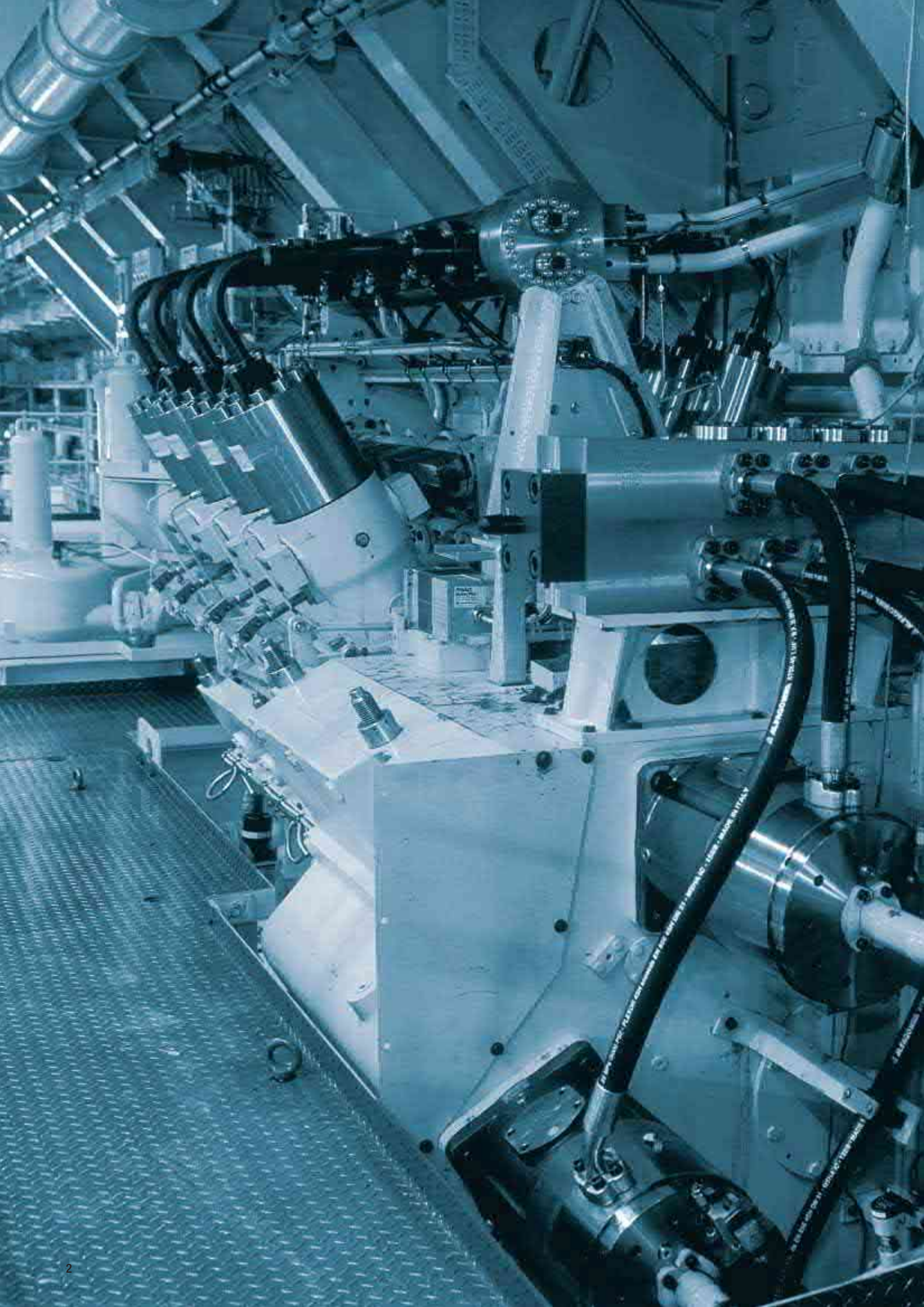


WÄRTSILÄ RT-flex96C AND WÄRTSILÄ RTA96C  
TECHNOLOGY REVIEW







## WÄRTSILÄ RT-flex96C AND WÄRTSILÄ RTA96C TECHNOLOGY REVIEW

This is a brief guide to the technical features and benefits of Wärtsilä RT-flex96C and RTA96C low-speed marine diesel engines.

|   |    |
|---|----|
| INTRODUCTION.....   | 4  |
| DEVELOPMENT BACKGROUND .....                                    | 6  |
| RT-flex: CONCEPT AND BENEFITS .....                             | 8  |
| RT-flex COMMON-RAIL SYSTEM APPLIED.....                         | 8  |
| RT-flex: REAL IN-SERVICE FUEL ECONOMY.....                      | 10 |
| RT-flex: CLEANER IN THE ENVIRONMENT.....                        | 10 |
| RTA96C:<br>THE TRADITIONAL CAMSHAFT ARRANGEMENT.....            | 11 |
| ENGINE STRUCTURE .....  | 13 |
| RUNNING GEAR .....  | 14 |
| COMBUSTION CHAMBER.....   | 17 |
| PISTON-RUNNING BEHAVIOUR.....                                   | 17 |
| TURBOCHARGING AND SCAVENGE AIR SYSTEM .....                     | 18 |
| INSTALLATION ARRANGEMENTS .....                                 | 19 |
| WASTE HEAT RECOVERY:<br>FUEL SAVING WITH REDUCED EMISSIONS..... | 20 |
| MAINTENANCE .....   | 21 |
| SHIP REFERENCES.....  | 22 |
| MAIN TECHNICAL DATA.....  | 23 |



12-cylinder Wärtsilä RT-flex96C engine giving 68,640 kW (93,360 bhp).

## INTRODUCTION

The Wärtsilä RT-flex96C and RTA96C low-speed marine diesel engines, with a power range of 25,320 to 84,420 kW, are tailor-made for the economic, reliable propulsion of large, fast container liners. They offer clear, substantial benefits:

- High power outputs at optimum shaft speeds
- Reliability and proven design
- Competitive first cost
- Economical fuel consumption over the whole operating range
- Low cylinder oil feed rate
- Three years between overhauls
- Low maintenance costs

- Full compliance with the NO<sub>x</sub> emission regulation of Annex VI of the MARPOL 1973/78 convention.

The Wärtsilä RT-flex96C has additional benefits:

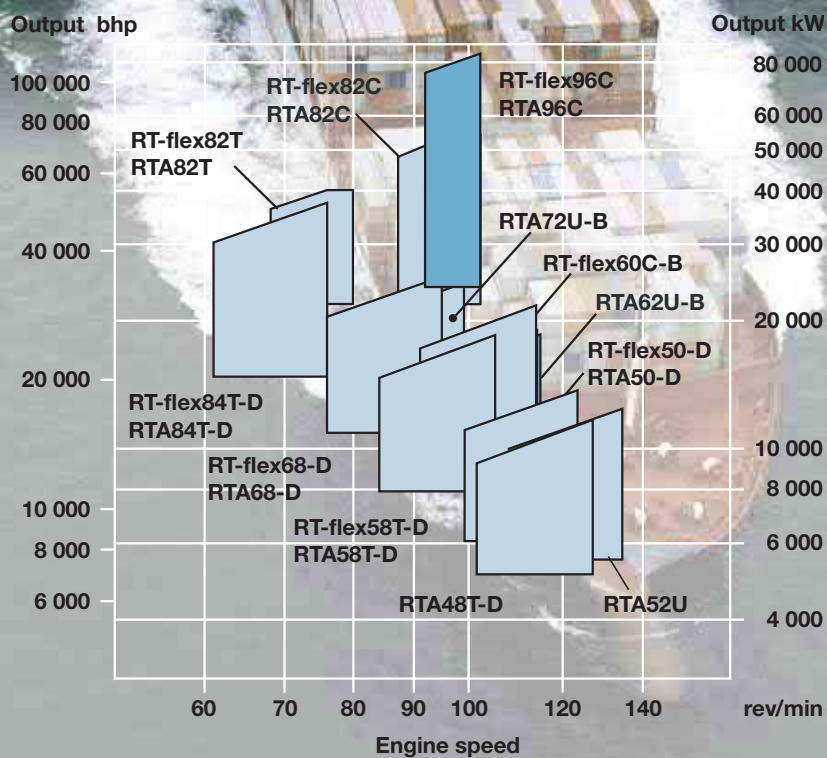
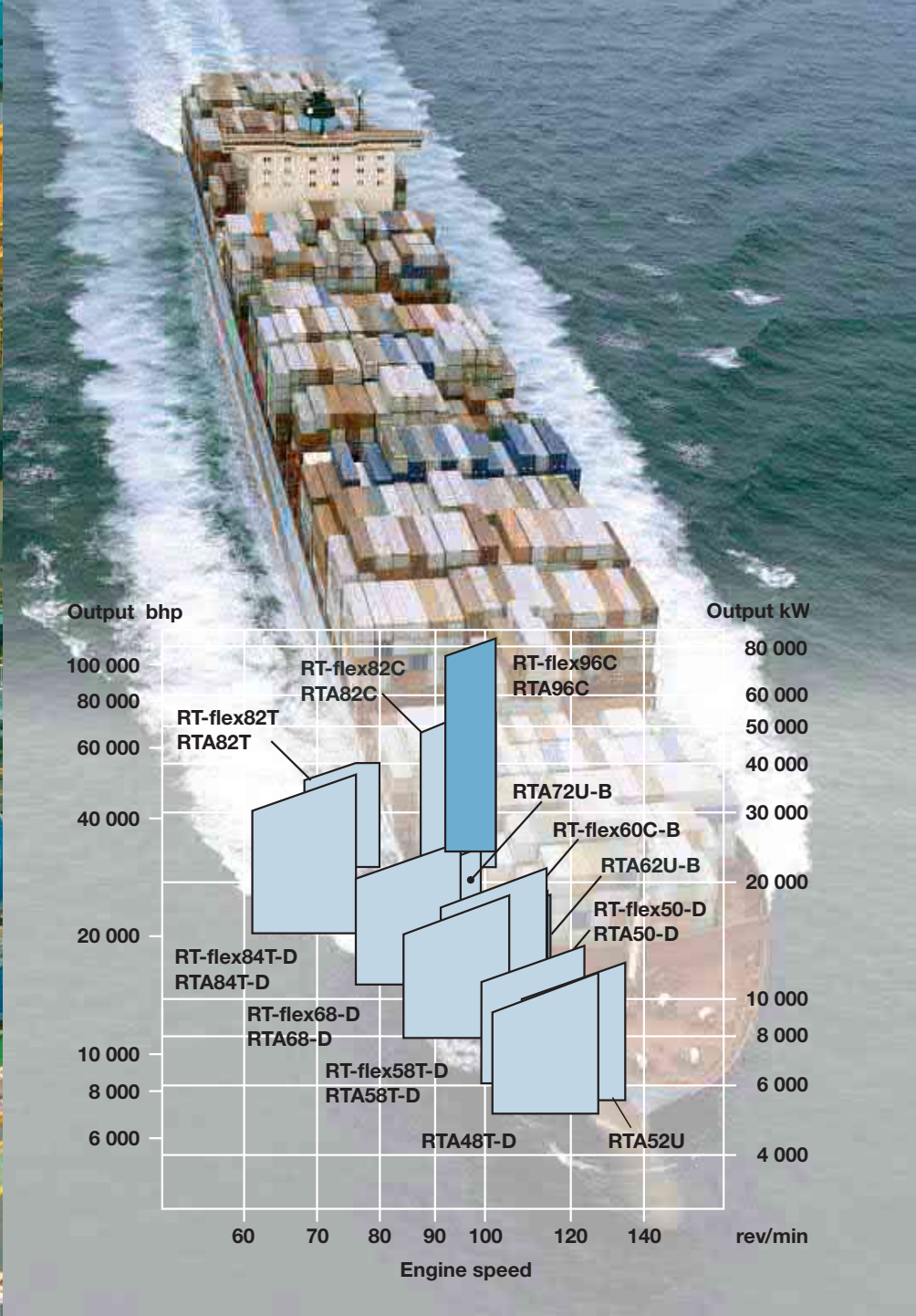
- Smokeless operation at all running speeds
- Better fuel economy in the part-load range
- Lower steady running speeds
- Reduced maintenance requirements with simpler engine setting and extendable time between overhauls.

The Wärtsilä RTA96C two-stroke diesel engine was introduced in December 1994 to meet

the demand for even higher power outputs to propel the then coming generation of larger and faster container ships. It followed in a long line of RTA-series engines with each generation bringing higher power outputs to cater for ever increasing ship sizes.

The RTA96C was readily accepted in the market. Its reliability was acknowledged very quickly by the containership operators and led to a very good reputation, further applications and repeat orders.

The Wärtsilä RT-flex96C two-stroke diesel engine was introduced in 2003 by combining the latest common-rail technology for fuel injection and valve actuation with fully-



integrated electronic control and the well-established RTA96C engine.

The 14-cylinder RT-flex96C engines extend the power spectrum of the RTA series up to 84,420 kW (114,800 bhp). Thus with waste heat recovery systems which can add up to 12 per cent of engine power, RT-flex96C engines can meet the propulsion requirements of large, fast container ships from up to around 12,000 TEU capacity at service speeds of around 25 knots.

#### Principal parameters of Wärtsilä RT-flex96C and RTA96C engines

|                         |         |        |
|-------------------------|---------|--------|
| Bore                    | mm      | 960    |
| Stroke                  | mm      | 2500   |
| Output MCR, R1          | kW/cyl  | 6030   |
|                         | bhp/cyl | 8200   |
| Speed range, R1-R3      | rpm     | 102–92 |
| BMEP at R1              | bar     | 19.6   |
| Pmax                    | bar     | 153    |
| Mean piston speed at R1 | m/s     | 8.5    |
| Number of cylinders     |         | 6–14*  |
| BSFC: at full load, R1  | g/kWh   | 171    |
|                         | g/bhph  | 126    |

\* 13- and 14-cylinder engines only in RT-flex version.



## 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-flex96C and RTA96C engine types are good examples of this policy.

When the design of the RTA96C was introduced in 1994, it was based fully on the well-established RTA84C to take advantage of the wealth of experience in theoretical design, testbed research and operating service from the RTA84C and other previous RTA-series engines. The first RTA96C engines entered service in 1997.

In 2000, the cylinder power of the RTA96C was raised by some four per cent by utilising potential already in the design. A 14-cylinder model was also added to bring the maximum power up to 80,080 kW (108,920 bhp). The increased power output was made possible by

the very satisfactory service experience with the engines in service.

Further improvements were subsequently achieved by the introduction of various design measures to improve piston-running behaviour. These improvements reduce wear rates of cylinder liners and piston rings, extend times between overhauls and allow reduced cylinder oil feed rates.

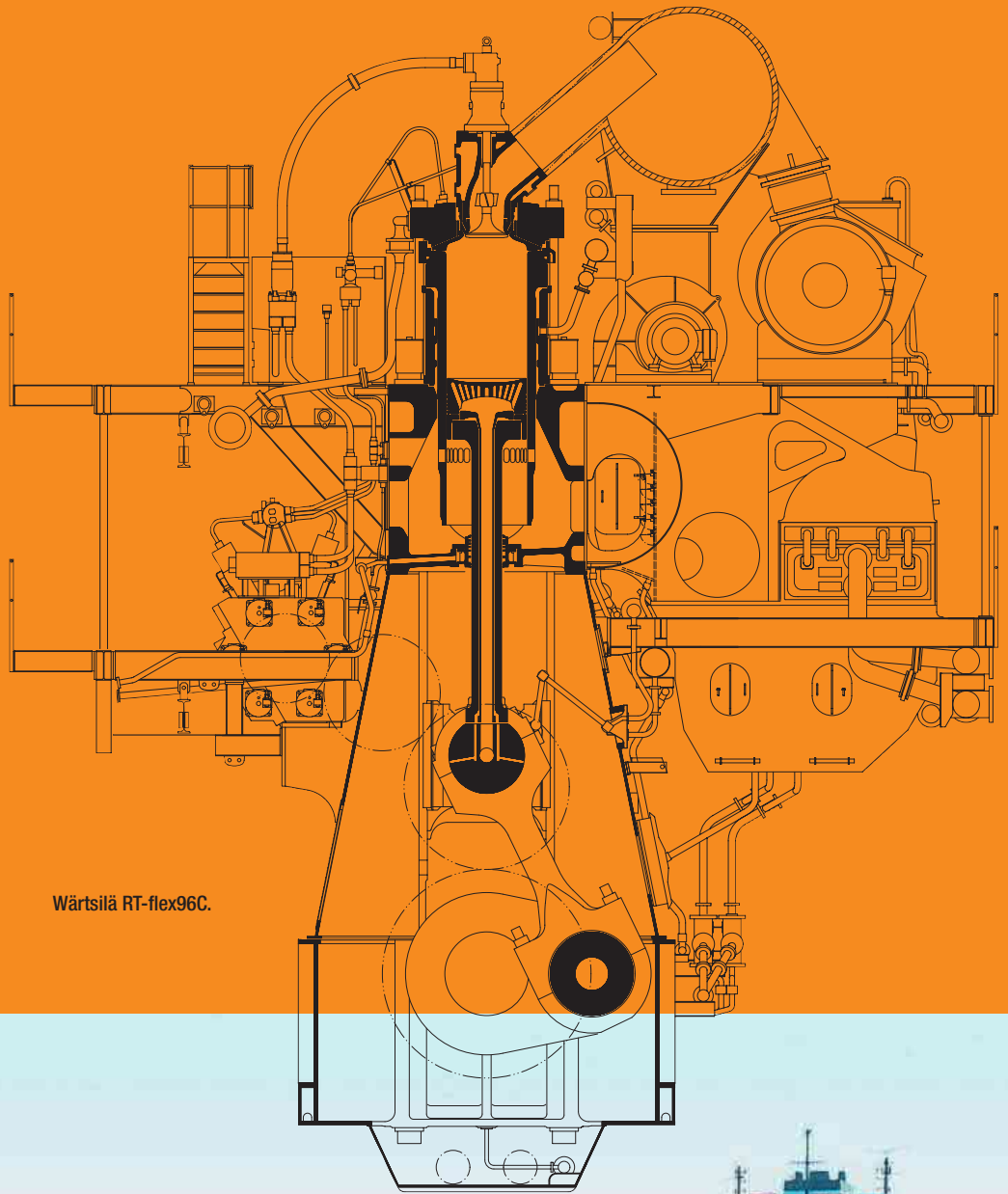
A major step forward was achieved when the RTA96C was combined with the RT-flex electronically-controlled common-rail technology for fuel injection and valve actuation to create the RT-flex96C engine introduced in 2003. At the same time, the decision was taken that the 13- and 14-cylinder engines would only be built in RT-flex form.

The RT-flex common-rail technology had been introduced first in the RT-flex58T-B engine. Service results with this engine, which entered service in September 2001, were

excellent, clearly demonstrating that the new RT-flex system offers distinctive operational benefits which are not possible with camshaft engines. Thus the experience from the RT-flex58T-B engine type, the RT-flex60C engine first built in 2002, and the full-sized RT-flex58T research engine since June 1998 were employed in the development of the RT-flex96C engine.

The first RT-flex96C engines were shop tested in April 2004 (eight-cylinder engine) and June 2004 (12-cylinder engine). These subsequently entered service in November and December 2004 respectively.

The power outputs of RT-flex96C and RTA96C engines were further raised at the end of 2007 by 5.4 per cent. Thus the MCR outputs were increased from 5720 to 6030 kW/cylinder, bringing the output of the 14-cylinder engines to 84,420 kW.



Wärtsilä RT-flex96C.



## 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-flex96C is basically a standard Wärtsilä low-speed two-stroke marine diesel engine, except that, instead of the usual camshaft and its gear drive, fuel injection pumps, exhaust valve actuator pumps and reversing servomotors, it is equipped with a common-rail system for fuel injection, exhaust valve actuation and air starting, and full electronic control of these engine functions.

The common-rail injection system operates with just the same grades of heavy fuel oil as are already standard for Wärtsilä low-speed engines.

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 lower 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.



Rail unit at the cylinder top level of the RT-flex96C engine with electronic control units on the front of the rail unit for good access.

## RT-flex COMMON-RAIL SYSTEM APPLIED

The common rail for fuel injection is a manifold 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 running on multi-lobe cams.

Fuel is delivered from this common rail through a separate injection control unit for each engine cylinder to the standard fuel injection valves which are hydraulically operated in the usual way by the high-pressure fuel oil. The control units, using quick-acting Wärtsilä rail valves, regulate the timing of fuel injection, control the volume of fuel injected, and set the shape of the injection pattern. The three fuel injection valves in each cylinder

cover are 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:

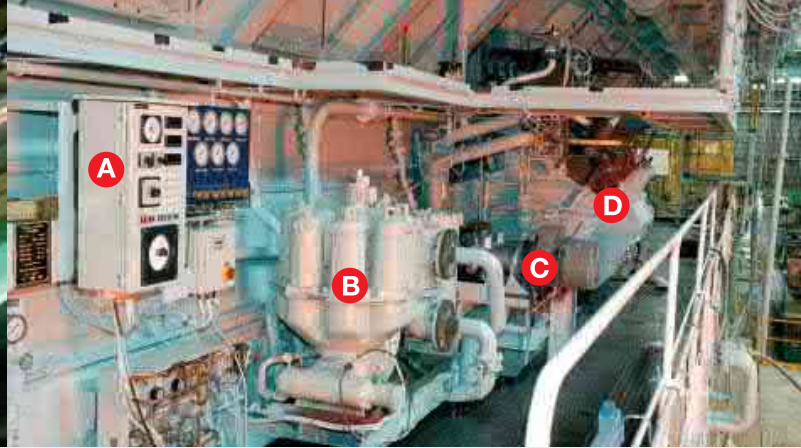
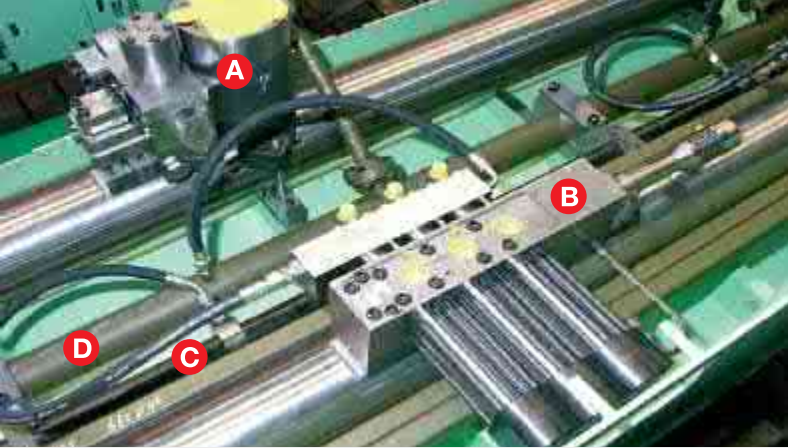
- Precise volumetric control of fuel injection, with integrated flow-out security
- Variable injection rate shaping and free selection of injection pressure
- Stable pressure levels in common rail and supply pipes
- Possibility for independent control and shutting off of individual fuel injection valves
- 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 in timing for valve opening and closing.

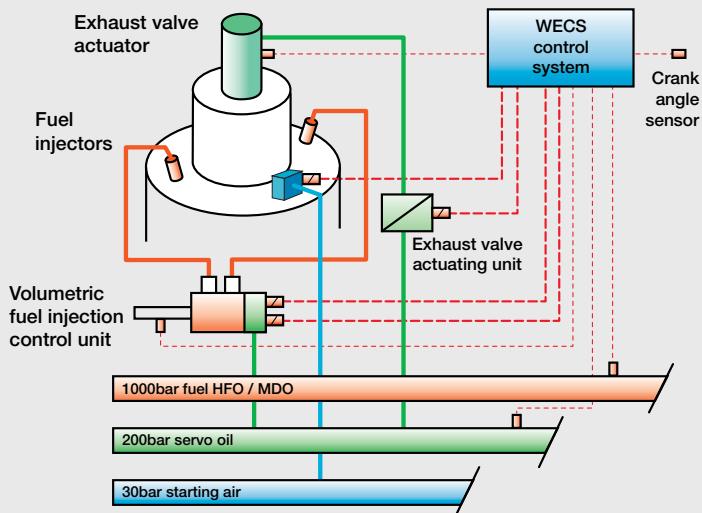
All functions in the RT-flex system are controlled and monitored through the integrated Wärtsilä WECS-9520 electronic control system. This is a modular system with separate microprocessor control units for each cylinder, and overall control and supervision by duplicated microprocessor control units. The latter provide the usual interface for the electronic governor and the shipboard remote control and alarm systems.





Inside the rail unit of an RT-flex96C engine during assembly. The exhaust valve actuator (A) is mounted on the servo oil rail and the injection control unit (B) is on the fuel rail. Next to the fuel rail is the smaller control oil rail (C) and the return pipe for servo and control oil (D).

Various RT-flex equipment on the lower platform of a 12RT-flex96C engine. From left to right, these include (A) the local engine control panel, (B) the automatic fine filter for servo and control oil, (C) the two electrically-driven control oil pumps and (D) the supply unit.



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



Supply unit for a 12RT-flex96C engine with the fuel pumps in Vee-form arrangement on the left and the servo pumps on the right of the central gear drive.

## 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.

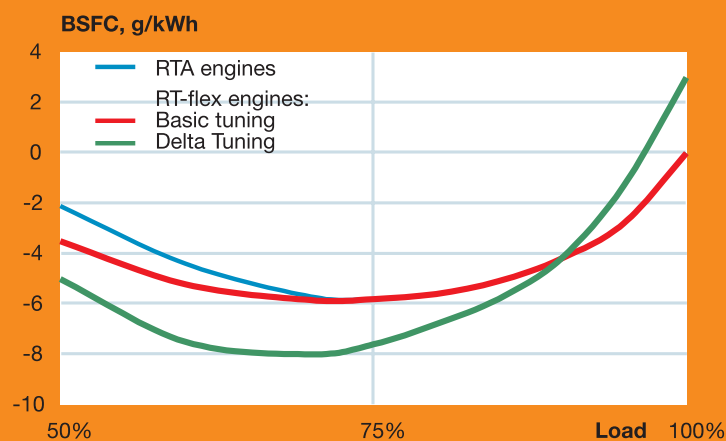
Similar freedom in exhaust valve timing allows the RT-flex system to keep combustion air excess high by earlier valve closing as the load/speed is reduced. This is not only advantageous for fuel consumption but also limits component temperatures, which would normally increase at low load. Lower turbocharger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

Another important contribution to fuel economy of the RT-flex96C engines is the capability to adapt easily the injection timing to various fuel properties having a poor combustion behaviour.

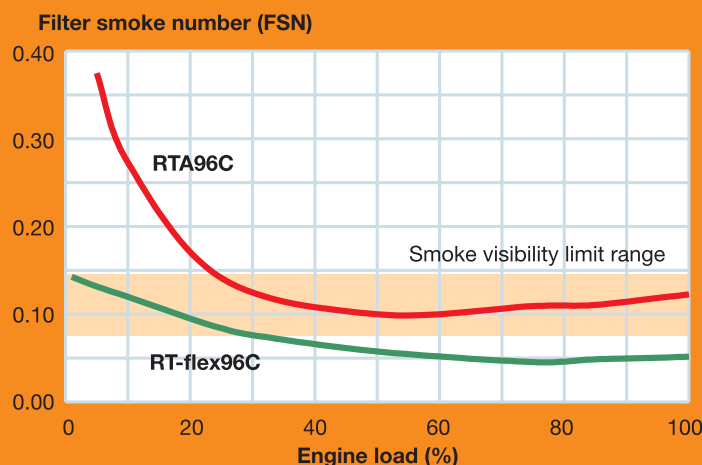
### DELTA TUNING:

#### 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 at less than 90 per cent engine power. The consequent increase in  $\text{NO}_x$  in that operating range is compensated by reducing  $\text{NO}_x$  emissions in the high load range. With both BSFC curves, the engines comply with the  $\text{NO}_x$  regulation of the MARPOL 73/78 convention.



The new alternative BSFC curve for RT-flex96C engines given by Delta Tuning compared with the original BSFC curves. All curves shown are for engines complying with the IMO  $\text{NO}_x$  regulation.



Smoke emission measurements for RT-flex96C engines compared with the RTA96C engines, both using marine diesel oil.

## 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 comply with the  $\text{NO}_x$  emissions limit of Annex VI of the MARPOL 73/78 convention as standard.

RT-flex engines, however, come comfortably below this  $\text{NO}_x$  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.

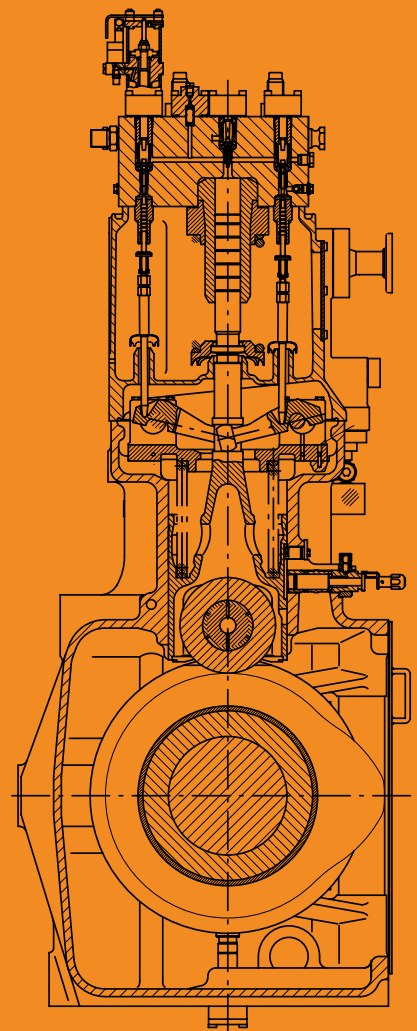
Yet the environmental benefits of RT-flex engines need not be restricted by the current state-of-the-art. As all settings and adjustments within the combustion and scavenging processes are made electronically, future adaptations will be possible simply through changes in software, which could be readily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

A major reduction in all exhaust emissions, including  $\text{CO}_2$ , can be obtained with RT-flex96C engines by combining the engine with a high-efficiency waste heat recovery plant (see page 20).

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  $\text{NO}_x$ ,  $\text{SO}_x$  and  $\text{CO}_2$ , in both RTA and RT-flex engines.



12-cylinder Wärtsilä RTA96C engine giving 68,640 kW.



Fuel injection pump with double control valves.

## RTA96C: THE TRADITIONAL CAMSHAFT ARRANGEMENT

The Wärtsilä RTA96C retains the traditional, mechanical camshaft arrangement for fuel injection pumps and valve drives.

The camshaft-driven fuel injection pumps are of the well-proven double-valve controlled type that has been traditional in Wärtsilä low-speed engines. Injection timing is controlled by separate suction and spill valves regulated through eccentrics on hydraulically-actuated lay shafts. Consequently, great flexibility in timing is possible through the variable fuel injection timing (VIT) system for improved part-load fuel consumption, and for the fuel quality setting (FQS) lever to adjust the injection timing according to the fuel oil quality.

The valve-controlled fuel injection pump, in comparison with a helix type, has a plunger with a significantly greater sealing length. The higher volumetric efficiency reduces the torque in the camshaft. Additionally, injection from a valve-controlled pump is far more

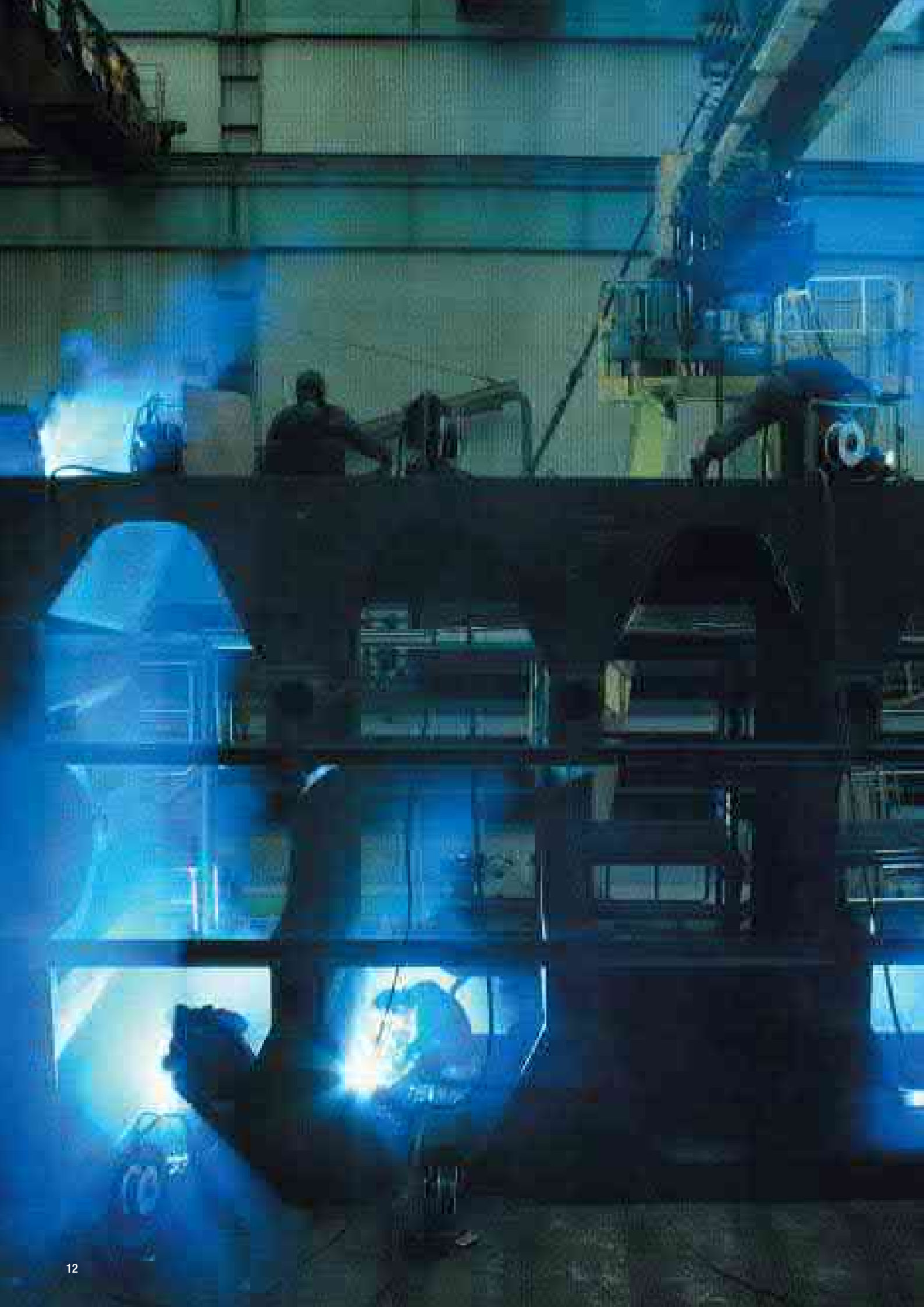
stable at very low loads and rotational shaft speeds down to 15 per cent of the rated speed are achieved. Valve control also has benefits of less deterioration of timing over the years owing to less wear and to freedom from cavitation.

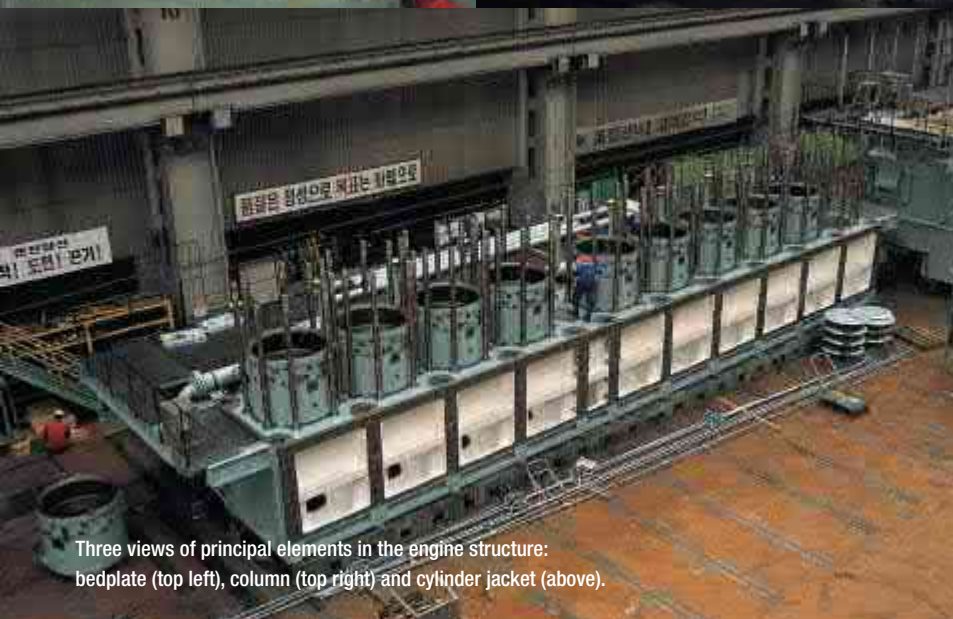
The camshaft is assembled from a number of segments, one for each pump housing. The segments are connected through SKF sleeve couplings. Each segment has an integral hydraulic reversing servomotor located within the pump housing.

The camshaft drive uses the well-proven arrangement of gear wheels housed in a double column located at the driving end in the centre of the engine, depending upon number of cylinders. There are three gear wheels in the camshaft drive. The main gear wheel on the crankshaft is in one piece and flange-mounted.

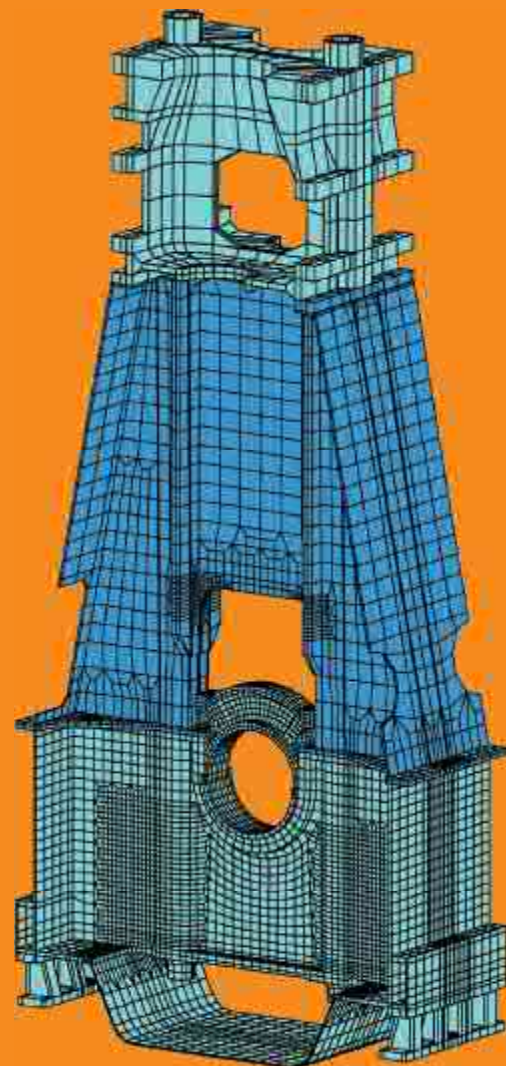


Pump housing with fuel injection pumps and exhaust-valve actuator pumps.





Three views of principal elements in the engine structure: bedplate (top left), column (top right) and cylinder jacket (above).



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

## ENGINE STRUCTURE

Wärtsilä RT-flex96C and RTA96C engines have a well-proven type of structure, with a 'gondola'-type bedplate surmounted by very rigid, A-shaped double-walled columns and cylinder blocks, 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 cylinder jacket is assembled from individual cast-iron cylinder blocks, bolted together to form a rigid whole. The supply unit in RT-flex engines, or the fuel pump blocks in RTA engines, are 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 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.



Lowering the crankshaft into the bedplate.

## 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 then shrunk into the crank web.

The main bearings have white metal shells. The main bearing caps are held down by two pairs of 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.

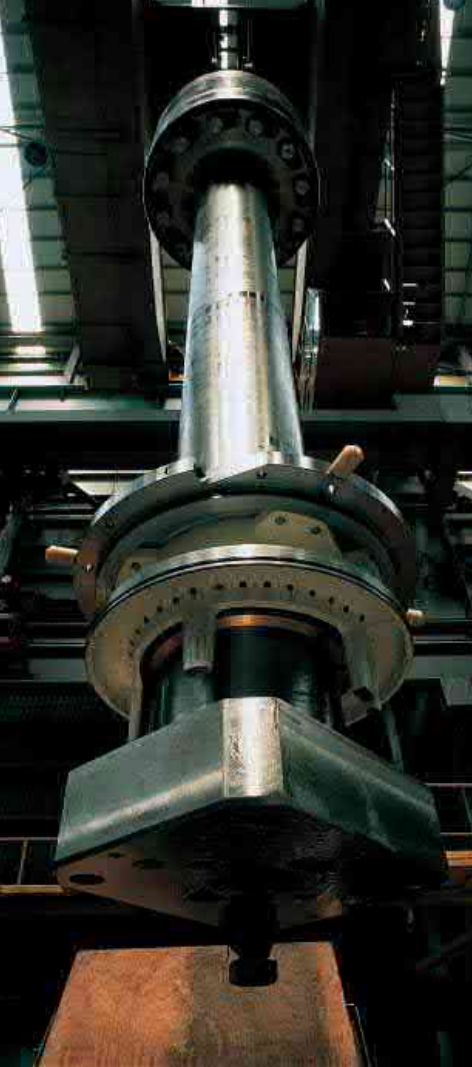
The crosshead bearing is designed to the same principles as for all other RTA and RT-flex

engines. It also features a full-width lower half bearing. The crosshead bearings have thin-walled shells of white metal for a high load-bearing capacity. Wärtsilä low-speed engines retain the use of a separate elevated-pressure lubricating oil supply to the crosshead. It provides hydrostatic lubrication which lifts the crosshead pin off the shell during every revolution to ensure that sufficient oil film thickness is maintained under the gas load. This has proved crucial to long-term bearing security.

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.

Today's RTA and RT-flex engines employ an improved design of piston rod gland with gas-tight top scraper rings, and large drain areas and channels. Hardened piston rods are now standard to ensure long-term stability in the gland behaviour.

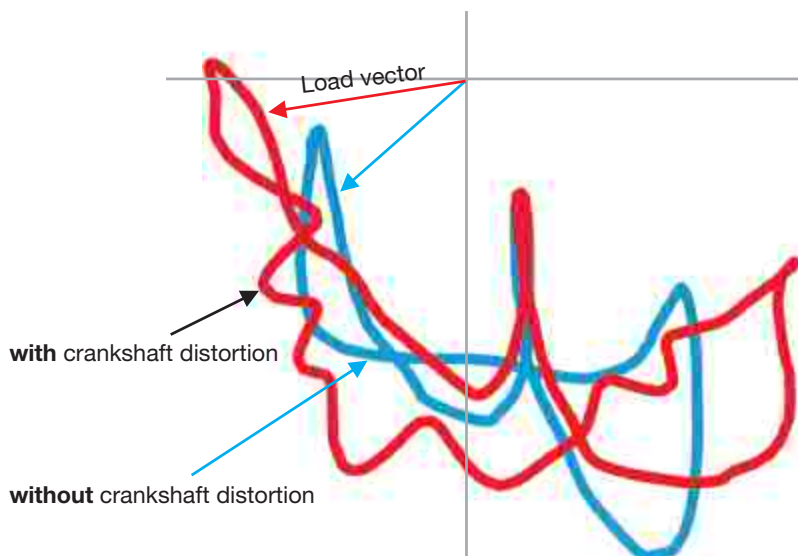




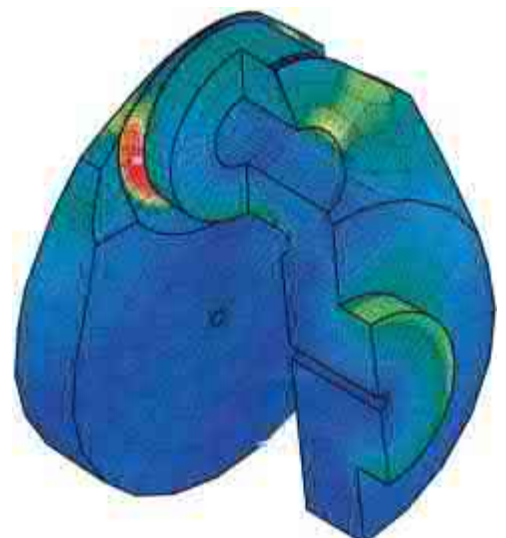
Piston, piston rod and gland box.



Crosshead pins with guide shoes.



Load diagrams for main bearing with and without crankshaft distortion taken into account.



Finite-element analysis of the crank throw of the RT-flex96C under full dynamic loading.



Bore-cooled pistons from the underside.



Cooling oil spray nozzles at top of piston rod.



# 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 modern calculation tools were invaluable with the RTA96C which has a rather shallow combustion chamber owing to its comparatively short stroke/bore ratio, and care was needed with the large quantity of fuel injected to avoid impingement on component surfaces.

The well-proven bore-cooling principle is also employed in all the combustion chamber components to control their temperatures, as well as thermal strains and mechanical stresses.

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 80A which is housed in a bolted-on valve cage. The engines have three fuel injection valves symmetrically distributed in the 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 a fairly even temperature distribution right across the crown surface. No coatings are necessary.

The cylinder liner is also bore cooled. Its surface temperatures are optimised for good piston-running behaviour.

## PISTON-RUNNING BEHAVIOUR

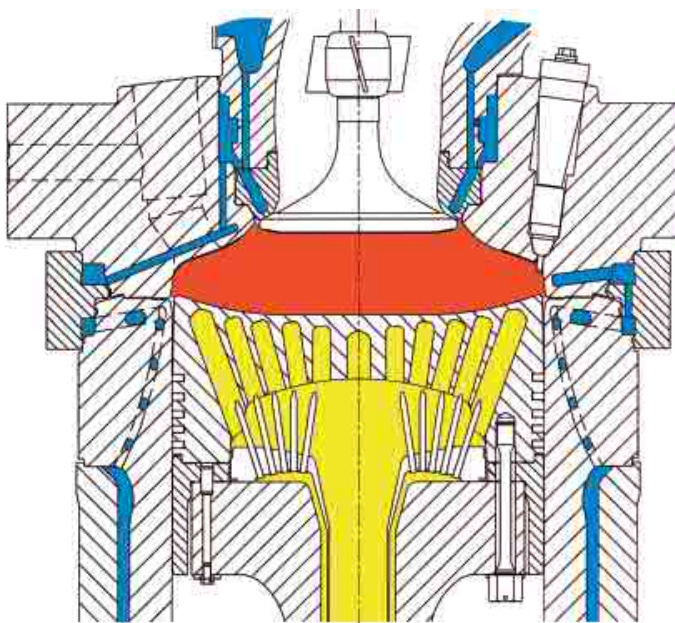
Today the time between overhaul (TBO) of low-speed marine diesel engines is largely determined by the piston-running behaviour and its effect on the wear of piston rings and cylinder liners. For this reason, Wärtsilä RT-flex96C and RTA96C engines now incorporate a package of design measures that enable 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 newly-built RT-flex96C and RTA96C engines for improved piston-running behaviour now include:

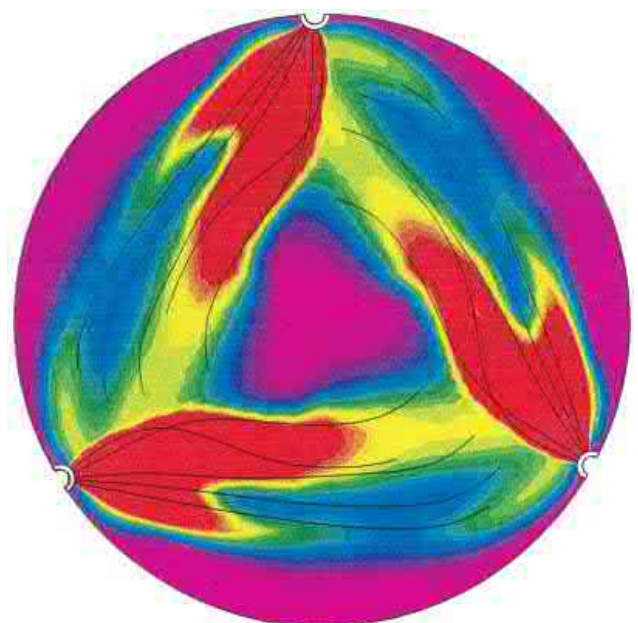
- Liner of the appropriate material, with sufficient hard phase
- Careful turning of the liner running surface and plateau honing of the liner over the full length of the running surface
- Optimised surface temperatures on the cylinder liner without any insulation or insulating tubes
- Chromium-ceramic coated, pre-profiled piston rings in all piston grooves
- Anti-Polishing Ring (APR) with double-acting scraper edges at the top of the cylinder liner
- Increased thickness of chromium layer in the piston-ring grooves
- Two bronze rubbing bands on short piston skirt
- Load-dependent accumulator lubricating system for cylinder lubrication.

A key element good piston-running is the surface finish of the cylinder liner. Careful machining and plateau honing gives the liner an ideal running surface for the piston rings, together with an optimum surface microstructure.

The Anti-Polishing Ring (APR) 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. The APR has a smaller clearance with the piston crown, and two scraper edges for greater cleaning effect.



Fully bore-cooled combustion chamber.



Analysis of fuel distribution and injection trajectories in the cylinder. Colours indicate concentration with blue/green for the stoichiometric mixture. No combustion calculated.



The Anti-Polishing Ring (APR) for RTA96C and RT-flex96C engines has a revised geometry with two edges to clean the piston top land during both the up and down strokes of the piston.

Piston of an RTA96C engine after testing at 110 per cent load. The piston has chromium ceramic rings in all grooves and two bronze rubbing bands in the short skirt.

It is important that the liner wall temperature is optimised over the piston stroke. The use of chromium-ceramic coated piston rings in all grooves allows lower liner temperatures which are now achieved without mid-stroke insulation.

Whilst trying to avoid corrosive wear by optimising liner wall temperatures, it is necessary to take out as much water as possible from the scavenge air. Thus, the 'underslung' scavenge air receiver combined with highly-efficient vane-type water separators fitted after the air cooler and the effective water drainage arrangements are absolutely essential for good piston running.

Timed, load-dependent cylinder lubrication is provided by the latest Wärtsilä Pulse Lubricating System (PLS) which ensures optimum distribution of cylinder lubricating oil

on the running surface of the cylinder liner. In PLS, the feed rate and timing are electronically controlled at the lubricator pump. There is full flexibility in the setting of the lubricator timing point, and volumetric metering ensures constant oil dosage patterns across the engine load range. The dosage in quantity and timing is precisely regulated even for low feed rates. The guide feed rate for PLS-equipped engines after running-in is 0.7–0.8 g/kWh.

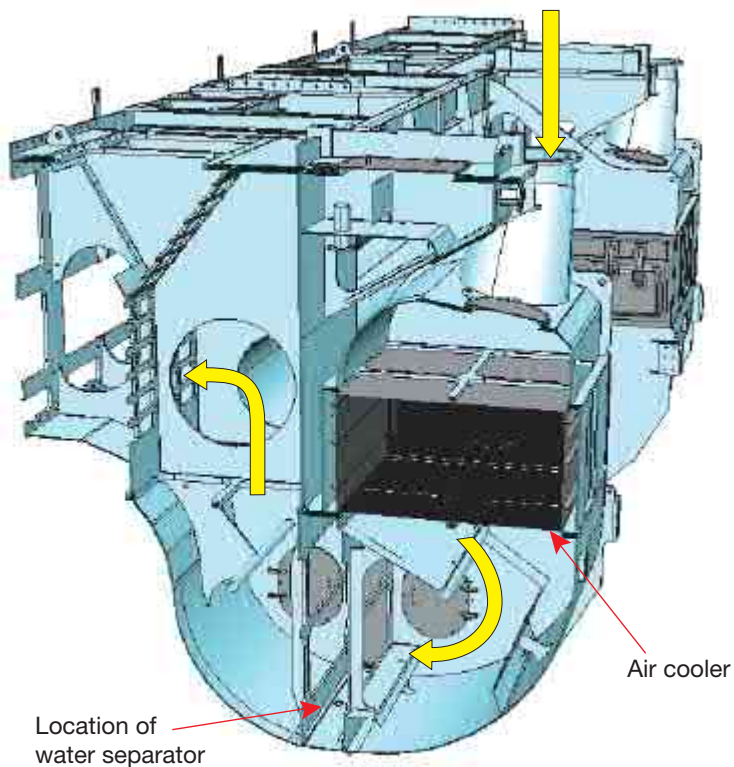
## TURBOCHARGING AND SCAVENGE AIR SYSTEM

The RT-flex96C and RTA96C 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

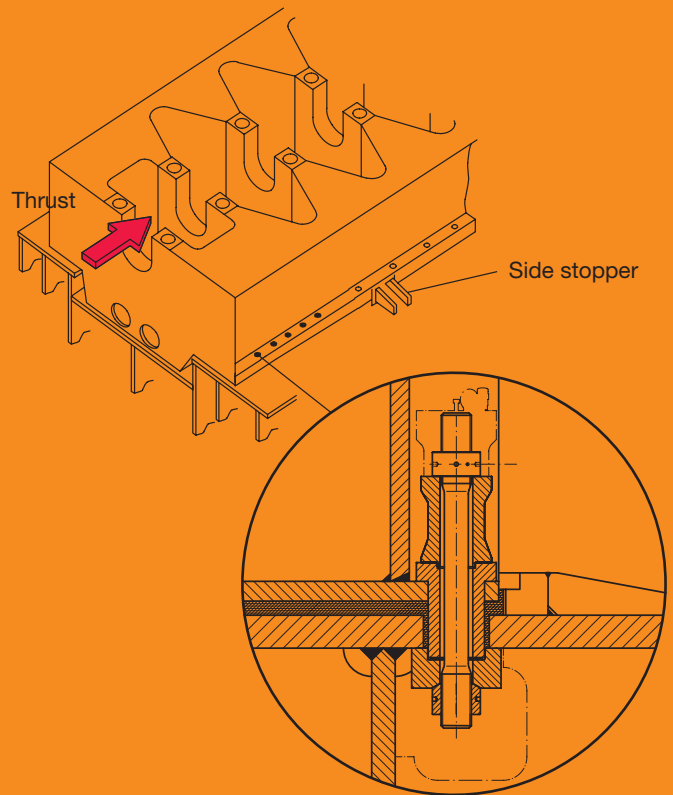
air is delivered by a constant-pressure turbocharging system with one or more high-efficiency exhaust gas turbochargers depending on the numbers of cylinders. For starting and during slow-running, the scavenge air delivery is augmented by electrically-driven auxiliary blowers.

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 fixed foot 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 water separator. The highly-efficient water separator



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



Arrangements for transmitting propeller thrust to the engine seatings for the RT-flex96C and RTA96C engines. The inset shows the thrust sleeve for the thrust bolts.

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. For example, a 12-cylinder RT-flex96C or RTA96C requires 14 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 standard equipment.

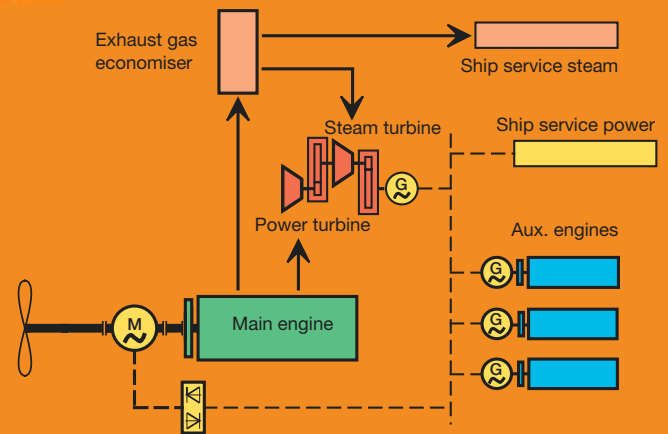
Turbogenerator set for the high-efficiency waste heat recovery plant, with the exhaust-gas power turbine on the left, the generator on the right, and the steam turbine to the right of centre.



**Indicative performance of RT-flex96C engines with high-efficiency waste heat recovery (WHR) plant\***

| RT-flex96C engine                | 10 cylinders | 12 cylinders | 14 cylinders |
|----------------------------------|--------------|--------------|--------------|
| Reference plant of engine alone: |              |              |              |
| Engine power, MCR kW             | 60,300       | 72,360       | 84,420       |
| Fuel consumption, g/kWh          | 171          | 171          | 171          |
| Plant combining engine and WHR:  |              |              |              |
| Engine power, MCR kW             | 60,300       | 72,360       | 84,420       |
| WHR turbogenerator output, kWe   | 7460         | 8950         | 10,440       |
| Overall fuel consumption, g/kWh  | 156          | 156          | 156          |

\* Indicative values based on standard reference conditions and 100 per cent engine power at the R1 rating. The engines with WHR plant employ Delta Tuning.



Schematic of a typical waste heat recovery plant for container ships in the 7000-9000 TEU range.

## WASTE HEAT RECOVERY: FUEL SAVING WITH REDUCED EMISSIONS

An extended form of high-efficiency waste heat recovery plant has been developed for Wärtsilä RT-flex96C engines, providing an environmentally-clean solution to reducing ships' fuel consumption. The generated electrical power can be about 12 per cent of the engine power, and is employed to assist ship propulsion or for supplying shipboard services.

The generated power thus contributes significant savings in both fuel costs and overall exhaust-gas emissions, such as CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>, etc. It is the only technology commercially available today that reduces both fuel consumption and exhaust emissions at the same time.

The waste heat recovery plant follows the

well-established concept of passing the exhaust gases of the ship's main engine through an exhaust-gas economiser to generate steam for a turbine-driven generator. However, the quantity of energy recovered from the exhaust gases is maximised by adapting the engine to the lower air intake temperatures that are available by drawing intake air from outside the ship (ambient air) instead of from the ship's engine room. The engine turbochargers are matched for the lower air intake temperatures thereby increasing the exhaust energy.

At the same time, today's high-efficiency turbochargers have surplus capacity at the engine's upper load range when matched for ambient air intake. Thus about 10% of the

engine's exhaust gas flow can be branched off to drive a power turbine which is incorporated in the turbogenerator package.

The overall result of the new concept is that the quantity of energy recoverable in an exhaust-gas economiser and in the power turbine is increased without affecting the air flow through the engine. There is thus no increase in the thermal loading of the engine and there is no adverse effect on engine reliability.

Heat is also recovered from the engine's scavenge air and jacket cooling water for feedwater heating. The scavenge air coolers are designed in such a way that the boiler feed water can be heated close to the evaporation temperature.



## MAINTENANCE

Primary objectives in the design and development of Wärtsilä low-speed engines 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 hydraulically tightened. For the

RT-flex96C and RTA96C, the dimensions and weights of these 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. In fact, the knowledge for operation and maintenance of RT-flex engines can be included in Wärtsilä's

usual one-week courses for RTA-series engines available for ships' engineers. Training time usually given to the camshaft system, fuel pumps, valve actuating pumps, and reversing servomotors is simply given instead to the RT-flex system.

# SHIP REFERENCES

Wärtsilä 12RTA96C



Wärtsilä 9RTA96C



Wärtsilä 10RTA96C

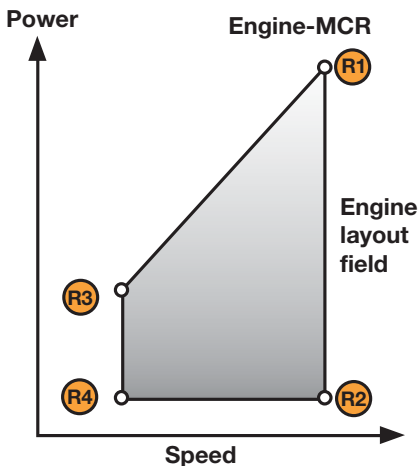


Wärtsilä 10RTA96C

# 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%.
- Wärtsilä RT-flex96C engines have a lower part-load fuel consumption than the corresponding Wärtsilä RTA96C engines.
- 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-flex96C – Wärtsilä RTA96C

|                               |                                 |
|-------------------------------|---------------------------------|
| Cylinder bore                 | 960 mm                          |
| Piston stroke                 | 2500 mm                         |
| Speed                         | 92 - 102 rpm                    |
| Mean effective pressure at R1 | 19.6 bar                        |
| Piston speed                  | 8.5 m/s                         |
| Fuel specification:           | 730 cSt/50°C                    |
| Fuel oil                      | 7200 sR1/100°F                  |
|                               | ISO 8217, category ISO-F-RMK 55 |

## RATED POWER: PROPULSION ENGINES

| Cyl. | Output in kW/bhp at |         |        |        |        |         |        |        |
|------|---------------------|---------|--------|--------|--------|---------|--------|--------|
|      | 102 rpm             |         |        |        | 92 rpm |         |        |        |
|      | R1                  |         | R2     |        | R3     |         | R4     |        |
|      | kW                  | bhp     | kW     | bhp    | kW     | bhp     | kW     | bhp    |
| 6    | 36 180              | 49 200  | 25 320 | 34 440 | 32 580 | 44 280  | 25 320 | 34 440 |
| 7    | 42 210              | 57 400  | 29 540 | 40 180 | 38 010 | 51 660  | 29 540 | 40 180 |
| 8    | 48 240              | 65 600  | 33 760 | 45 920 | 43 440 | 59 040  | 33 760 | 45 920 |
| 9    | 54 270              | 73 800  | 37 980 | 51 660 | 48 870 | 66 420  | 37 980 | 51 660 |
| 10   | 60 300              | 82 000  | 42 200 | 57 400 | 54 300 | 73 800  | 42 200 | 57 400 |
| 11   | 66 330              | 90 200  | 46 420 | 63 140 | 59 730 | 81 180  | 46 420 | 63 140 |
| 12   | 72 360              | 98 400  | 50 640 | 68 880 | 65 160 | 88 560  | 50 640 | 68 880 |
| 13   | 78 390              | 106 600 | 54 860 | 74 620 | 70 590 | 95 940  | 54 860 | 74 620 |
| 14   | 84 420              | 114 800 | 59 080 | 80 360 | 76 020 | 103 320 | 59 080 | 80 360 |

## BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

|           | g/kWh | g/bhph | g/kWh | g/bhph | g/kWh | g/bhph | g/kWh | g/bhph |
|-----------|-------|--------|-------|--------|-------|--------|-------|--------|
| Load 100% | 171   | 126    | 163   | 120    | 171   | 126    | 164   | 121    |
| BMEP, bar | 19.6  |        | 13.7  |        | 19.6  |        | 15.2  |        |

## PRINCIPAL ENGINE DIMENSIONS (MM) AND WEIGHTS (TONNES)

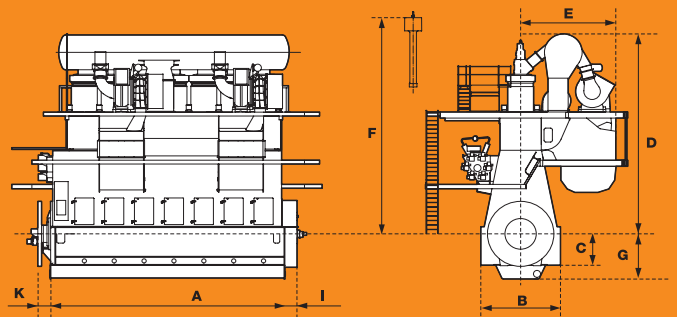
| Cyl. | A      | B     | C     | D      | E     | F*     | G     | I   | K   | Weight |
|------|--------|-------|-------|--------|-------|--------|-------|-----|-----|--------|
| 6    | 11 564 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 1 160  |
| 7    | 13 244 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 1 290  |
| 8    | 15 834 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 1 470  |
| 9    | 17 514 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 1 620  |
| 10   | 19 194 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 1 760  |
| 11   | 20 874 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 1 910  |
| 12   | 22 554 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 2 050  |
| 13   | 24 234 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 2 160  |
| 14   | 25 914 | 4 480 | 1 800 | 10 925 | 5 380 | 12 950 | 2 594 | 723 | 676 | 2 300  |

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

13- and 14-cylinder engines are only available in RT-flex versions, and not RTA versions.

All the above data apply to both RTA96C and RT-flex96C versions. However, there may be differences in weights for the RT-flex96C.

Wärtsilä RT-flex engines are also available with part-load optimisation for lower fuel consumptions.



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.

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