WÄRTSILÄ Engines

WÄRTSILÄ RT-flex50 TECHNOLOGY REVIEW


E95.02
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This is a brief guide to the technical features and benefits of Wärtsilä RT-flex50-D low-speed marine diesel engines.

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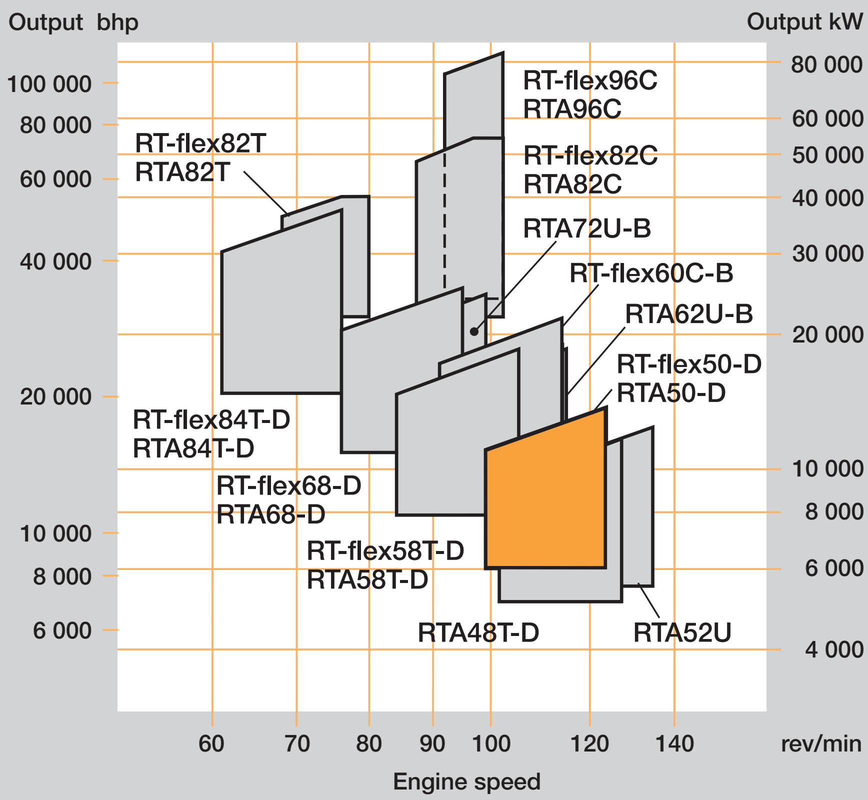
Six-cylinder Wärtsilä RT-flex50 engine
developing 9960 kW (13,560 bhp).



INTRODUCTION

The Wärtsilä RT-flex50 low-speed marine diesel engines, with a power range of 6100 to 13,960 kW, are tailor-made for the economic, reliable propulsion of a wide range of ship types and sizes from handymax and panamax bulk carriers to product tankers and feeder container vessels.

They offer clear, substantial benefits:

- High reliability
- Three years' operation between overhauls
- Economical fuel consumption over the whole operating range
- Low cylinder oil feed rate
- Low system oil losses
- Low exhaust gas emissions
- Capable of extremely low, stable running speeds.

The Wärtsilä RT-flex50 two-stroke diesel engine was introduced in March 2003 to provide a competitive prime mover in its power range for a broad range of ship types and sizes. It combines the latest common-rail technology for fuel injection and valve actuation with fully-integrated electronic control and the well-established Wärtsilä low-speed engine principles. It thus brings the same benefits of common-rail technology to bulk carriers, tankers, feeder container ships and medium-sized cargo ships as have already been demonstrated in Wärtsilä low-speed engines, of several sizes up to the most powerful.

PRINCIPAL PARAMETERS OF WÄRTSILÄ RT-flex50-D ENGINES

Bore	mm	500
Stroke	mm	2050
Output MCR, R1	kW/cyl	1745
	bhp/cyl	2375
Speed range, R1–R3	rpm	124–99
BMEP at R1	bar	21.0
Pmax	bar	170
Mean piston speed at R1	m/s	8.5
Number of cylinders		5–8
BSFC: at full load, R1	g/kWh	169
	g/bphp	124

DEVELOPMENT BACKGROUND

Wärtsilä has a policy of continuously updating its engine programme and engine designs to adapt them to the latest market requirements and to deliver the benefits of technical improvements. The Wärtsilä RT-flex50 engine is a good example of this policy.

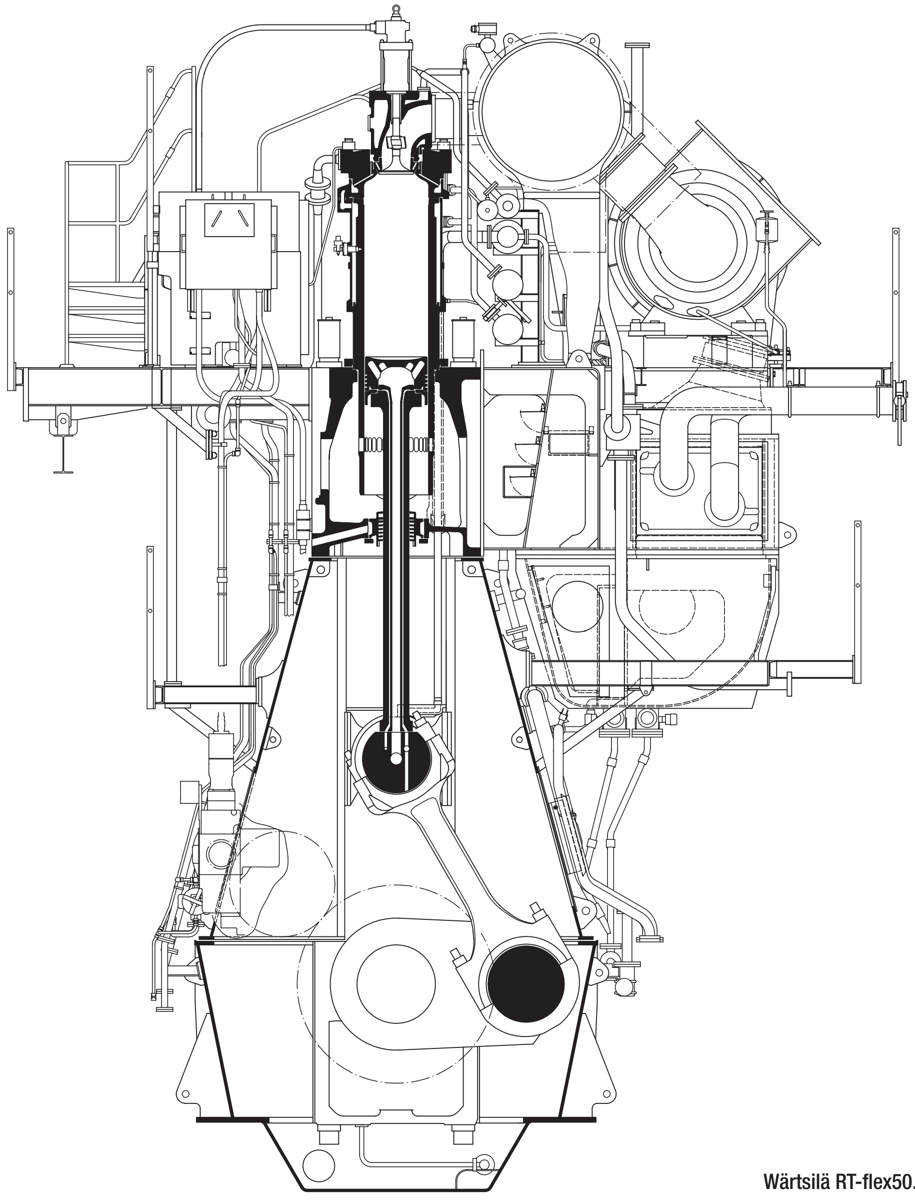
The Wärtsilä RT-flex50 is based on the Wärtsilä RTA50 engine type that has been jointly developed by Wärtsilä with Mitsubishi Heavy Industries Ltd in Japan. The RTA50 has a conventional mechanical camshaft system for fuel injection and valve operation. Introduced in 2003 the RT-flex50 was developed by Wärtsilä and incorporates the latest electronically-controlled common-rail technology for fuel injection and valve actuation. The new technology offers distinctive operational benefits which are not possible with camshaft engines.

The parameters of the RT-flex50 were selected to provide optimum matches to the power and speed requirements of a broad range of ship types and sizes while, at the same time, leading to compact engine dimensions.

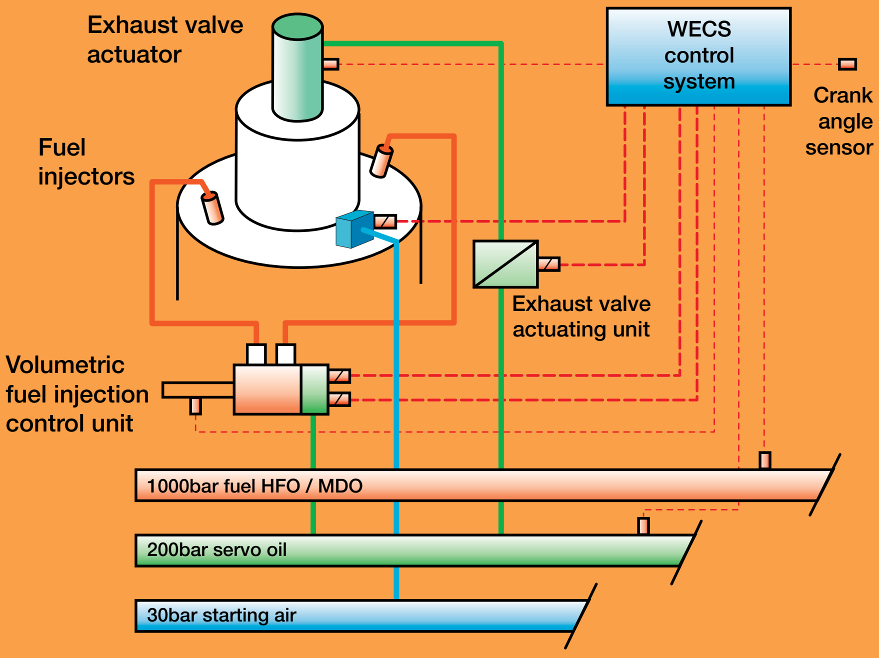
The first RT-flex50 engines went into service in January and March 2006.

In October 2007, to meet the market need for increased powers in the ship types using RT-flex50 engines, the D version of the RT-flex50 was introduced with a 5% increase in power output with maximum continuous outputs being raised to 1745 kW/cylinder at the same speed.

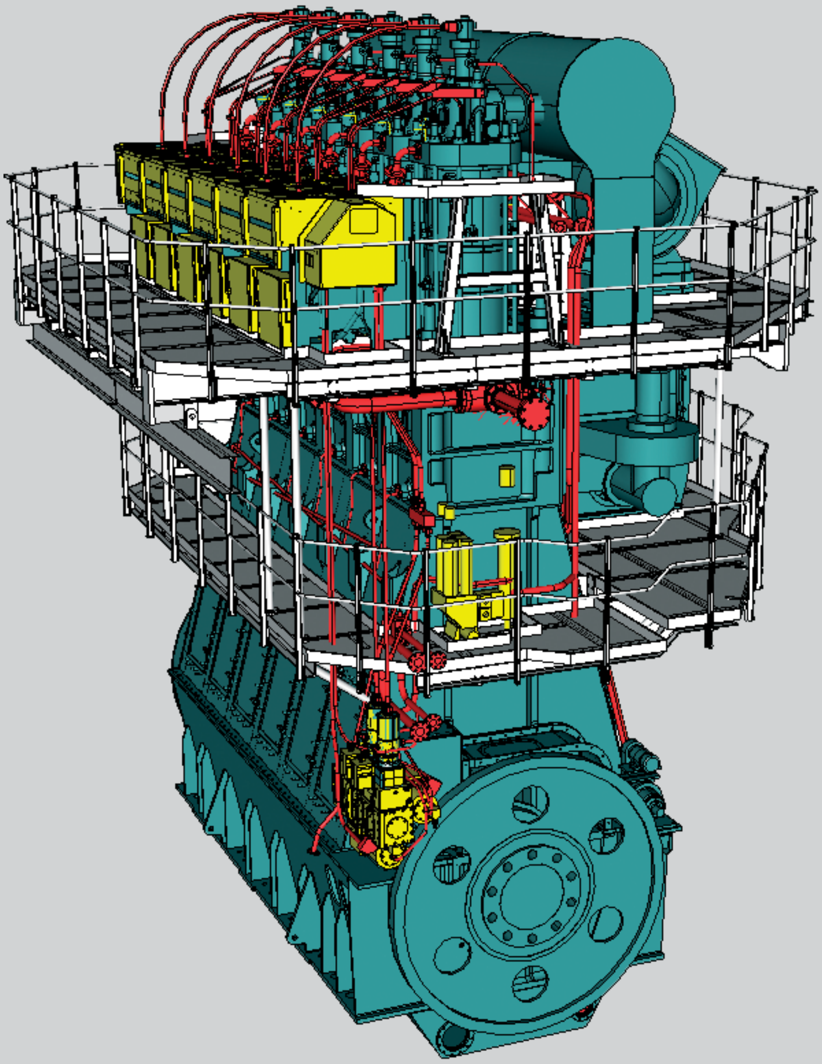
At the same time the application of the latest, high-efficiency turbochargers enabled the brake specific fuel consumptions (BSFC) to be reduced by 2 g/kWh in the D version. Thus at the maximum continuous rating R1, the full-load BSFC was reduced from 171 to 169 g/kWh.



Wärtsilä RT-flex50.



Schematic of the Wärtsilä RT-flex system with electronically-controlled common-rail systems for fuel injection and exhaust valve operation.



Wärtsilä 6RT-flex50 with the principal elements of the RT-flex system in yellow.

RT-flex: CONCEPT AND BENEFITS

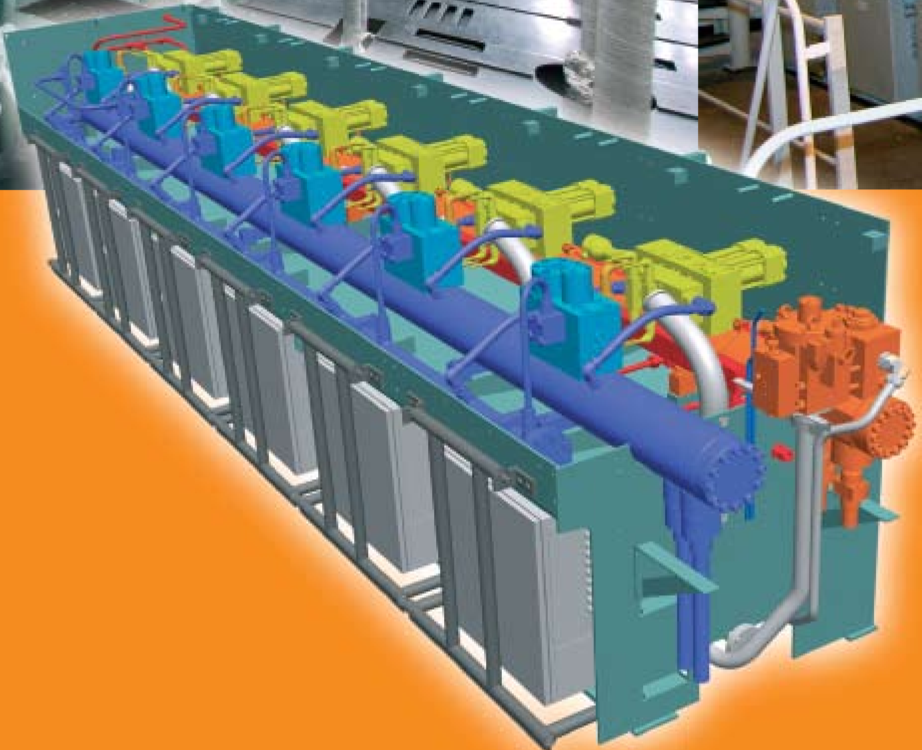
The Wärtsilä RT-flex system is the result of a long project since the 1980s to develop low-speed marine engines without the constraints imposed by mechanical drive of fuel injection pumps and valve actuation pumps but with far greater flexibility in engine setting to reach future requirements. The objective is to deliver operational benefits to the shipowners.

The Wärtsilä RT-flex50 is basically a standard Wärtsilä low-speed two-stroke marine diesel engine in which a common-rail system for fuel injection and exhaust valve actuation, and full electronic control of these engine functions, is employed instead of the traditional mechanical camshaft system.

The RT-flex engines offer a number of interesting benefits to shipowners and operators:

- Smokeless operation at all operating speeds
- Lower steady running speeds, in the range of 10–15 per cent nominal speed, obtained smokelessly through sequential shut-off of injectors while continuing to run on all cylinders
- Reduced running costs through reduced part-load fuel consumption and longer times between overhauls
- Reduced maintenance requirements, with simpler setting of the engine. The 'as-new' running settings are automatically maintained
- Reduced maintenance costs through precise volumetric fuel injection control leading to extendable times between overhauls. The common-rail system with its volumetric control gives excellent balance in engine power developed between cylinders and between cycles, with precise injection timing and equalised thermal loads
- Reliability is given by long-term testing of common-rail hardware in component test rigs
- Higher availability owing to the integrated monitoring functions
- High availability also given by the built-in redundancy, provided by the ample capacity and duplication in the supply pumps, main delivery pipes, crank-angle sensors, electronic control units and other key elements.

Cylinder top level of the RT-flex50 engine with the fuel injection and valve actuation pipes rising out of the rail unit under the platform.



Rail unit of the RT-flex50 engine showing the fuel rail in orange and the servo oil rail in blue.

RT-flex COMMON-RAIL SYSTEM APPLIED

The common rail for fuel injection is a single-piece pipe running the length of the engine at just below the cylinder cover level. The common rail and other related pipe work are neatly arranged beneath the top engine platform and readily accessible from above.

The common rail is fed with heated fuel oil at the usual high pressure (nominally 1000 bar) ready for injection. The supply unit has a number of high-pressure pumps actuated by cams driven through gearing from the crankshaft.

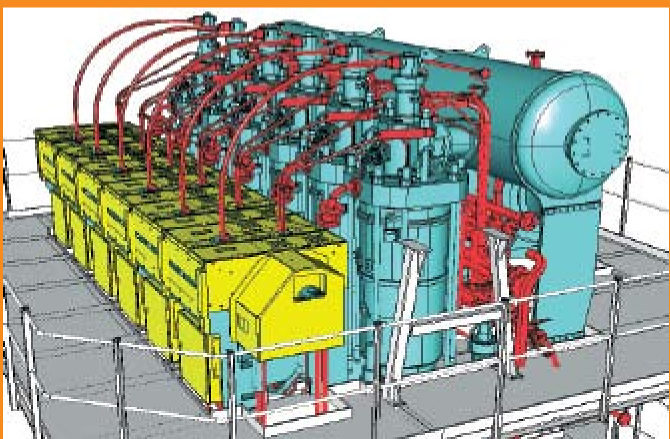
Fuel is delivered from this common rail through a separate injection control unit (ICU) for each engine cylinder to the standard fuel injection valves which are operated in the usual way by the high-pressure fuel oil. The injection control units are mounted directly on the fuel rail. Using quick-acting Wärtsilä rail valves, they regulate the timing of fuel injection, control the volume of fuel injected, and set the shape of the injection pattern. Each ICU serves the two fuel injection valves in its corresponding cylinder cover. Each injection valve is separately controlled so that, although they normally act in unison, they can also be programmed to operate separately as necessary.

The key features of the Wärtsilä RT-flex common-rail system are:

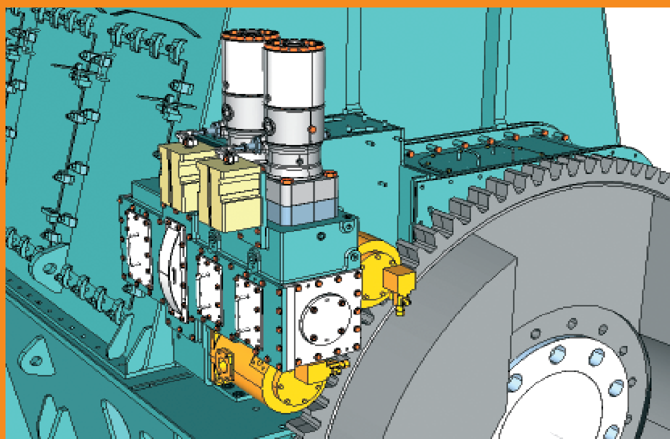
- Precise volumetric control of fuel injection, with integrated flow-out security
- Variable injection rate shaping and free selection of injection pressure
- Stable pressure levels in common rail and supply pipes

Rail unit at the cylinder top level of the 6RT-flex50 engine, with the electronic control units on the front for good access.

Supply unit of a 6RT-flex50 engine with fuel pumps vertically mounted on top and the servo pumps beneath and behind.



Rail unit of the RT-flex50.



Supply unit of a 6RT-flex50 engine.

- Possibility for independent control and shutting off of individual fuel injection valves
- Ideally suited for heavy fuel oil through clear separation of the fuel oil from the hydraulic pilot valves
- Well-proven standard fuel injection valves
- Proven, high-efficiency common-rail fuel pumps.

The RT-flex system also encompasses exhaust valve actuation and starting air control. The exhaust valves are operated in much the same way as in existing RTA engines by a hydraulic pushrod but with the actuating energy now coming from a servo oil rail at 200 bar pressure. The servo oil is supplied by high-pressure hydraulic pumps incorporated in the supply unit with the fuel supply pumps. The electronically-controlled actuating unit for each cylinder gives full flexibility for setting the timing of valve opening and closing.

All functions in the RT-flex system are controlled and monitored through the integrated Wärtsilä WECS-9520 electronic control system. This is a modular system with a separate FCM-20 microprocessor control unit for each cylinder. A shipyard interface box, with an additional FCM-20 unit as an on-line spare, provides all connections to other systems such as the remote control and alarm systems. All internal and external communication is provided through bus systems.

RT-flex: REAL IN-SERVICE FUEL ECONOMY

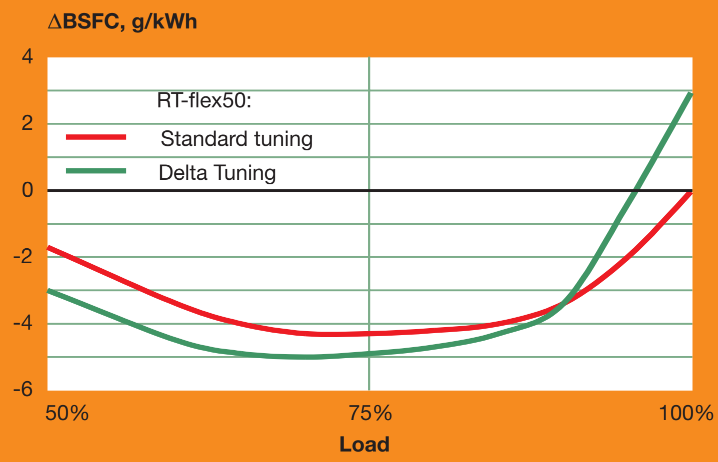
Whereas Wärtsilä RTA-series engines have excellent fuel consumption in general, the RT-flex system enables further improvements to be achieved in the part-load range. This is because of the freedom allowed by the RT-flex system in selecting optimum injection pressure, fuel injection timing and exhaust valve timing at all engine loads or speeds, while ensuring efficient combustion at all times, even during dead slow running.

Similar freedom in exhaust valve timing allows the RT-flex system to keep combustion air excess high by earlier valve closing as the load/speed is reduced. This is not only advantageous for fuel consumption but also limits component temperatures, which would normally increase at low load. Lower turbocharger efficiencies at part load normally result in low excess combustion air with fixed valve timing.

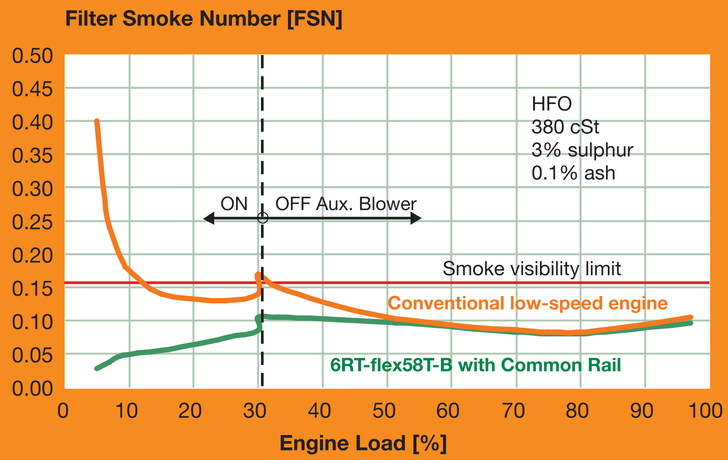
Another important contribution to fuel economy of the RT-flex50 engines is the capability to adapt easily the injection timing to various fuel properties having a poor combustion behaviour.

Delta Tuning: A fuel efficiency alternative

Through their flexibility in engine setting, RT-flex engines also have an alternative fuel consumption curve as standard to give lower BSFC (brake specific fuel consumption) in what is for many ships the main operating range. Through Delta Tuning, the BSFC is lowered in the mid- and low-load operating range below 90 per cent engine power. The consequent increase in NO_X in that operating range is compensated by reducing NO_X emissions in the high load range. With both BSFC curves, the engines comply with the NO_X regulation of the MARPOL 73/78 convention.



The alternative BSFC curve for RT-flex50 engines given by Delta Tuning compared with the standard BSFC curve. Both curves are for engines complying with the IMO NO_X regulation.



Smoke emission measurements from the sea trials of the Gypsum Centennial demonstrate the smokeless operation of RT-flex engines compared with conventional low-speed marine engines.

RT-flex: CLEANER IN THE ENVIRONMENT

Exhaust gas emissions have become an important aspect of marine diesel engines. All Wärtsilä RTA and RT-flex engines as standard comply with the NO_X emissions limit set by IMO in Annex VI of the MARPOL 73/78 convention.

RT-flex engines, however, come comfortably below this NO_X limit by virtue of their extremely wide flexibility in optimising the fuel injection and exhaust valve processes.

The most visible benefit of RT-flex engines is, of course, their smokeless operation at all ship speeds. The superior combustion with the common-rail system is largely because the fuel injection pressure is maintained at the optimum level irrespective of engine speed. In addition, at very low speeds, individual fuel injectors are selectively shut off and the exhaust valve timing adapted to help to keep smoke emissions below the visible limit.

Yet the environmental benefits of RT-flex engines need not be restricted by the current state-of-the-art. As all settings and adjustments within the combustion and scavenging processes are made electronically, future adaptations will be possible simply through changes in software, which could be readily retrofitted to existing RT-flex engines.

As well as investigating the scope of possibilities of the RT-flex system, Wärtsilä is carrying out a long-term research programme to develop techniques for further reducing exhaust emissions, including NO_X, SO_X and CO_2, in both RTA and RT-flex engines.

Bedplate 6RT-flex50.

ENGINE STRUCTURE

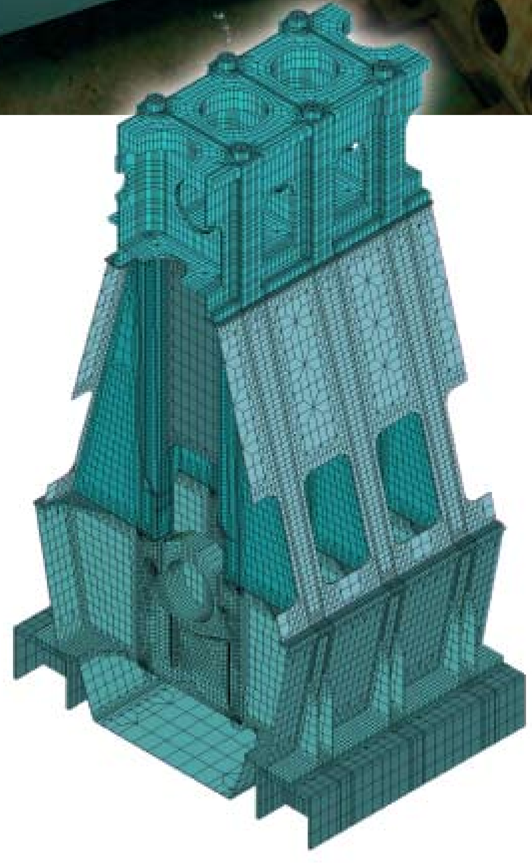
Wärtsilä RT-flex50 engines have a well-proven type of structure, with a 'gondola'-type bedplate surmounted by very rigid, A-shaped double-walled columns and cylinder block, all secured by pre-tensioned vertical tie rods. The whole structure is very sturdy with low stresses and high stiffness. Both bedplate and columns are welded fabrications which are also designed for minimum machining.

A high structural rigidity is of major importance for the today's two-stroke engine's long stroke. Accordingly the design is based on extensive stress and deformation calculations carried out by using a full three-dimensional finite-element computer model for different column designs to verify the optimum frame configuration.

The double-walled column has thick guide rails for greater rigidity under crosshead shoe forces. The RT-flex supply unit is carried on supports on one side of the column and the scavenge air receiver on the other side of the cylinder jacket. Access to the piston under-side is normally from the supply unit side, but is also possible from the receiver side of the engine, to allow for maintenance of the piston rod gland and also for inspecting piston rings.

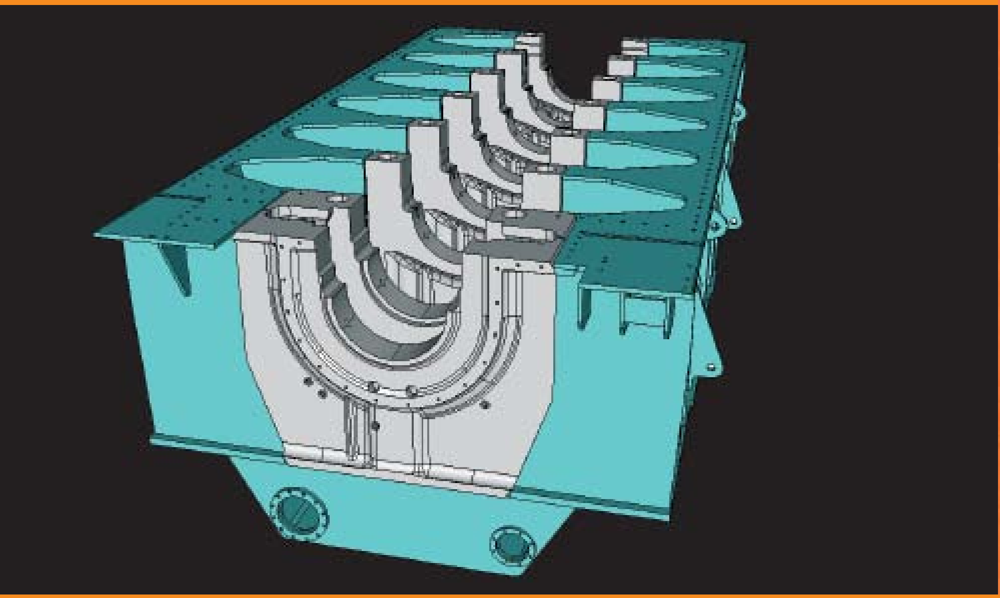
The cylinder jacket is a single-piece cast-iron cylinder block with a high rigidity. The cylinder liners are seated in the cylinder block, and are sufficiently robust to carry the cylinder covers without requiring a support ring. A light sleeve is applied to upper part of each liner to form a water jacket.

The tilting-pad thrust bearing is integrated in the bedplate. Owing to the use of gear wheels for the supply unit drive, the thrust bearing can be very short and very stiff, and can be carried in a closed, rigid housing.

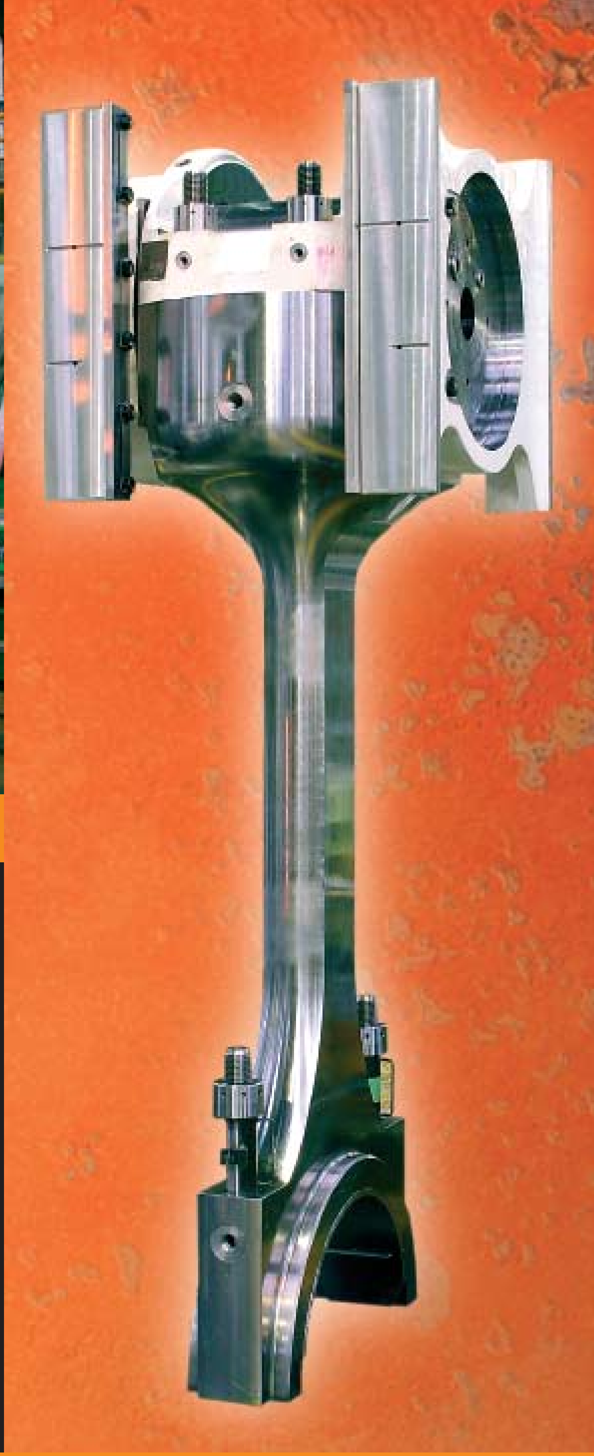


Finite-element model of the engine structure for computer analysis comprising the 'gondola' type bedplate, welded box-type columns and single-piece cast-iron cylinder block.

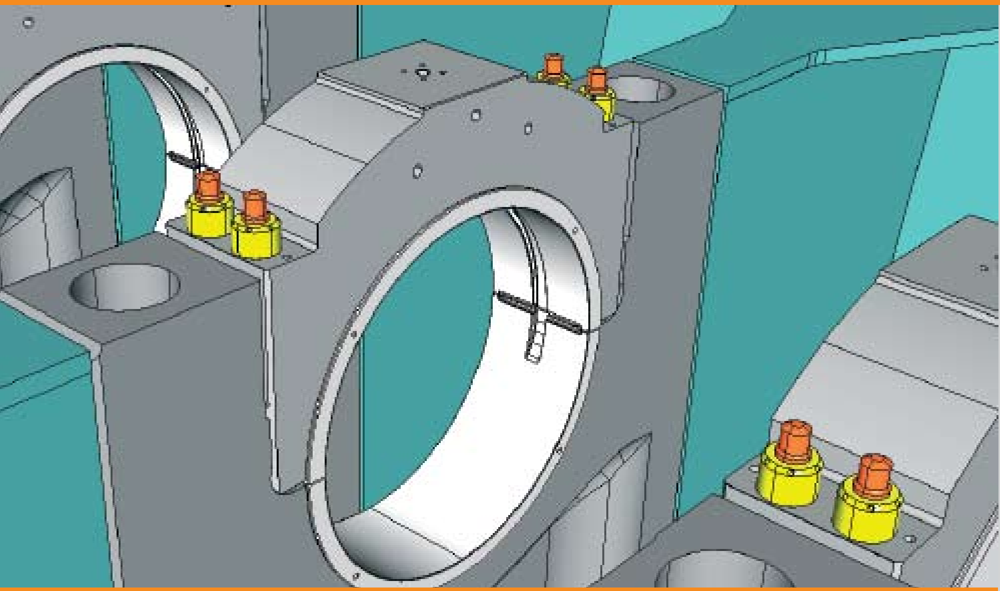
Column 6RT-flex50.



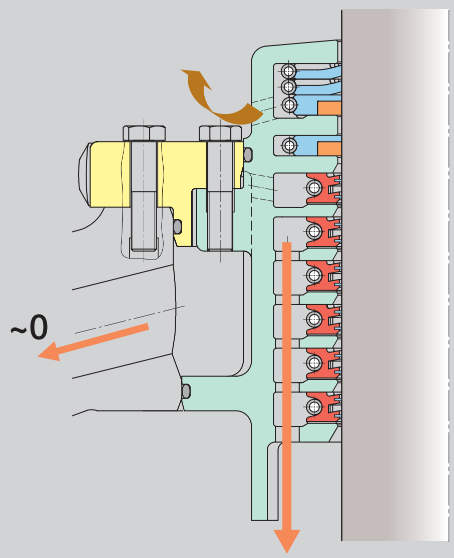
Bedplate 6RT-flex50.



Crosshead and connecting rod RT-flex50.

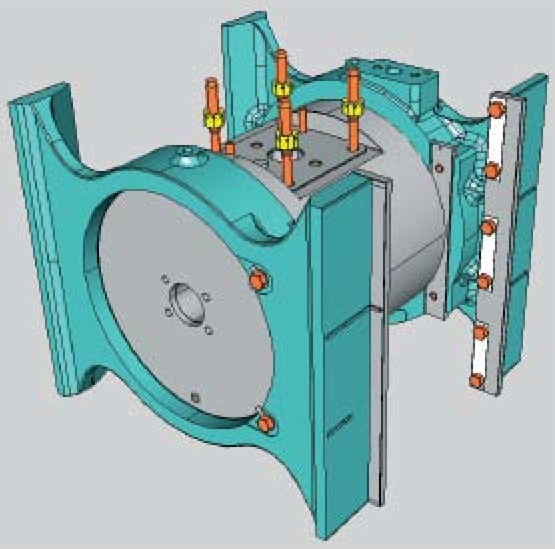


Main bearing housing in bedplate 6RT-flex50.

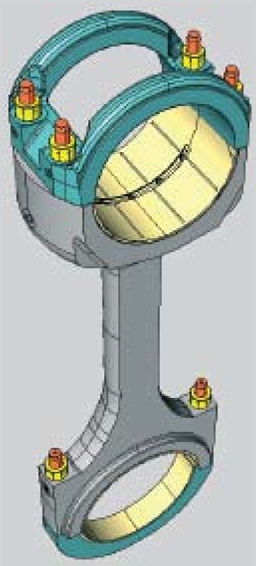


Piston rod gland RT-flex50.

Lowering the crankshaft into the bedplate, 6RT-flex50.



Crosshead RT-flex50.



Crosshead and connecting rod RT-flex50.

RUNNING GEAR

The running gear comprises the crankshaft, connecting rods, pistons and piston rods, together with their associated bearings and piston rod glands.

The crankshaft is semi-built comprising combined crank pin/web elements forged from a solid ingot and the journal pins are then shrunk into the crank webs.

The main bearings have white metal shells. Each main bearing cap is held down by four elastic holding down studs.

A better understanding of the main bearing loads is obtained with today's finite-element analysis and elasto-hydrodynamic calculation techniques as they take into account the structure around the bearing and vibration of the shaft. The FE model comprises the complete shaft and its bearings together with the surrounding structure. Boundary conditions, including the crankshaft stiffness, can thus be fed into the bearing calculation.

The crosshead bearing is designed to the same principles as for all other RTA and RT-flex engines. It also features a full-width lower half bearing with the crosshead pin being of uniform diameter. The crosshead bearings have thin-walled shells of white metal for a high load-bearing capacity.

Extensive development work has been put into the piston rod gland because of its importance in keeping crankcase oil consumption down to a reasonable level and maintaining the quality of the system oil.

The piston rod glands are of an improved design with highly-effective dirt scraping action in the top part and system oil scraping in the lower part. The glands are provided with large drain areas and channels. Losses of system oil are minimised as all scraped-off oil is recirculated internally to the crankcase. Hardened piston rods are now standard to ensure long-term stability in the gland behaviour.

Piston underside showing the cooling bores.

COMBUSTION CHAMBER

The combustion chamber in today's diesel engine has a major influence on the engine's reliability. Careful attention is needed for the layout of the fuel injection spray pattern to achieve moderate surface temperatures and to avoid carbon deposits.

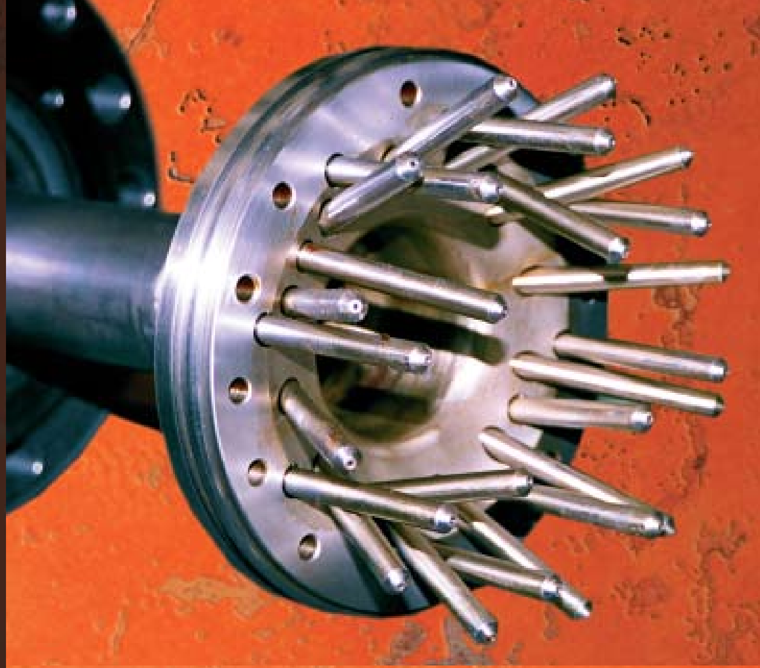
At Wärtsilä, optimisation of fuel injection is carried out first by the use of modern calculation tools, such as CFD (computerised fluid dynamics) analysis. The calculated results are then confirmed on the first test engines.

The well-proven bore-cooling principle is also employed in the cylinder cover, exhaust valve seat and piston crown to control their temperatures, as well as thermal strains and mechanical stresses. The surface temperatures of the cylinder liner are optimised for good piston-running behaviour, without requiring bore cooling of the liner.

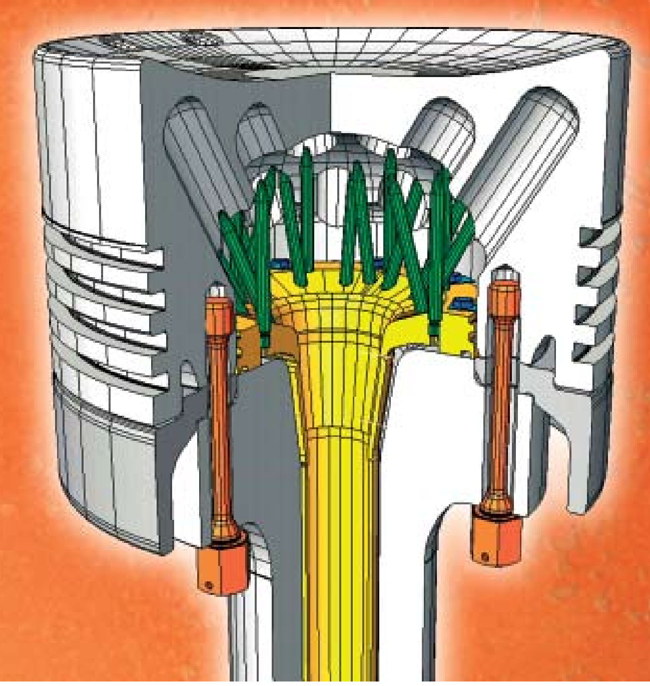
The solid forged steel, bore-cooled cylinder cover is secured by eight elastic studs. It is equipped with a single, central exhaust valve in Nimonic alloy which is housed in a bolted-on valve cage. Two fuel injection valves are symmetrically arranged in each cylinder cover. Anti-corrosion cladding is applied to the cylinder covers downstream of the injection nozzles to protect the cylinder covers from hot corrosive or erosive attack.

The pistons comprise a forged steel crown with a short skirt. Combined jet-shaker oil cooling of the piston crown provides optimum cooling performance. It gives very moderate temperatures on the piston crown with an even temperature distribution right across the crown surface.

Detail of the combustion chamber with bore-cooled cylinder cover and piston crown.



Piston of RT-flex50 (below) with nozzles (above) directing cooling oil sprays into the piston crown cooling bores.



PISTON-RUNNING BEHAVIOUR

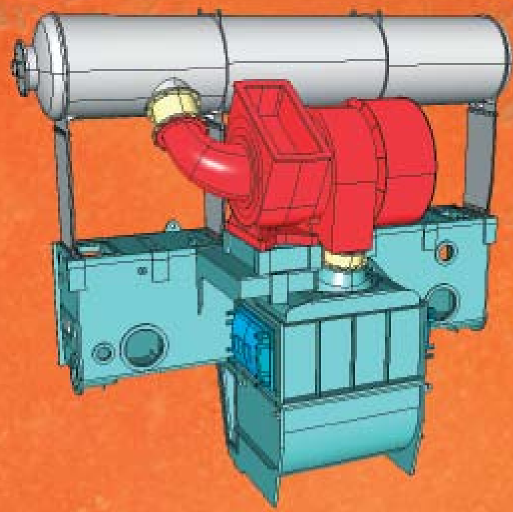
Today the time between overhaul (TBO) of low-speed marine diesel engines is largely determined by the piston-running behaviour and its effect on the wear of piston rings and cylinder liners. For this reason, Wärtsilä RT-flex50 engines now incorporate a package of design measures that enable the TBO of the cylinder components, including piston ring renewal, to be extended to at least three years, while allowing the further reduction of cylinder lubricating oil feed rate.

The standard design measures applied to RT-flex50 engines for improved piston-running behaviour include:

- Liner of the appropriate material
- Careful turning of the liner running surface and plateau honing of the liner over the full length of the running surface
- Mid-stroke liner insulation
- Pre-profiled piston rings in all piston grooves
- Chromium-ceramic coated, pre-profiled gas-tight piston ring in the top piston ring groove
- RC (Running-in Coating) piston rings in all lower piston grooves
- Anti-Polishing Ring (APR) at the top of the cylinder liner
- Increased thickness of chromium layer in the piston-ring grooves.
- Wärtsilä accumulator system for cylinder lubrication.

A key element is the deep-honed liner. Careful machining and deep honing gives the liner an ideal running surface for the piston

Piston and piston rod of the RT-flex50. The piston has a chromium-ceramic coated gas-tight ring in the top groove, and RC (Running-in Coating) piston rings in all lower piston grooves.



Turbocharging and scavenge air system of the 6RT-flex50.

rings, together with an optimum surface microstructure.

The Anti-Polishing Ring prevents the build up of deposits on the top land of the piston which can damage the oil film on the liner and cause bore polishing.

It is also important that the liner wall temperature is optimised to keep the liner surface above the dew point temperature throughout the piston stroke to avoid cold corrosion. At the same time, the ‘underslung’ scavenge air receiver and the highly-efficient vane-type water separators with effective water drainage arrangements ensure that as much water as possible is taken out of the scavenge air.

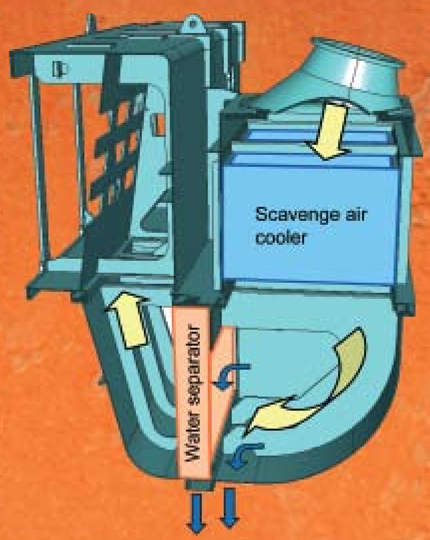
Load-dependent cylinder lubrication is provided by the well-proven Wärtsilä accumulator system which provides the timely quantity of lubricating oil for good piston-running. The lubricating oil feed rate is controlled according to the engine load and can also be adjusted according to engine condition. The system allows feed rates down to 1.1 g/kWh for engine loads of 50–100% and all fuel sulphur contents above 1.5%, though a feed rate of 0.9 g/kWh is possible after analysis of engine performance.

TURBOCHARGING AND SCAVENGE AIR SYSTEM

The RT-flex50 engines are uniflow scavenged with air inlet ports in the lower part of the cylinder and a single, central exhaust valve in the cylinder cover. Scavenge air is delivered by a constant-pressure turbocharging system with one or more high-efficiency exhaust gas turbochargers depending on the numbers of cylinders. For starting and during slow-running, the scavenge air delivery is augmented by electrically-driven auxiliary blowers.

The scavenge air receiver is of an underslung design with integral non-return flaps, air cooler, water separator and the auxiliary blowers. The turbochargers are mounted on the scavenge air receiver which also carries the support for the exhaust manifold.

Immediately after the horizontal air cooler, the scavenge air is swung round 180 degrees to the engine cylinders, in the process passing through the vertically-arranged



Scavenge air flow from the turbocharger through the horizontal scavenge air cooler and the vertically-mounted water separator, exiting left to the engine cylinders.

water separator. The highly-efficient water separator comprises a row of vanes which divert the air flow and collect the water. There are ample drainage provisions to remove completely the condensed water collected at the bottom of the separator. This arrangement provides the effective separation of condensed water from the stream of scavenge air which is imperative for satisfactory piston-running behaviour.

INSTALLATION ARRANGEMENTS

Wärtsilä low-speed engines have specific design features that help to facilitate shipboard installation.

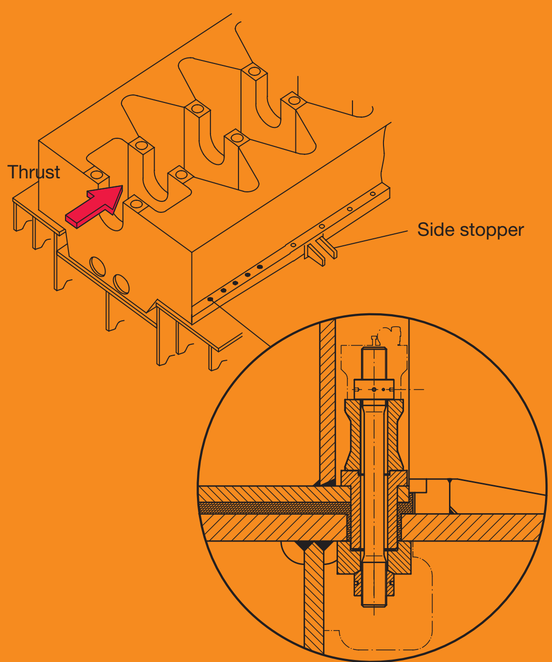
The engine layout fields give the ship designer ample freedom to match the engine to the optimum propeller for the ship.

The engines have simple seating arrangements with a modest number of holding down bolts and side stoppers. No end stoppers or thrust brackets are needed as thrust transmission is provided by fitted bolts or thrust sleeves which are applied to a number of the holding-down bolts. The holes in the tank top for the thrust sleeves can be made by drilling or even flame cutting. After alignment of the bedplate, epoxy resin chocking material is poured around the thrust sleeves.

All ancillaries, such as pumps and tank capacities, and their arrangement are optimised to reduce the installation and operating costs. The number of pipe connections on the engine that must be connected by the shipyard are minimised. The engine's electrical power requirement for the ancillary services is also kept down to a minimum.

A standard all-electric interface is employed for engine management systems – known as DENIS (Diesel Engine Interface Specification) – to meet all needs for control, monitoring, safety and alarm warning functions. This matches remote control systems and ship control systems from a number of approved suppliers.

The engine is equipped with an integrated axial detuner at the free end of the crankshaft. An axial detuner monitoring system developed by Wärtsilä is optional equipment for the RT-flex50 engine.



Arrangements for transmitting propeller thrust to the engine seatings for the RT-flex50 engines. The inset shows the thrust sleeve for the thrust bolts.

MAINTENANCE

Two of the primary objectives in the design and development of Wärtsilä low-speed engines that have beneficial effects on maintenance requirements are high reliability and long times between overhauls. Three years between overhauls are now being achieved by engines to the latest design standards. At the same time, their high reliability gives shipowners more freedom to arrange maintenance work within ships' sailing schedules.

Yet, as maintenance work is inevitable, particular attention is given to ease of maintenance by including tooling and easy access, and by providing easy-to -understand instructions.

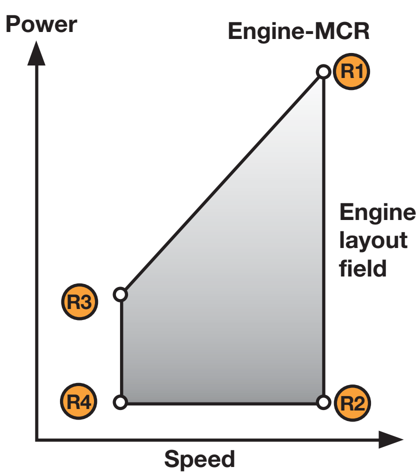
All major fastenings throughout the engine are tightened by hydraulic jacks. For the RT-flex50, the dimensions and weights of the jacks are kept low by the use of 1500 bar working pressure. Access to the crankcase continues to be possible from both sides of the engine. The handling of components within the crankcase is facilitated by ample provision for hanging hoisting equipment.

The Wärtsilä RT-flex system is designed to be user friendly, without requiring ships' engineers to have any special additional skills. The system incorporates its own diagnostic functions, and all the critical elements are made for straightforward replacement.

MAIN TECHNICAL DATA

DEFINITIONS:

- Dimensions and weights: All dimensions are in millimetres and are not binding. The engine weight is net in metric tonnes (t), without oil and water, and is not binding.
- R1, R2, R3, R4 = power/speed ratings at the four corners of the engine layout field (see diagram).
- R1 = engine Maximum Continuous Rating (MCR).
- Contract-MCR (CMCR) = selected rating point for particular installation. Any CMCR point can be selected within the engine layout field.
- BSFC = brake specific fuel consumptions (BSFC). All figures are quoted for fuel of lower calorific value 42.7 MJ/kg, and for ISO standard reference conditions (ISO 15550 and 3046). The BSFC figures are given with a tolerance of +5%.
- The values of power in kilowatts and fuel consumption in g/kWh are the standard figures, and discrepancies occur between these and the corresponding brake horsepower (bhp) values owing to the rounding of numbers. For definitive values, please contact Wärtsilä local offices.
- ISO standard reference conditions
  Total barometric pressure at R1 ....1.0 bar
  Suction air temperature ....25 °C
  Relative humidity.. 30%
  Scavenge air cooling water temperature:
  – with sea water ....25 °C
  – with fresh water ....29 °C



WÄRTSILÄ Engines

MAIN DATA Wärtsilä RT-flex50-D

Cylinder bore	500 mm
Piston stroke	2050 mm
Speed	99 - 124 rpm
Mean effective pressure at R1	21.0 bar
Piston speed	8.5 m/s
Fuel specification: Fuel oil	730 cSt/50°C 7200 sR1/100°F ISO 8217, category ISO-F-RMK 55

RATED POWER: PROPULSION ENGINES

Cyl.	Output in kW/bhp at							
	124 rpm				99 rpm			
	R1		R2		R3		R4	
	kW	bhp	kW	bhp	kW	bhp	kW	bhp
5	8 725	11 875	6 100	8 300	6 975	9 500	6 100	8 300
6	10 470	14 250	7 320	9 960	8 370	11 400	7 320	9 960
7	12 215	16 625	8 540	11 620	9 765	13 300	8 540	11 620
8	13 960	19 000	9 760	13 280	11 160	15 200	9 760	13 280

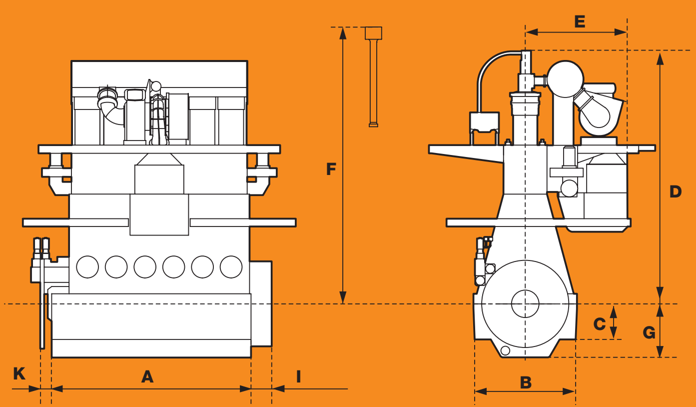
BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph
Load 100%	169	124	163	120	169	124	165	121
BMEP, bar	21.0		14.7		21.0		18.4	

PRINCIPAL ENGINE DIMENSIONS (MM) AND WEIGHTS (TONNES)

Cyl.	A	B	C	D	E	F*	G	I	K	Weight
5	5 227	3 150	1 088	7 646	3 300	9 270	1 636	631	355	200
6	6 107	3 150	1 088	7 646	3 300	9 270	1 636	631	355	225
7	6 987	3 150	1 088	7 646	3 300	9 270	1 636	631	355	255
8	7 867	3 150	1 088	7 646	3 300	9 270	1 636	631	355	280

* Standard piston dismantling height, can be reduced with tilted piston withdrawal.



WÄRTSILÄ

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 the marine and energy markets with products and solutions as well as services. Through innovative products and services, Wärtsilä sets out to be the most valued business partner of all its customers. This is achieved by the dedication of more than 16,000 professionals manning 150 Wärtsilä locations in 70 countries around the world. Wärtsilä is listed on The Nordic Exchange in Helsinki, Finland.

03.2008 / Bock's Office / Waasa Graphics

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