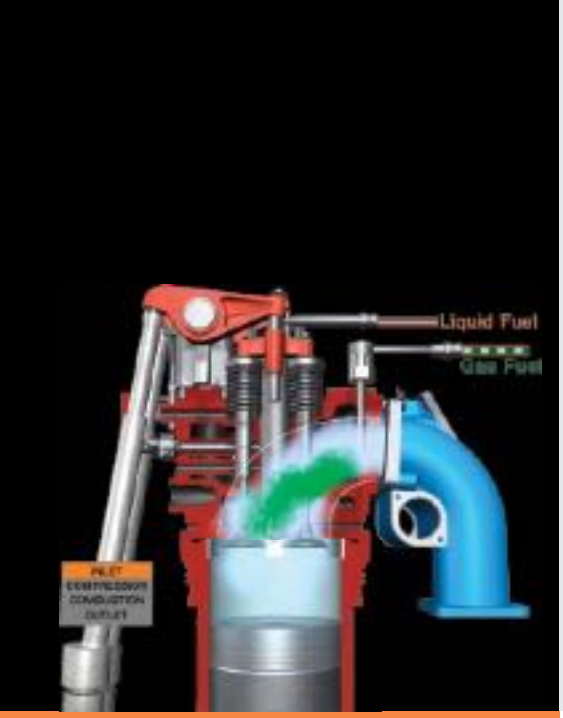
The Wärtsilä 50DF is designed to provide high output with fuel flexibility, low emission rates, high efficiency and high reliability. The engine functions are controlled by an advanced automation system that allows optimum running conditions to be set independent of the ambient conditions or fuel.

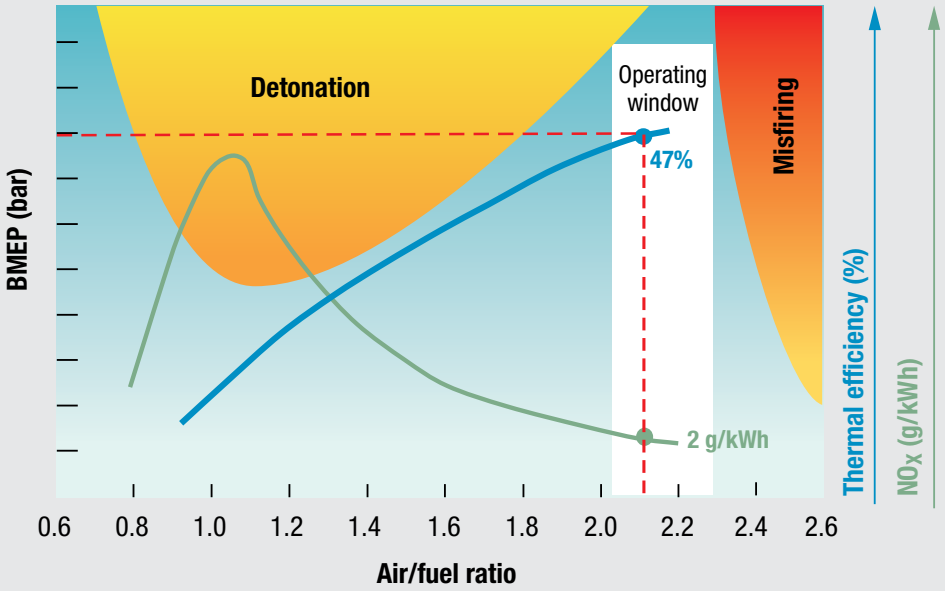
Both the gas admission and pilot fuel injection are electronically controlled. This ensures that the correct air-fuel ratio can be set for each cylinder individually and that the minimum amount of pilot fuel can be injected while ensuring safe and stable combustion. All parameters are controlled automatically 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 Wärtsilä 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's NOx emissions comply with the Word Bank guidelines for dual-fuel engines as well as the upcoming IMO Tier II standard.





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.

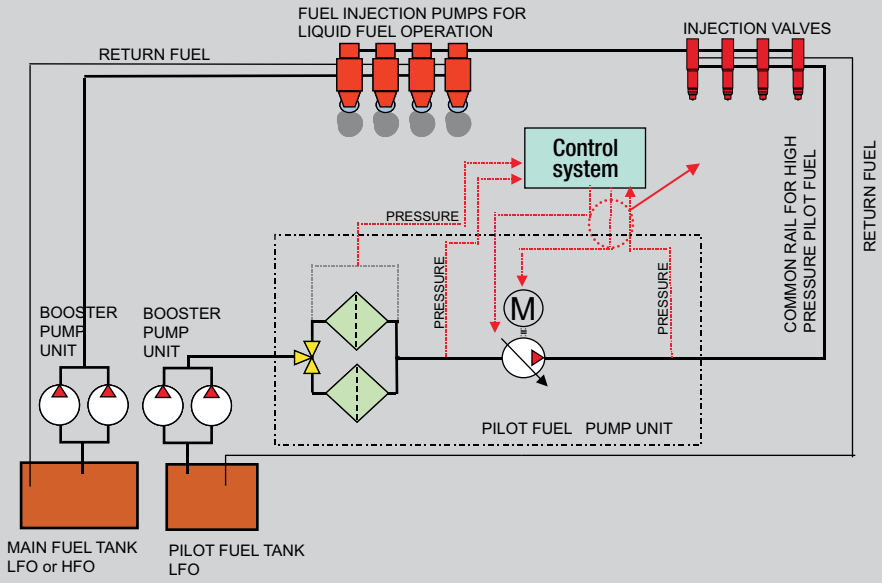
FUEL SYSTEM

The fuel system of the Wärtsilä 50DF trifuel has been divided into three: one for gas, one for liquid fuel and a separate pilot fuel system. The Wärtsilä 50DF is normally started in diesel mode using both main diesel and pilot fuel. Gas admission is activated when combustion is stable in all cylinders. 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. When running the engine in liquid fuel mode the pilot is also in use to ensure nozzle cooling.

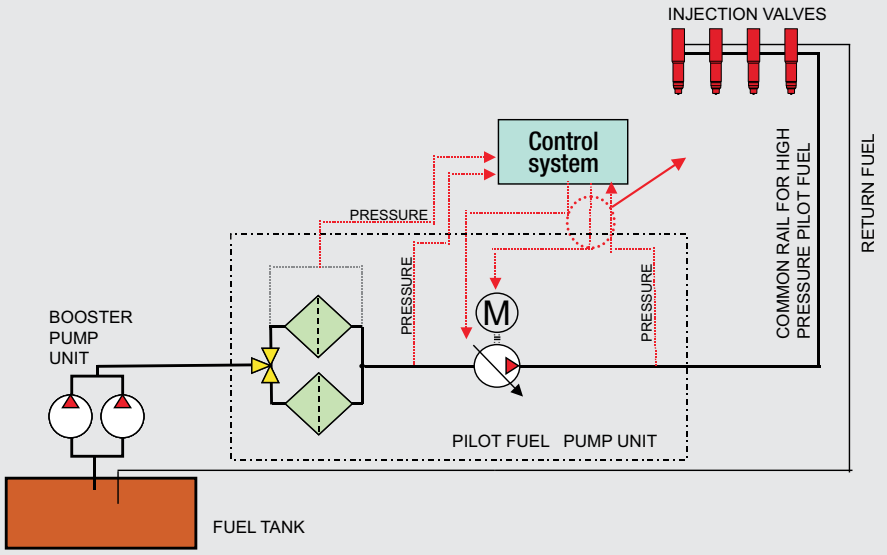
The power plant engine can also be delivered without the liquid fuel system. In this case the engine is started on pilot fuel with gas admission activated when engine is up in speed. The synchronisation and loading is done on gas. The pilot fuel consumption is here the same less than 1 % of full load fuel consumption. This option is not available for marine installations.

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



Wärtsilä 50DF fuel oil system for light fuel and heavy fuel oil.



Wärtsilä 50DF as a pure gas engine with pilot only, available for power plant installations.

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/m^3. 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 piping in marine installations is of double wall design as standard.

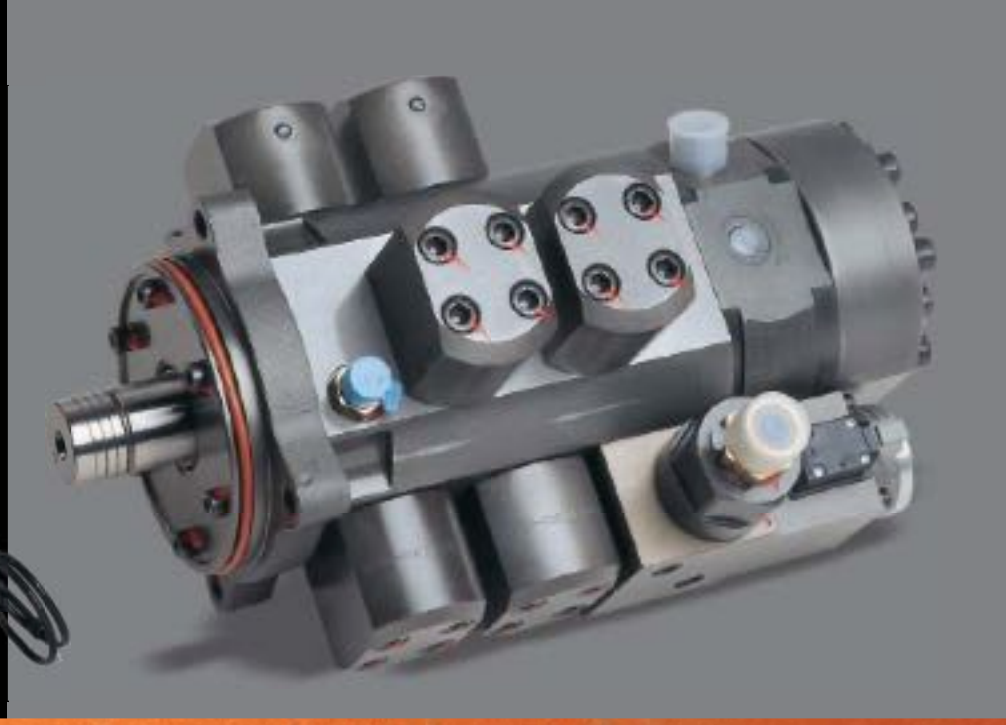
DIESEL OIL SUPPLY

The fuel oil supply on the engine is divided into two separate systems: one for the pilot fuel and the other for liquid 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 pilot fuel system is separated from the liquid fuel system with separate connections on the engine. The liquid fuel is separated from the pilot fuel system and 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 for LFO or HFO operation and the smaller for pilot fuel oil when the engine is running in gas mode and also in liquid fuel operation to ensure nozzle cooling. 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

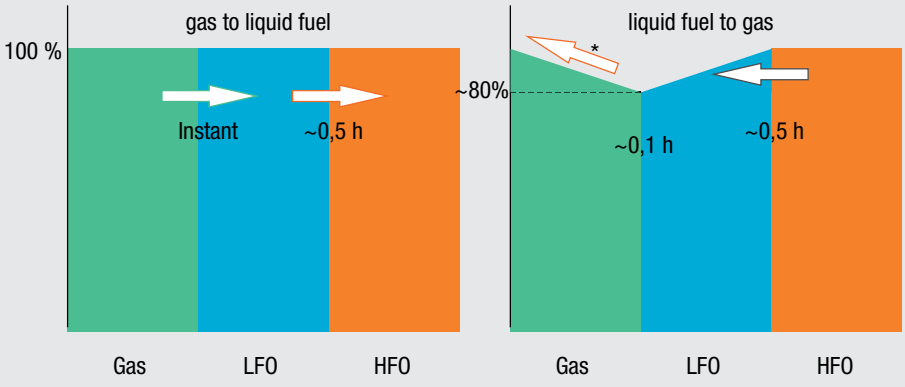
The Wärtsilä 50DF utilizes the well-proven monoblock injection pump developed by Wärtsilä. This pump withstands the high pressures involved in fuel injection and has a constant-pressure relief valve to avoid cavitation. The fuel pump is ready for operation at all times and will switch over from gas to fuel oil 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.

"INSTANT" CHANGE OVER FROM GAS TO HFO MODE WITH THE TRI-FUEL SOLUTION

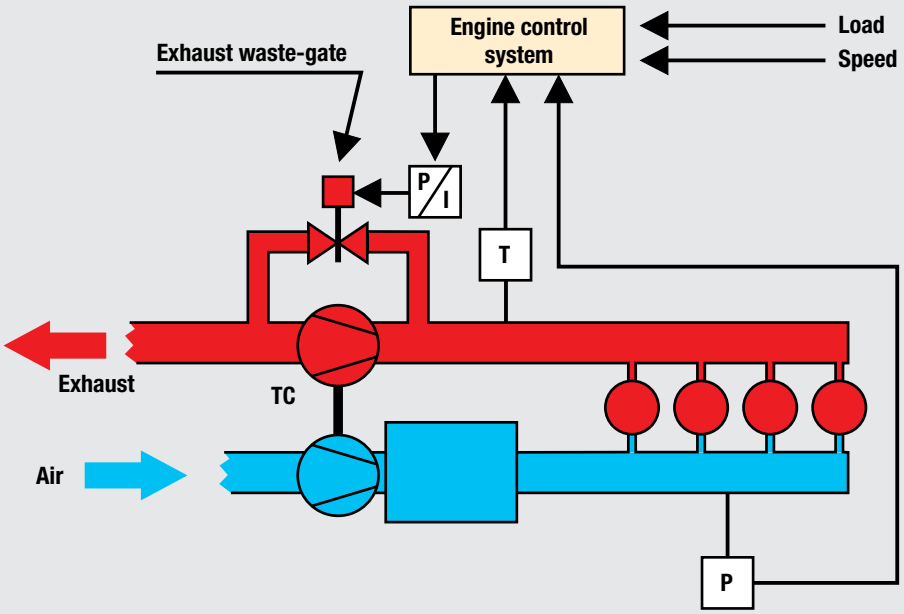


In the tri-fuel solution the twin injection nozzles are used also for HFO operation.
The LFO pilot is in use also during the HFO operation.
* The time to reach full load on gas depends on duration of HFO operation.

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.

In the event of for instance a gas supply interruption, the engine converts from gas to fuel oil operation at any load instantaneously and automatically. Futhermore, the separate liquid fuel system makes it possible to switch over from LFO to HFO without load reduction. The pilot fuel is in operation during HFO operation to ensure nozzle cooling. The pilot fuel consumption is less than 1% of full load fuel consumption. Switching over to LFO from HFO operation can also be done without load reduction. From LFO to gas operation, the switch can be made as described above. This operation flexibility is the real advantage of the tri-fuel system.



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. Power plant engines of V-type are also available with an open interface system where the cooling circuits can be connected separately. This makes optimized heat recovery and optimized cooling system possible. The LT pump is always in serial connection with second stage of CA cooler. The HT pump is always in serial connection with the jacket cooling circuit Both HT and LT water pumps are engine-driven.

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. Cylinder heads are equipped with starting valves.

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.

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.

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.

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

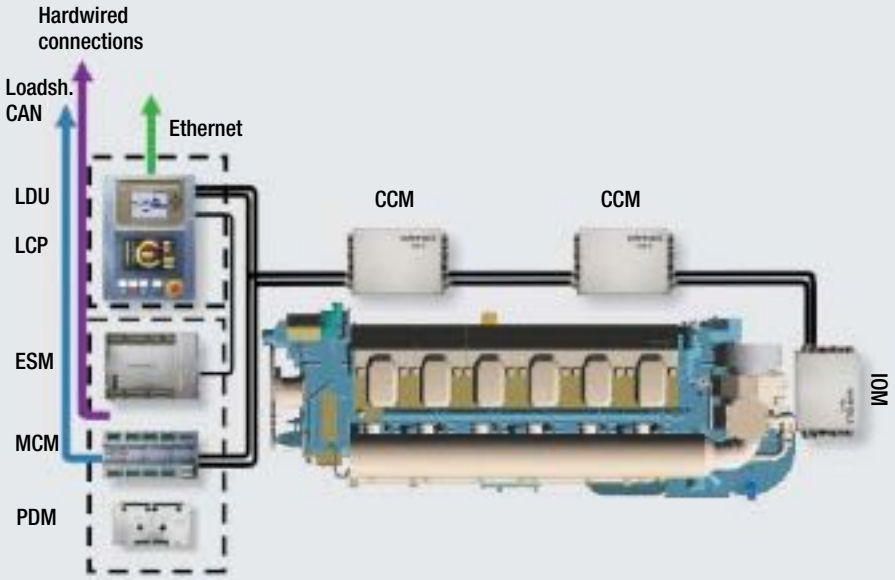
The Wärtsilä 50DF is equipped with the modular-built Spex (single pipe exhaust) turbocharging system, which combines the advantages of both pulse and constant pressure charging. The interface between engine and turbocharger is streamlined with a minimum of flow resistance on both exhaust and air sides. 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 due to point-to-point cabling, high quality cables and rugged mounting of engine electronics
- Easy interfacing with external systems via a databus
- Reduced cabling on and around the engine
- High flexibility and easy customizing



UNIC C3

- 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 reduces cabling 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.

FUELS

GAS FUEL 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/Nm^3	> 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/Nm^3	< 25
Chlorine + fluorines	mg/Nm^3	< 50
Particles or solids content	mg/Nm^3	< 50
Particles or solids size	μm	< 5
Gas inlet temperature	°C	0-60
Gas inlet pressure	bar (g)	3.9 at LHV 36

LIQUID FUEL QUALITY

The Wärtsilä 50DF is designed for continuous operation, without reduction in the rated output, on pilot and liquid main 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 liquid main 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 **Engines**

MAIN TECHNICAL DATA WÄRTSILÄ 50DF

Cylinder bore	500 mm
Piston stroke	580 mm
Cylinder output	950/975 kW/cyl
Speed	500, 514 rpm
Mean effective pressure	20.0 bar
Piston speed	9.7, 9.9 m/s

MARINE ENGINES, IMO Tier II

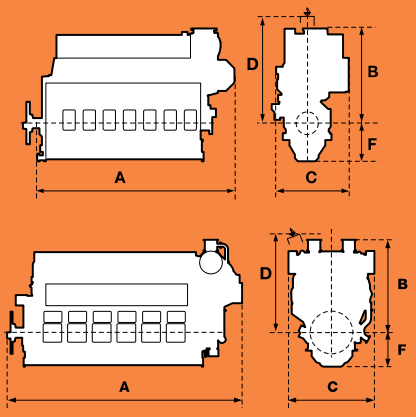
RATED POWER

Engine type	50 Hz		60 Hz	
	Engine kW	Gen. kW	Engine kW	Gen. kW
6L50DF	5 700	5 500	5 850	5 650
8L50DF	7 600	7 330	7 800	7 530
9L50DF	8 550	8 250	8 775	8 470
12V50DF	11 400	11 000	11 700	11 290
16V50DF	15 200	14 670	15 600	15 050
18V50DF	17 100	16 500	17 550	16 940

Generator output based on a generator efficiency of 96.5%.

ENGINE DIMENSIONS (MM) AND WEIGHTS (TONNES)

Engine type	A	B	C	D	F	Weight
6L50DF	8 115	3 580	2 850	3 820	1 455	96
8L50DF	9 950	3 600	3 100	3 820	1 455	128
9L50DF	10 800	3 600	3 100	3 820	1 455	148
12V50DF	10 465	4 055	3 810	3 600	1 500	175
16V50DF	12 665	4 055	4 530	3 600	1 500	220
18V50DF	13 725	4 280	4 530	3 600	1 500	240



POWER PLANT ENGINES

TECHNICAL DATA 50 HZ/500 RPM

	Unit	18V50DF	18V50DF*
Power, electrical	kW	16621	16621
Heat rate	kJ/kWh	7616	8185
Electrical efficiency	%	47.3	44.0
Technical data 60 Hz/514 rpm			
Power, electrical	kW	17076	17076
Heat rate	kJ/kWh	7616	8185
Electrical efficiency	%	47.3	44.0
Dimensions and dry weight with generating set			
Length	mm	18780	18780
Width	mm	4090	4090
Height	mm	6020	6020
Weight	tonne	355	355

Heat rate and electrical efficiency at generator terminals, including engine-driven pumps, ISO 3046 conditions and LHV. Tolerance 5%. Power factor 0.8. Gas Methane Number >80. *in liquid mode.

WÄRTSILÄ

Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. By emphasising technological innovation and total efficiency, Wärtsilä maximises the environmental and economic performance of the vessels and power plants of its customers. Wärtsilä is listed on the NASDAQ OMX Helsinki, Finland.

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