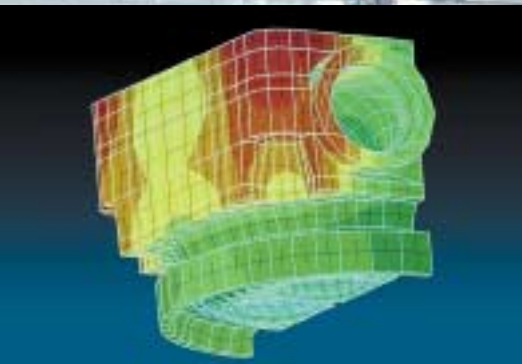
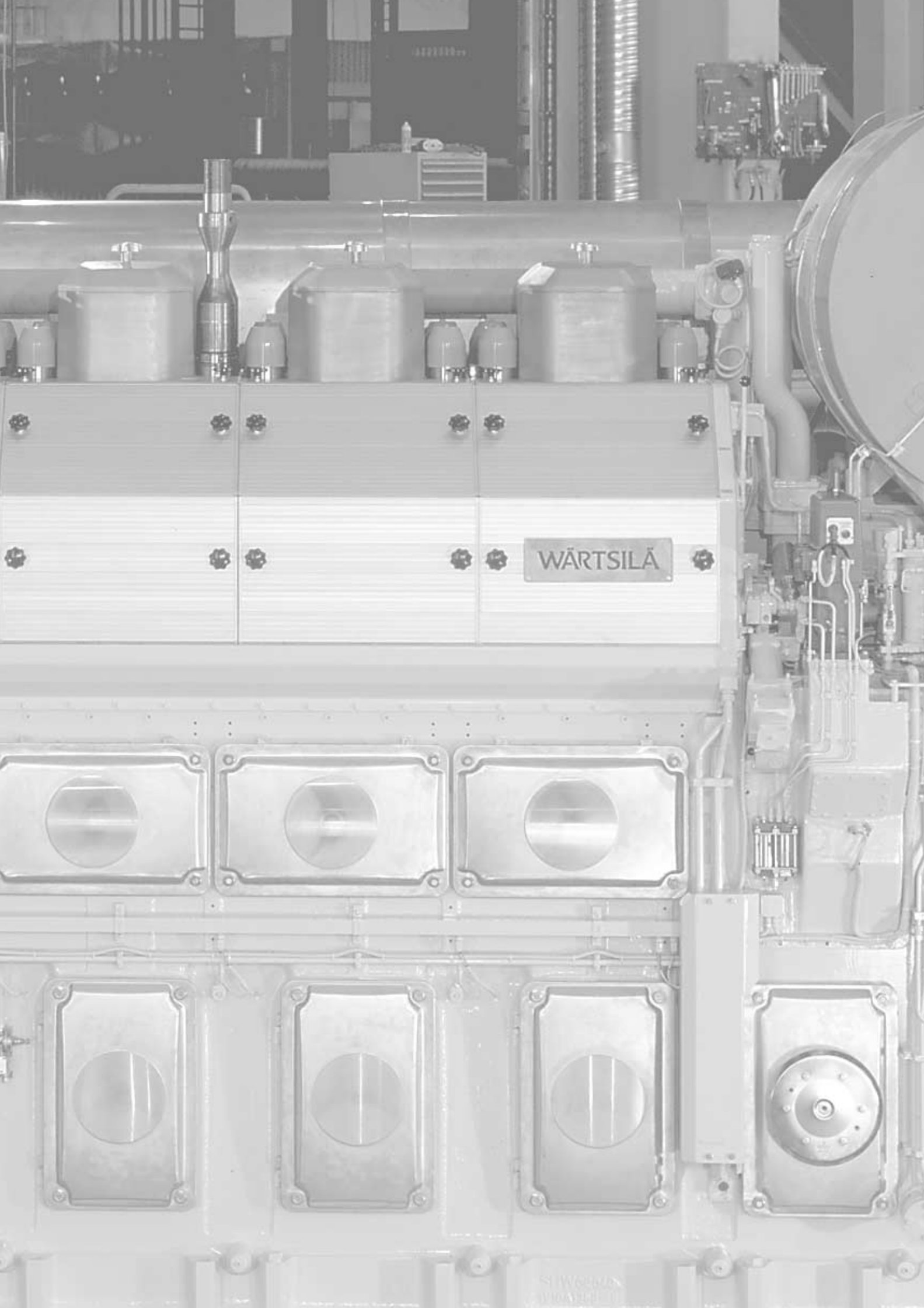


Technology Review





WÄRTSILÄ

SIEMENS
WÄRTSILÄ

Technology Review

This is a summary of Wärtsilä NSD's approach to design and technology in the Wärtsilä 46 engine.

Design Philosophy	4
Development Policy	5
Low NO _x Combustion	6
Direct Water Injection	8
Injection Pump, Injection Valve	10
Fuel System	11
Turbocharging System	12
Piston, Piston Ring Set	14
Connecting Rod	15
Cylinder Liner and Anti-polishing Ring	16
Cylinder Head	17
Crankshaft, Bearings	18
Camshaft and Valve Gear	19
Engine Block	20
Cooling Systems	22
Lubricating Oil System	23
Automation System	24
Maintenance	25
Main Technical Data	26

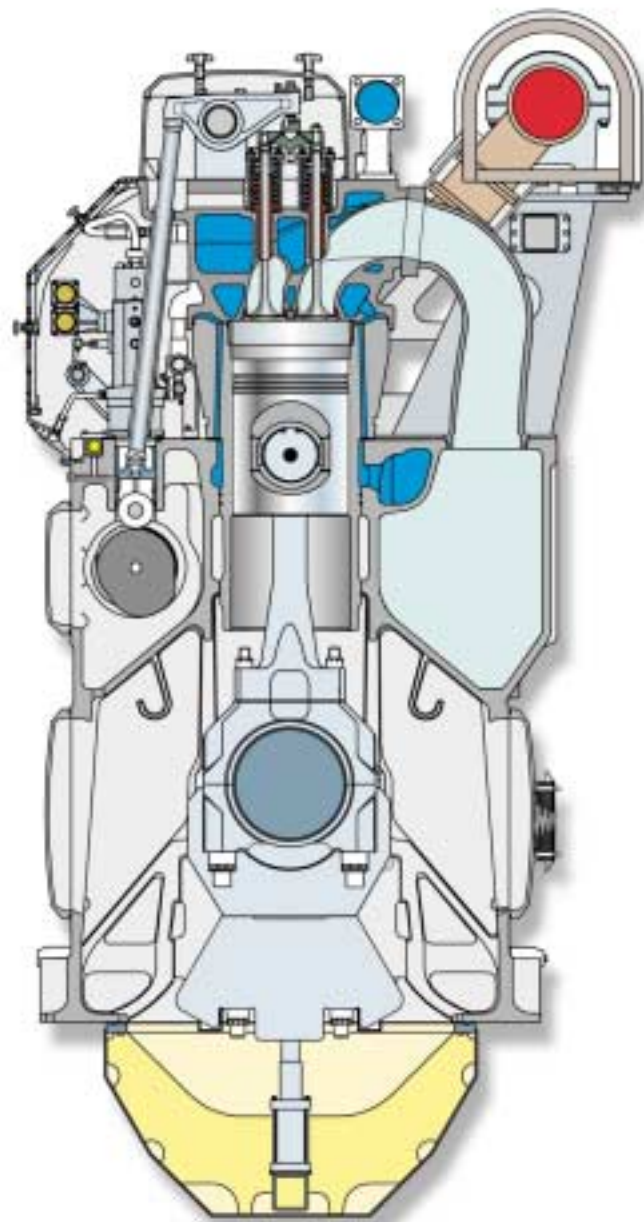
Design Philosophy



Wärtsilä NSD engine designs are based on generations of know-how combined with innovations in response to customer needs.

The Wärtsilä 46 engine offers customers the following core values:

- Real reliability
- Low operating costs
- Low exhaust gas emissions
- Easy and cost-effective installation
- Proven flexible mounting technology
- Easy maintenance



The Wärtsilä 46 is a medium-speed engine for which Reliability and Total Economy have been the guiding principles.

Extensive testing in our modern diesel laboratory backed up by several thousand running hours have made the Wärtsilä 46 a Really Reliable diesel engine. Laboratory testing is full-scale engine testing: it covers various types of endurance testing, and also combustion measurements and system optimizations. All these confirm theoretical calculations, simulations as well as performance mapping of such factors as heat balance, fuel and lube oil consumption, exhaust emission, noise and vibration level.

Wärtsilä NSD Corporation works in close co-operation with the customer in conducting field tests and follow-ups of selected test components. Data on wear rates, maintenance intervals and consumption rates are collected regularly. This activity is part of a long-term customer relationship creating an even better product.



Due to its excellent combustion performance and reliability level the Wärtsilä 46 has become the most popular engine for power generation onboard new cruise vessels. Voyager of the Seas is equipped with six 12-cylinder Wärtsilä 46 V-engines with a total output of 75,600 kW.

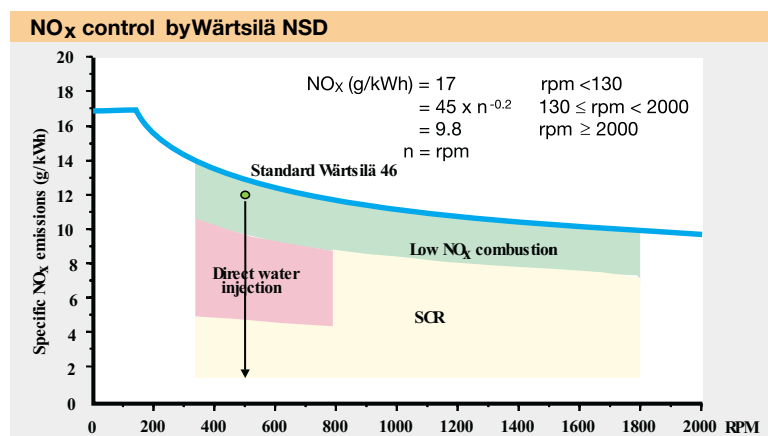
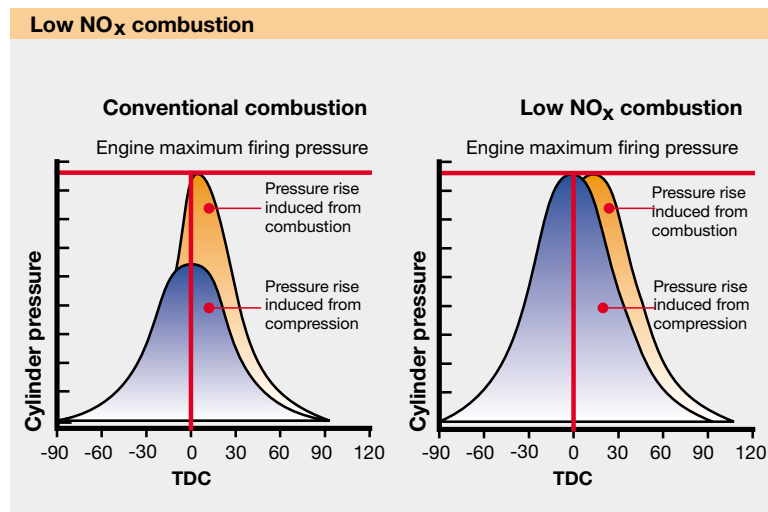
The Rio Negro Power Master plant in Manaus, Brazil. The plant has a total capacity of 158 MW and is equipped with ten 18-cylinder Wärtsilä 46 engines as prime movers.



Low NO_x Combustion

Any hydrocarbon can be burnt provided the temperature is right and there is sufficient oxygen. However, the way it is burnt has a great effect on thermal efficiency and exhaust emissions, particularly NO_x formation. Wärtsilä NSD has developed a low NO_x combustion process which reduces the NO_x level up to 50% without compromising on thermal efficiency. The low NO_x combustion technology is based on the following:

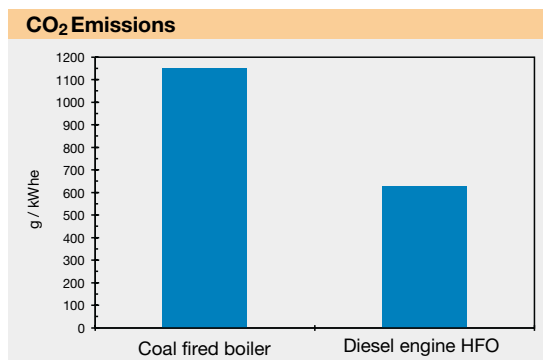
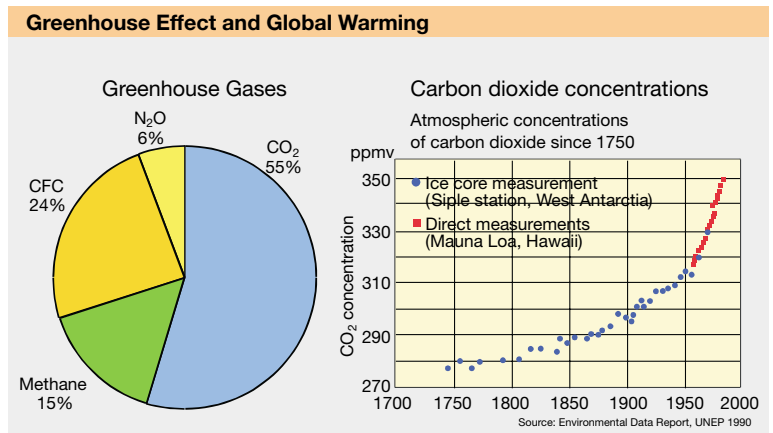
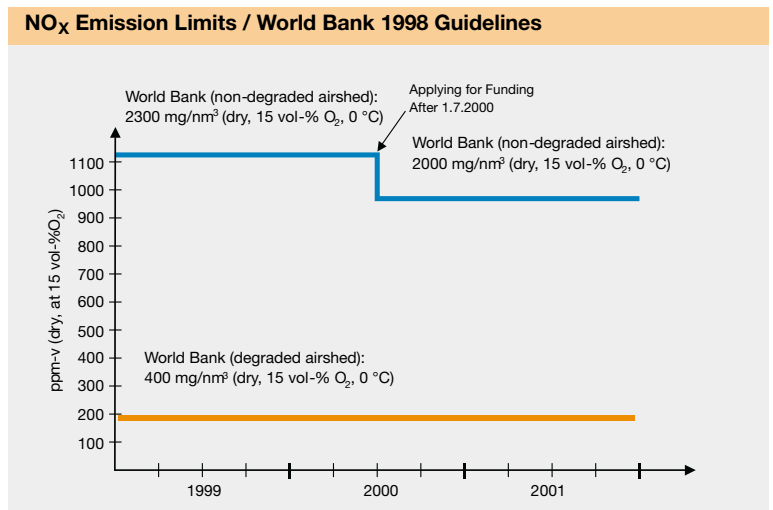
- A higher combustion air temperature at injection start drastically reduces the ignition delay
- A retarded injection start and shorter injection period means that combustion takes place at the optimal point with respect to efficiency
- Improved fuel atomization
- Modified combustion space for improved mixing



When talking about Power Plant stack emissions nitrogen oxides (NO_x), sulphur dioxides (SO_x) and particles (as dry dust) are in focus. World Bank Guidelines 1998 for "Thermal Power: Guidelines for New Plants" take into account the air quality in the surrounding of the power plant when defining the applicable stack limits.

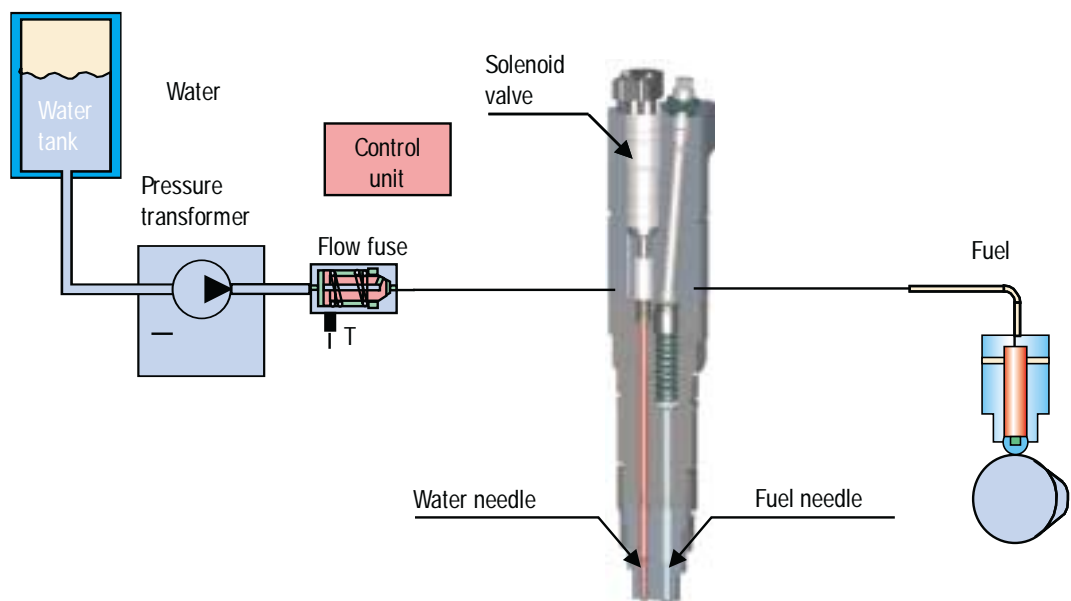
The 46-engine is designed for minimum NO_x emissions at an optimum fuel consumption. Engine is fulfilling the new (from 1.7.2000) World Bank NO_x stack limit for "nondegraded areas". In a "degraded area" which might be the case for a big city with heavy car traffic, etc. the stack limit for NO_x is lower and a SCR catalyst is to be applied. Emissions of sulphur dioxides and particles are fuel related (mainly dependent on sulphur and ash content of the fuel).

In the future the carbon dioxide (CO₂) emission will be in focus due to its' expected impact on the global warming. An efficient diesel power plant has relatively low CO₂ emissions. The Kyoto Protocol provisions allow for a Clean Development Mechanism (CDM) under which carbon offsets trading between certain countries will become possible in the future, the mechanism is still however under development.



Direct Water Injection

- The engine with direct water injection is equipped with a combined injection valve and nozzle that allows injection of water and fuel oil into the cylinder.
- This means that neither of the modes (water on /off) will affect the operation of the engine.
- Water is fed to the cylinder head at high pressure, 210 bar. High water pressure is generated in a high-pressure water pump module. The pumps and filters are built into modules to enable easy, and require a minimum of space.
- A flow fuse is installed on the cylinder head side. The flow fuse acts as a safety device, shutting off the water flow into the cylinder if the water needle gets stuck.
- Water injection timing and duration is electronically controlled by the control unit, which gets its input from the engine output.
- NO_x reduction of 50-60 % can be reached without adversely affecting power output.
- DWI system can be installed also as a retrofit.





M/S Mistral delivered to Godby Shipping in January 1999 – one of the first of seven forest product carriers equipped with Direct Water Injection.

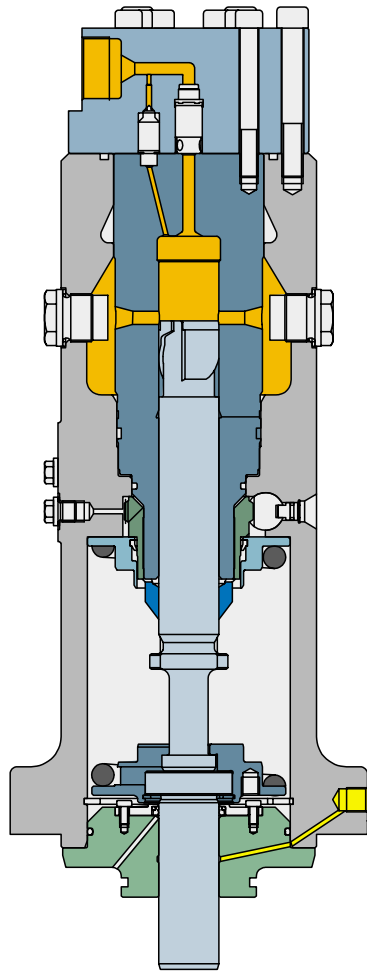


The Ro-Ro vessel Seagard is powered by one Wärtsilä 16V46, output 15 600 kW at 500 rpm and equipped with Direct Water Injection.



The Silja Symphony and its sister vessel Silja Serenade are equipped with Direct Water Injection on all main engines (4 x 9L46).

Injection Pump



Injection pump contains the following features:

- The monoelement design is a rigid and distortion-free solution even at high injection pressures.
- A constant pressure relief valve eliminates the risk of cavitation erosion by maintaining a residual pressure, which is on a safe level over the whole operating field.
- A drained and sealed-off compartment between the pump and the tappet prevents leakage fuel from mixing with lubricating oil.
- Precalibrated pumps are interchangeable.

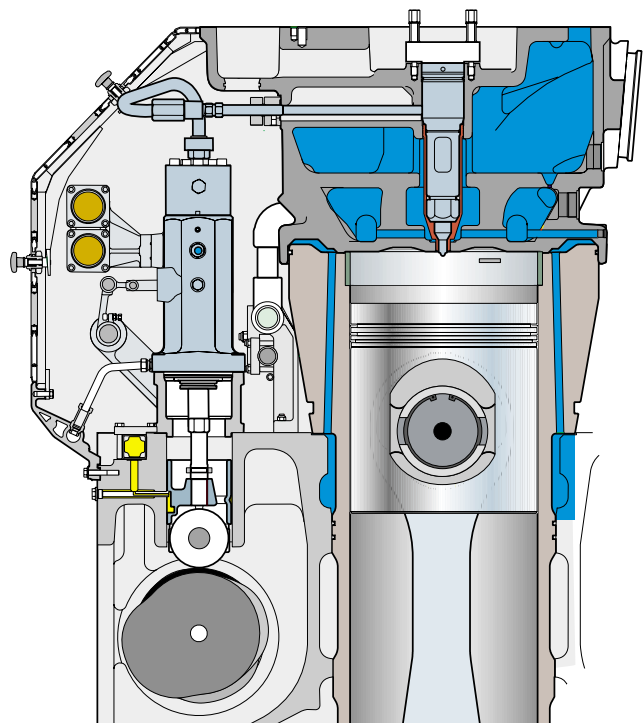
Injection Valve

- The valve is designed to have a small heat absorbing surface facing the combustion space together with efficient heat transfer to the cooling water. This eliminates the need for a separate nozzle temperature control system.
- The fuel is transported the shortest way from the pump to the valve, i.e. via a high pressure pipe in the cylinder head.





- The fuel system pipes and main components are located in a Hot Box providing maximum safety at high pre-heating temperature.
- Fuel pipes outside the Hot Box are also carefully shielded.
- The system is designed for minimum pressure pulsation.
- Leakage fuel from pipes, injection valves and pumps is collected in a closed piping system, which keeps the Hot Box and the engine dry and clean.



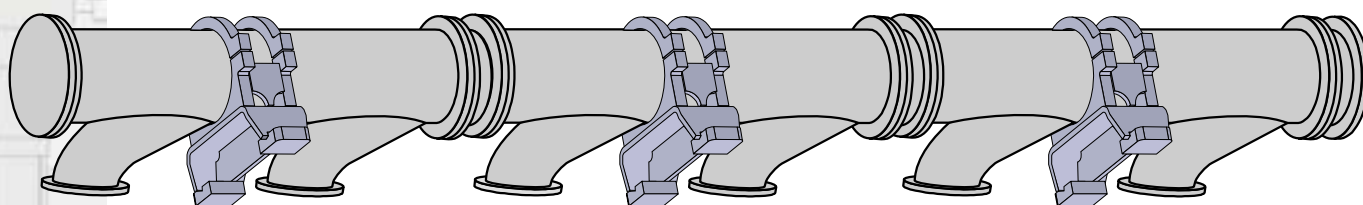
Turbocharging System



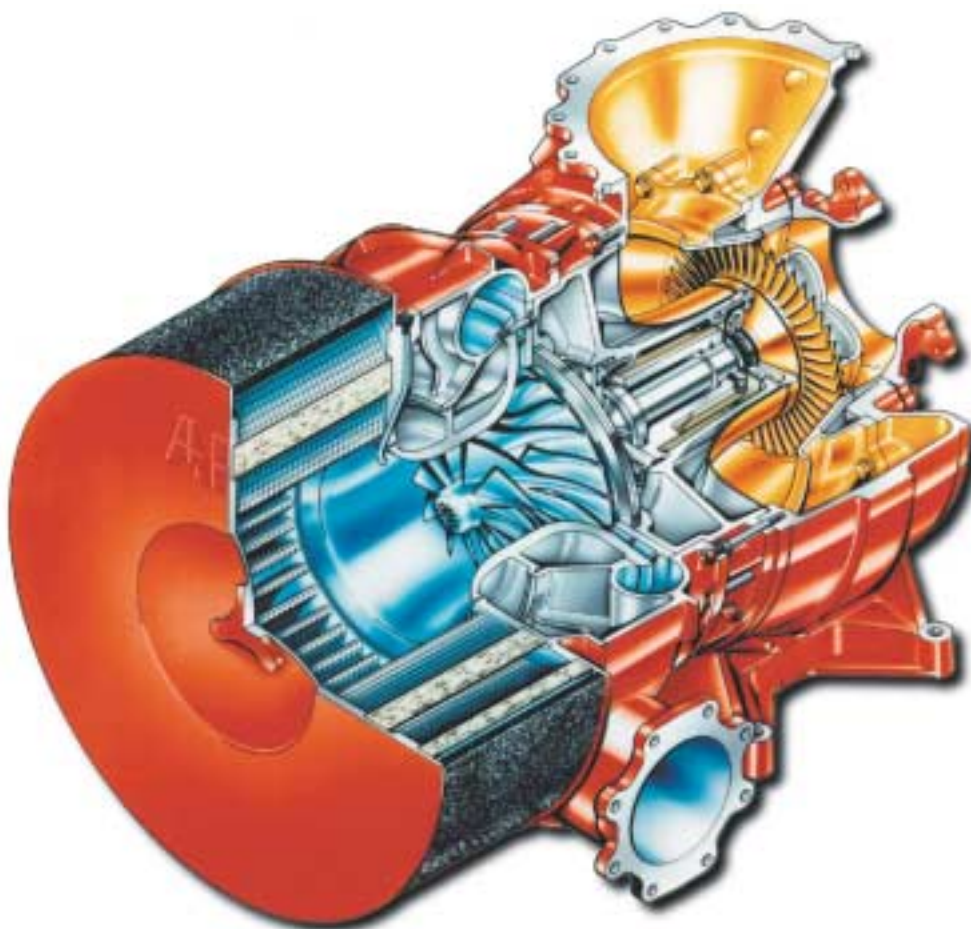
Wärtsilä 46 is provided with Spex (Single pipe exhaust) system and with high efficiency turbocharger.

- The Spex turbocharging system is an exhaust gas system that combines the advantages of both pulse and constant pressure charging.
- Compared with a constant pressure system, the ejector effect of the gas pulses will provide better turbine efficiency at partial loads.
- The Spex system is practically free from interference. This means very small deviations in the scavenging between the cylinders and consequently an even exhaust gas temperature.

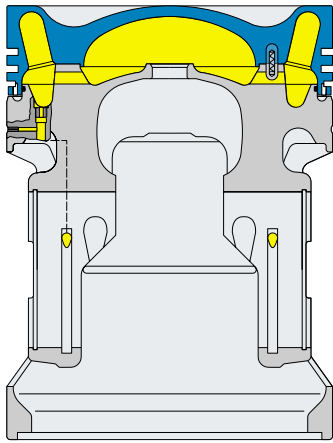
SPEX



- The modular-built exhaust gas systems are durable enough to handle high pressure ratios and pulse levels, but at the same time elastic enough to cope with thermal expansion in the system.
- The turbocharger has the highest available efficiency.
- The turbocharger is equipped with plain bearings and there is no cooling water.
- The turbocharger is fitted with cleaning devices for both the compressor and the turbine side.
- Exhaust waste-gate and air by-pass are used to obtain specific requirements on the operating range, load response or partial load.



Piston



- A composite low-friction piston with a nodular cast iron skirt and a steel top.
- The special cooling gallery design assures efficient cooling and high rigidity for the piston top. The design can handle combustion pressures beyond 200 bar.
- Hardened top ring grooves assure a long lifetime.

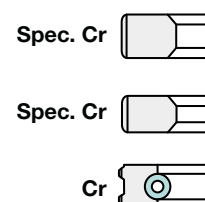
Low friction is ensured by the skirt lubrication system featuring:

- A well distributed clean oil film that eliminates the risk of piston ring scuffing and reduces the wear rate.
- Cleaner rings and grooves free from corrosive combustion products.
- Hydraulically damped tilting movements provided by an oil pad between the liner and the piston, resulting in less noise and wear.



Piston Ring Set

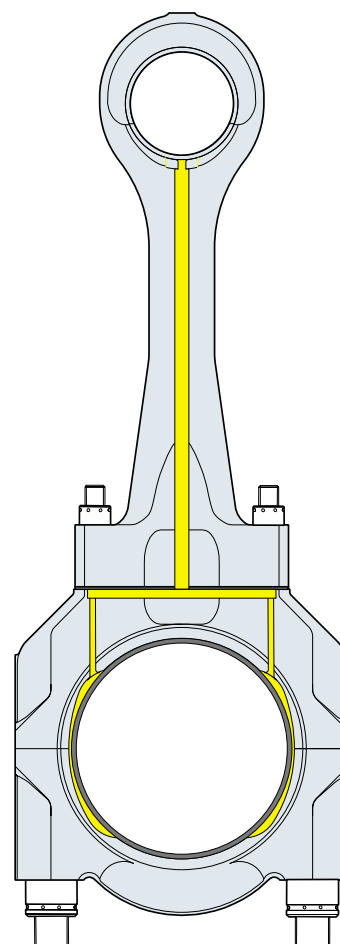
- Low friction three-ring set
- Special wear resistant coating for the compression rings
- Dimensioned and profiled for maximum sealing and pressure balance.





The connecting rod is a three-piece marine design, where combustion forces are distributed over a maximum bearing area and where the relative movements between mating surfaces are minimized.

- Piston overhauling is possible without touching the big end bearing and the bearing can be inspected without removing the piston.
- The three-piece design also reduces the piston overhauling height.
- All nuts are tightened with hydraulic tool.



Cylinder Liner and Anti-polishing Ring



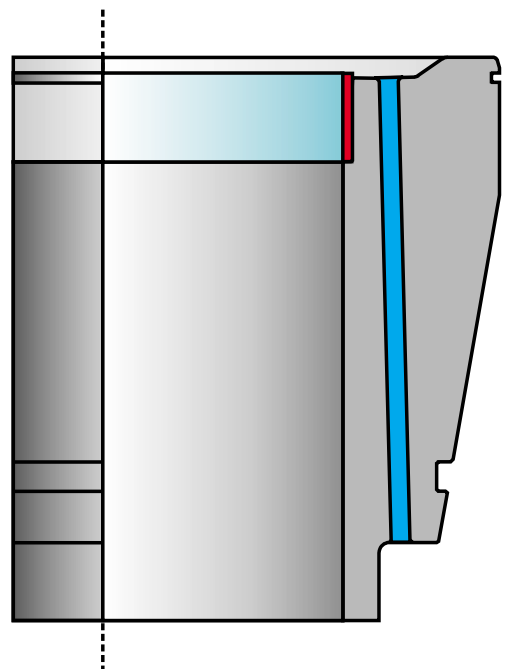
Cylinder liner deformations are normally caused by cylinder head clamping, thermal and mechanical load. Thanks to a special design with a high collar-to-stroke ratio, the deformations in this liner are very small. A round liner bore in combination with excellent lubrication improves conditions for the piston rings and reduces wear.

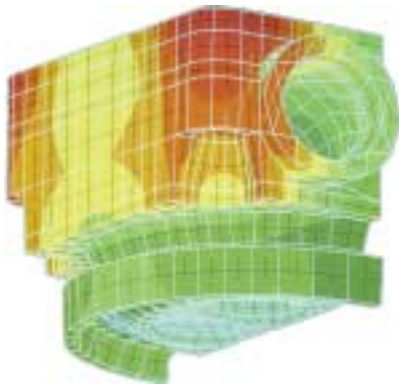
To eliminate the risk of bore polishing, the liner is provided with an anti-polishing ring in the upper part. The purpose of this ring is to “calibrate” the carbon deposits on the piston top land to a thickness small enough to prevent contact between the liner inner wall and the deposits on the

piston top land. “Bore-polishing” can lead to local liner wear and increased lube oil consumption.

The temperature distribution in the cylinder liner is important not only in terms of stress and deformation but also decisive for the cylinder liner wear rate. The temperature must remain above the sulphuric acid dew point to avoid corrosion, but at the same time remain sufficiently low to avoid lubricating oil breakdown.

The material composition is based on long experience with the special grey cast iron alloy developed for excellent wear resistance and high strength.





The cylinder head design is based on reliability and easy maintenance.

- A rigid box like design for even circumferential contact pressure between the cylinder head and the cylinder liner.
 - Four cylinder head fixing bolts are used, which simplifies maintenance.
 - No valve cages are used; this improves reliability and provides greater scope for optimization of the exhaust port flow characteristics.
- Efficient water-cooled exhaust valve seat rings.
 - Valve rotators on both exhaust as well as inlet valves guarantee an even thermal and mechanical load on the valves.



Crankshaft



The crankshaft design allows for use of high combustion pressure and still maintains a conservative bearing load.

The crankshaft is:

- Forged in one piece and fully machined.
- Rigid due to moderate bore/stroke ratio and large pin and journal diameters.
- Fitted with counterweights on every crankweb.
- Designed for full power take-off, also from the free end.

Bearings

The Thick-Pad bearing design emphasizes one key concept: Reliability.

The bearing loads have been reduced by increasing crankshaft journal and pin diameters as well as length.

- Low bearing loads allow for softer bearing materials with greater conformability and adaptability. This makes the bearing virtually seizure-free.



- The camshaft is built of single cylinder sections with integrated cams.
- The camshaft sections are connected through separate bearing journals, which makes it possible to remove the shaft sections sideways from the camshaft compartment.
- The valve follower is of the roller tappet type, where the roller profile is slightly convex for good load distribution.
- The valve mechanism includes rocker arms working on yokes guided by pins.
- Both exhaust and inlet valves receive a forced rotation from Rotocaps during every opening cycle. This forced rotation provides for even temperature distribution and wear of the valves, and keeps the sealing surface free from deposits. Good heat conduction is the result.

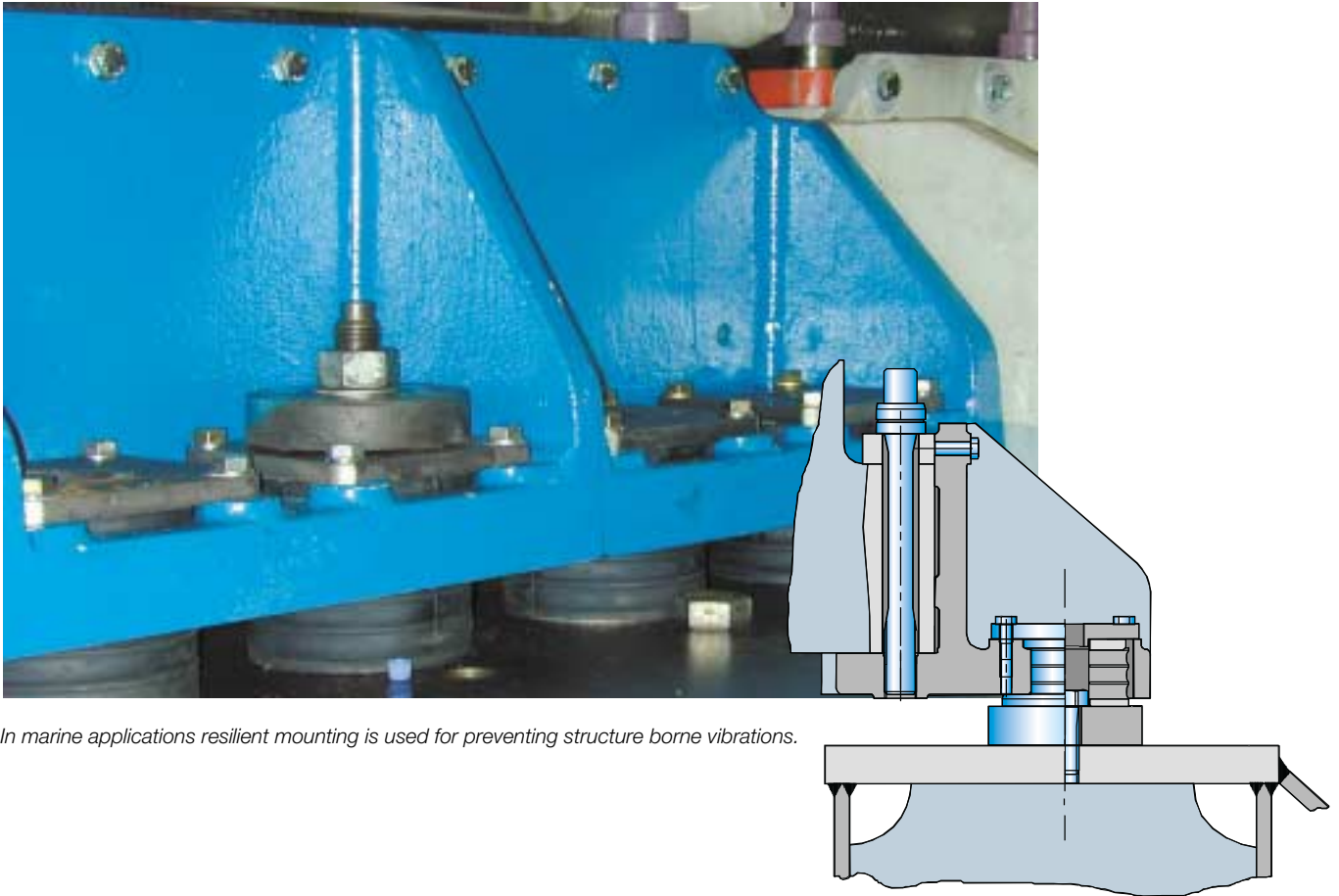


Engine Block



- The engine block is manufactured of nodular cast iron in order to achieve the rigid and durable construction needed for flexible mounting.
- The main bearings are of the underslung type, with hydraulically tightened bolts.
- Side bolts add further rigidity to the main bearing housing.
- In-line engines are equipped with an integrated air receiver featuring increased rigidity, simplicity and cleanliness.

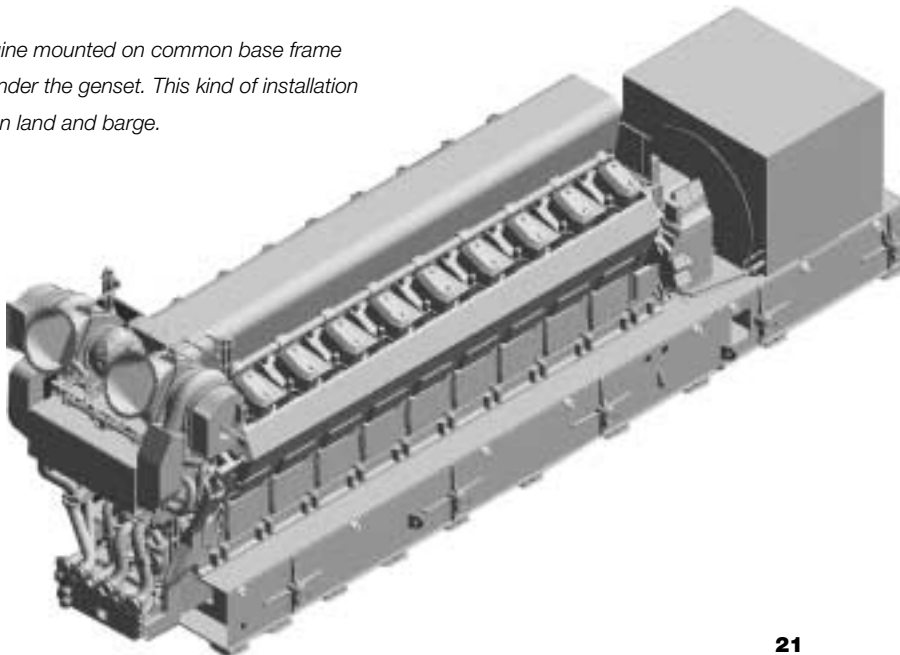
Resilient mounting – Marine applications



In marine applications resilient mounting is used for preventing structure borne vibrations.

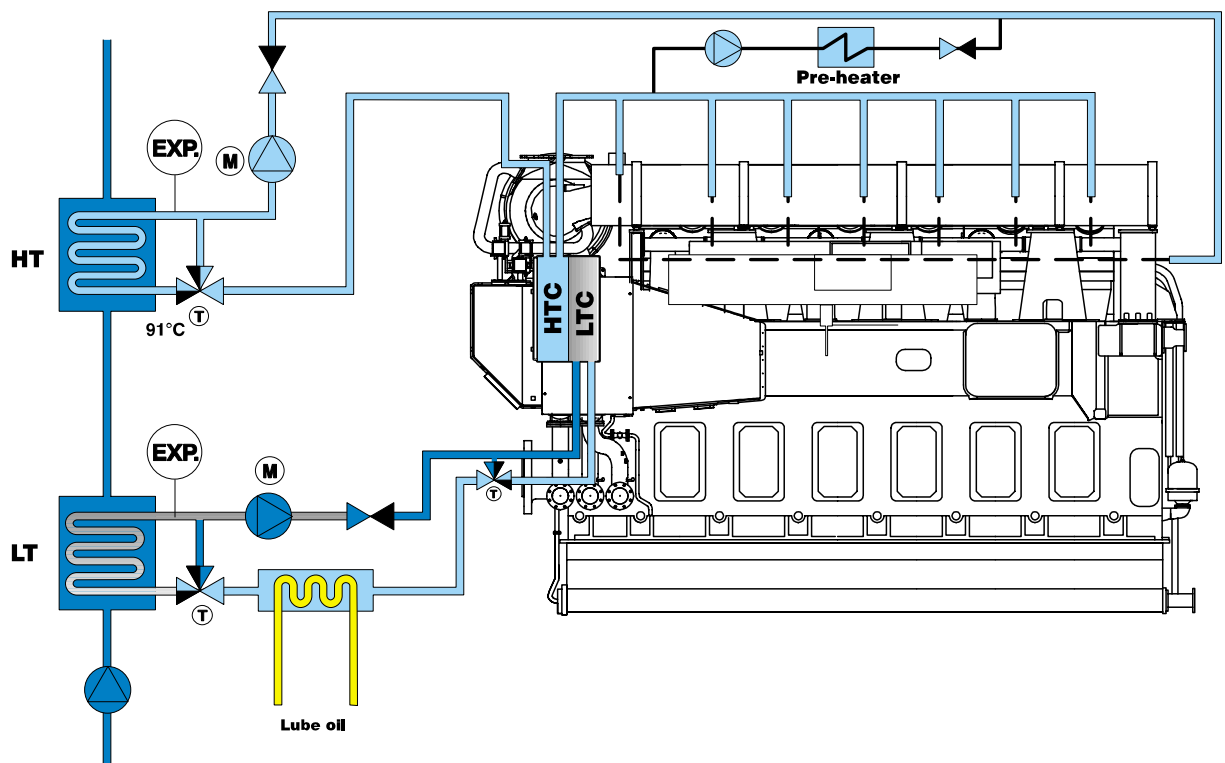
Resilient mounting – Power Plant applications

Power Plant 46 engine mounted on common base frame with steel springs under the genset. This kind of installation can be used both on land and barge.



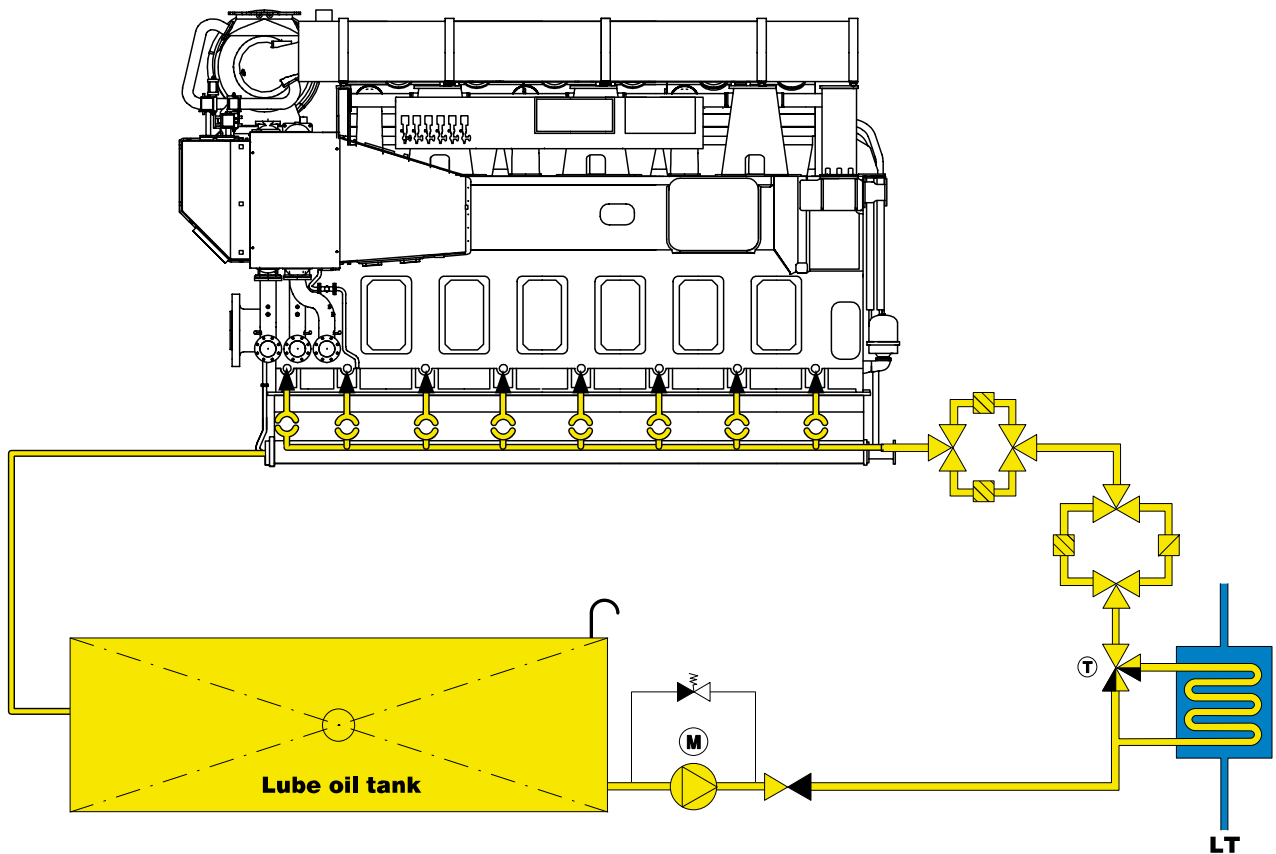
Cooling Systems

- The fresh water cooling system is divided into high temperature and low temperature cooling system.
- The high temperature cooling water system operates constantly at a high temperature level to make the temperature fluctuations in the cylinder components as small as possible and preventing from corrosion due to undercooling.
- For obtaining maximum heat recovery the charge air cooler is split into a high and low temperature section.
- Engine driven pumps can be provided as an option for marine application. In power plant application, these are standard.



Lubricating Oil System

- Marine engines have dry sump and power plant engines wet sump. The lube oil is treated outside the engine by continuous separating.
- On the way to the engine, the oil passes through a lube oil cooler, a full flow automatic filter unit and a safety filter for final protection.
- For the purpose of running-in, provision has been made for mounting special running-in filters in the crankcase in front of each main bearing.
- Engine driven lube oil pump can be provided as an option for marine application. In power plant application this is standard.



Automation System

- Automatic control and safety systems have been developed for unmanned operation and bridge control.
- The engine speed is controlled by a mechanical/hydraulic, electronic/hydraulic or electronic governor.
- Overspeed protection is doubled by use of an electropneumatic system acting directly on each fuel injection pump and a mechanical device acting on the control shaft.
- Slow turning prior to starting.
- Pre-start safety control and start blocking if control functions are not performed.
- Condition monitoring of main components based on reliable temperature measurement.
- Easy plug-in connections of sensors to prefabricated cabling modules.
- A more advanced electronic control unit (WECS) with provision for direct bus-connection will be offered as option.





During design and development the engine manufacturer emphasizes the necessity of easy maintenance by including tooling and easy access in the basic design and by providing easy-to-understand instructions.

The Wärtsilä 46 maintenance principle is substantiated by the following:

- A cylinder head with four fixing studs and simultaneous hydraulic tightening of all four studs.
- A hydraulic jack for the main bearing overhaul.
- Uniform one-cylinder camshaft pieces.
- Slip-on fittings are used wherever possible.
- Exhaust gas system insulation by using easy-to remove panels on a frame that is mounted flexibly on the engine.
- The three-piece connecting rod allows inspection of the big end bearing without removal of the piston, and piston overhaul without dismantling the big end bearing.

Main Technical Data

Marine Engines

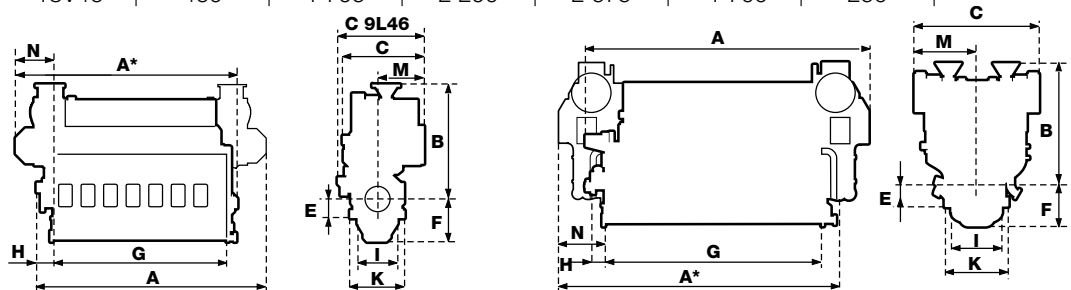
	Wärtsilä 46 A	Wärtsilä 46 B	Wärtsilä 46 C
Cylinder bore	460 mm	460 mm	460 mm
Piston stroke	580 mm	580 mm	580 mm
Cylinder output	905 kW/cyl.	975 kW/cyl.	1050 kW/cyl.
Engine Speed	450, 500, 514 rpm	500, 514 rpm	500, 514 rpm
Piston speed	8.7, 9.7, 9.9 m/s	9.7, 9.9 m/s	9.7, 9.9 m/s
Mean effective pressure	25.0, 22.5, 21.9 bar	24.3, 23.6 bar	26.1, 25.4 bar
Fuel Specification:			730 cSt/50°C
Fuel oil			7200 sRi/100°F
ISO 8217, category ISO-F-RMK 55			
Natural gas			

Rated power (kW)

Engine type	A-output			B-output		C-output	
	450 rpm	500 rpm	514 rpm	500 rpm	514 rpm	500 rpm	514 rpm
6L46	5430	5430	5430	5850	5850	6300	6300
8L46	7240	7240	7240	7800	7800	8400	8400
9L46	8145	8145	8145	8775	8775	9450	9450
12V46	10860	10860	10860	11700	11700	12600	12600
16V46	14480	14480	14480	15600	15600	16800	16800
18V46	16290	16290	16290	17550	17550	18900	18900

Principal engine dimensions (mm) and weights (tonnes)

Engine type	A*	A	B	C	E	F	G
6L46	7 580	8 290	3 350	2 880	650	1 457	6 170
8L46	9 490	10 005	3 605	3 180	650	1 457	7 810
9L46	10 310	10 825	3 605	3 270	650	1 457	8 630
12V46	10 026	10 380	3 660	4 415	800	1 502	7 850
16V46	12 345	12 480	4 000	5 350	800	1 502	10 050
18V46	13 445	13 580	4 000	5 350	800	1 502	11 150
	H	I	K	M	N	Weight	
6L46	460	1 445	1 940	1 650	1 015	95	
8L46	460	1 445	1 940	1 830	1 280	121	
9L46	460	1 445	1 940	1 830	1 280	137	
12V46	460	1 795	2 290	2 210	1 700	165	
16V46	460	1 795	2 290	2 675	1 700	225	
18V46	460	1 795	2 290	2 675	1 700	250	



Power Plant Engines

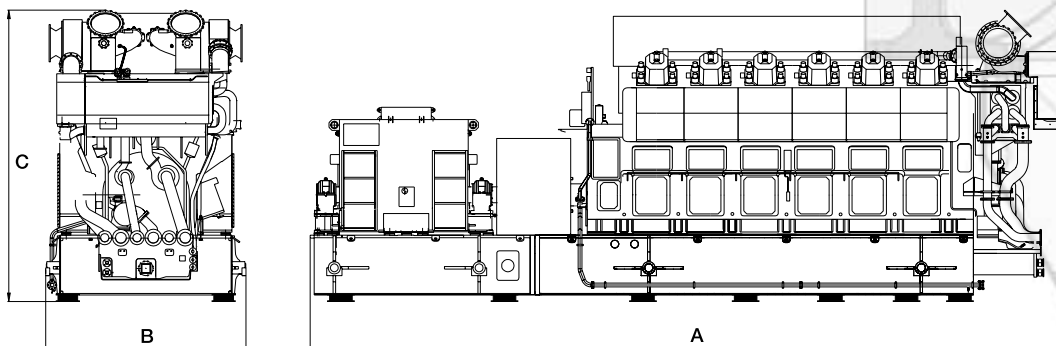
	Wärtsilä 46
Cylinder bore	460 mm
Piston stroke	580 mm
Cylinder output	975 kW/cyl.
Engine Speed	500, 514 rpm
Piston speed	9.7, 9.9 m/s
Mean effective pressure	24.3, 23.6 bar
Fuel Specification:	
Fuel oil	730 cSt/50°C 7200 sRi/100°F
ISO 8217, category ISO-F-RMK 55	
Natural gas	

Rated power

Engine type	500 rpm/50 Hz		514 rpm/60 Hz	
	Eng. kW	Gen. kW	Eng. kW	Gen. kW
6L46	5850	5675	5850	5675
8L46	7800	7565	7800	7565
9L46	8775	8510	8775	8510
12V46	11700	11350	11700	11350
16V46	15600	15130	15600	15130
18V46	17550	17025	17550	17025

Principal engine dimensions (mm) and weights (tonnes)

	A	B	C	Weight
6L46	13000	3700	5600	175
8L46	14700	3700	5600	237
9L46	15600	3700	5600	267
12V46	15400	4100	6000	235
16V46	17200	4100	6300	323
18V46	18300	4100	6300	363



Wärtsilä NSD Corporation is a global engineering company focusing on marine propulsion, power generation and industrial applications. Wärtsilä NSD designs, manufactures, licenses, markets and services Wärtsilä and Sulzer engines from 0.5 to 66 MW (700 to 90,000 bhp). The company engineers and provides complete propulsion systems for all vessel types and turnkey power plants from 1 to 300 MW.

With its global sales and service network and licensees in all major markets, Wärtsilä NSD is your local partner who can deliver the optimum solution to meet your present and future power needs.

Wärtsilä NSD Finland Oy
P.O.Box 252,
FIN-65101 Vaasa, Finland

Tel.	+358-6-3270
Fax Marine	+358-6-356 7188
Fax Power Plants	+358-6-356 9133

