SULZER **RT-flex60C**

Technology review

WÄRTSILÄ

SULZER **RT-flex60C**

Technology review

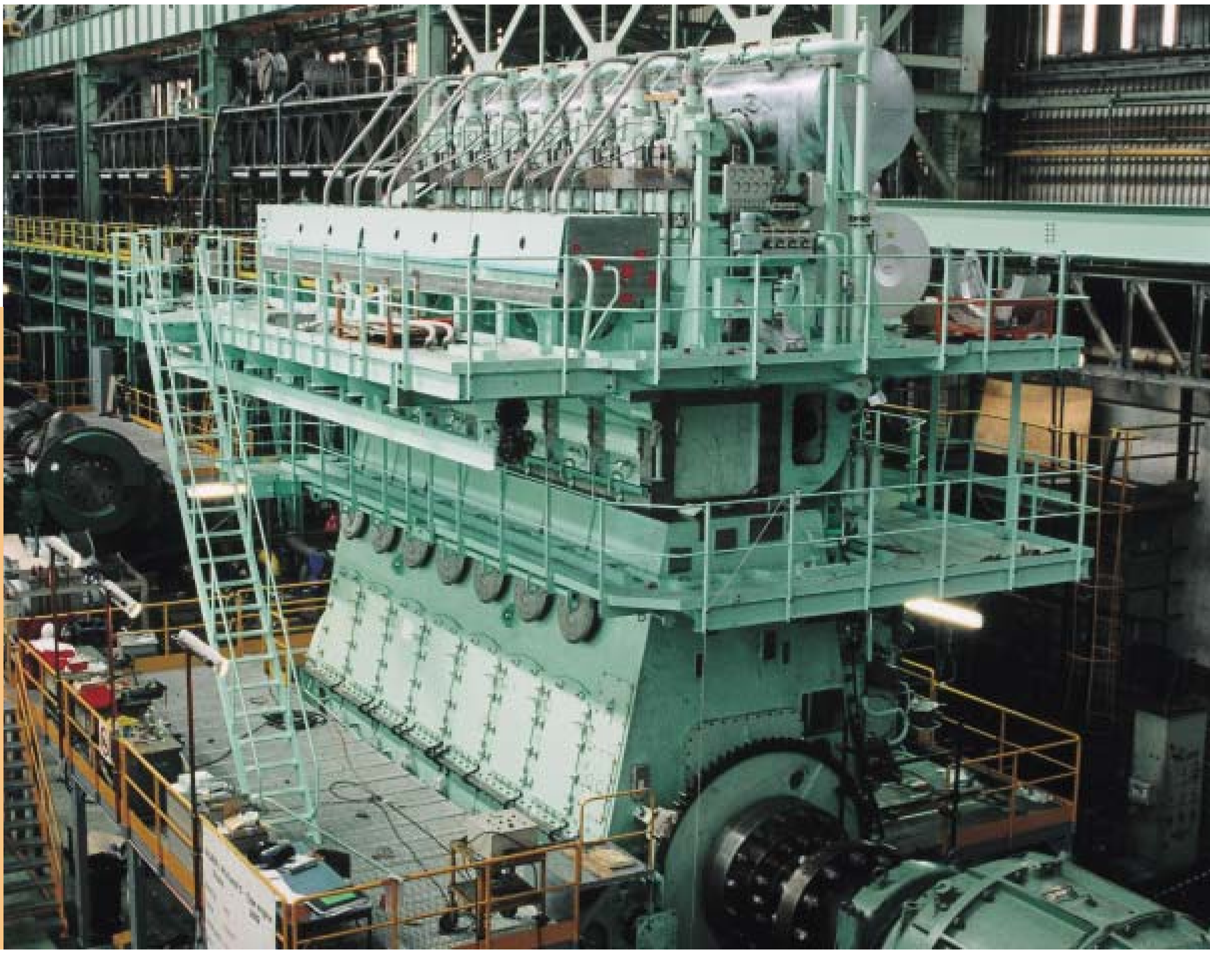
This is a brief guide to the technical features and benefits of the SULZER® RT-flex60C low-speed marine diesel engines.

Introduction

The Sulzer RT-flex60C low-speed marine diesel engines are tailor-made for the economic propulsion of container feeder vessels to serve the growing fleets of the major container lines. They are equally suitable for other vessel types such as reefers and car carriers with similar requirements.

In these roles, they offer clear and substantial benefits:

- Competitive first cost
- Lowest possible fuel consumption over the whole operating range
- Three years' time between overhauls
- Low maintenance costs owing to reliable and proven design
- Extremely good 'slow steaming' capability through the Sulzer RT-flex technology which offers a high degree of operational flexibility
- Full compliance with the NO_X emission regulation of Annexe VI of the MARPOL 1973/78 convention
- Smokeless operation even at lowest loads and speeds owing to the Sulzer RT-flex technology



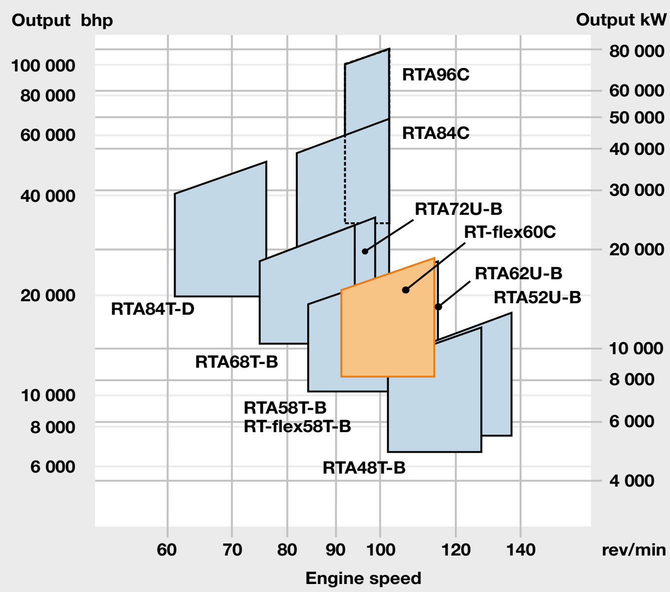
Sulzer 7RT-flex60C, of 16,520 kW at 114 rpm.

Development of the Sulzer RT-flex60C engine type was initiated in 1999. It was seen that the changing container ship newbuilding market was changing, not just at the upper end with the container liners but also in the middle range employed as feeder vessels. With container liner newbuildings becoming larger, with capacities of 5500TEU or more becoming common, and very many such vessels being contracted, it was clear that more container feeder vessels would be needed, of possibly up to 3000TEU capacity.

Such feeders need to be fast and efficient, calling for compact prime movers in the power range of around 12,000 to 19,000 kW, which became the power range for the RT-flex60C engine type.

Development of the Sulzer RT-flex system of electronically-controlled common-rail fuel injection and exhaust valve actuation was timely and has enabled the introduction of marine diesel engines with clear user benefits.

Principal parameters of Sulzer RT-flex60C engines		
Bore	mm	600
Stroke	mm	2250
Output, R1	kW/cyl bhp/cyl	2360 3210
Speed range, R1-R3	rpm	114–91
BMEP at R1	bar	19.5
Pmax	bar	155
Mean piston speed at R1	m/s	8.55
Number of cylinders		5–8
BSFC:		
at full load, R1	g/kWh g/bhph	170 125
at 85% load, R1	g/kWh g/bhph	167 123



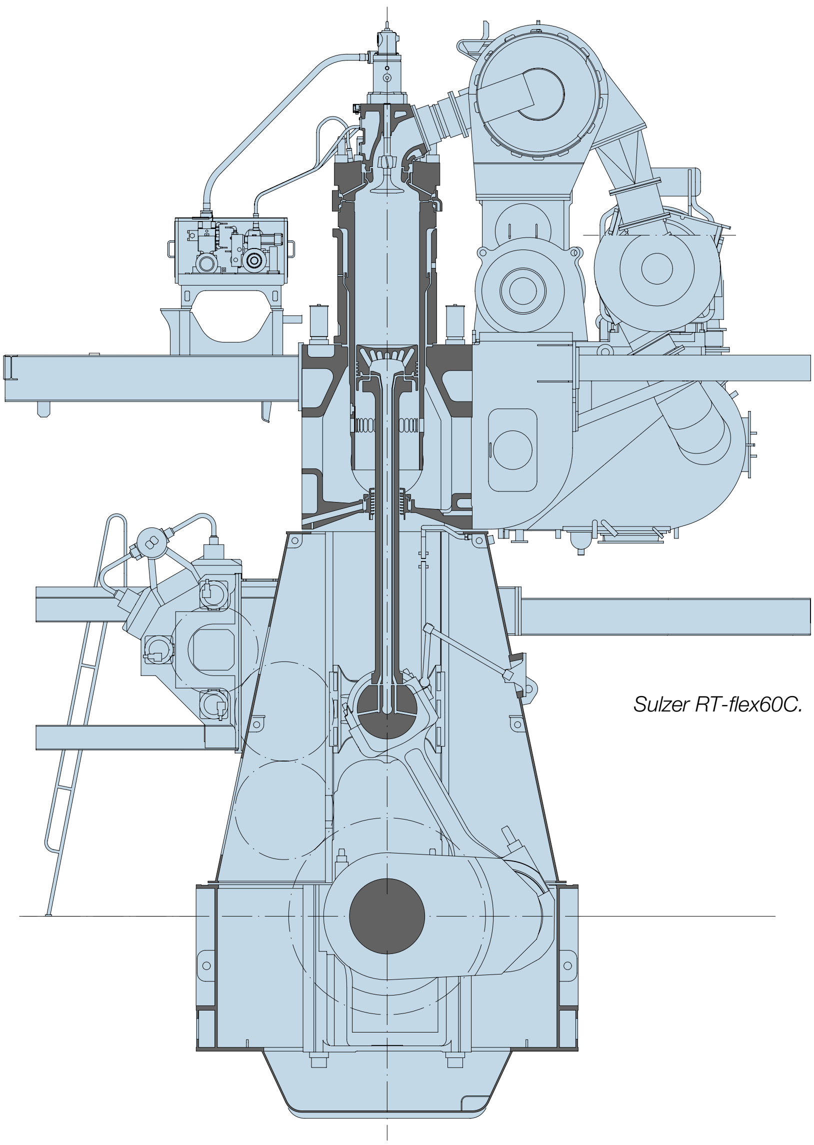
Development background

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 Sulzer RT-flex60C engine type is a good example of this policy.

The RT-flex60C incorporates many of the design features developed for the whole series of RTA-T as well as for the RTA96C engines. Particular care was taken to bring into account all recent service experience to obtain further improvement in the reliability of the new engine type. Troublefree operation is the primary goal.

It is more cost-effective to achieve these design objectives with a completely new engine design rather than further adapting existing engine designs. The opportunity was taken with a completely new design also to optimise its powers and speeds to suit the envisaged ship applications.

The RT-flex60C is the first Sulzer low-speed engine to incorporate the RT-flex system with electronically-controlled common-rail technology as



Sulzer RT-flex60C.

standard from the outset. It is not planned to offer the engine in a conventional camshaft version. The decision to follow this path was taken after the very positive reception by shipowners of the Sulzer RT-flex system after it was first applied to a full-scale research engine in June 1998. The RT-flex system offers distinctive operational benefits which are not possible with camshaft engines.

The first RT-flex engine went into shipboard service in September 2001, sufficiently before the first RT-flex60C was built in 2002 to incorporate the service experience.

The RT-flex60C engine also incorporates TriboPack technology from the outset. TriboPack design measures, today a well accepted standard, provide important improvements in piston-running behaviour, for more reliability, longer times between overhauls and lower cylinder oil feed rates.

Sulzer RT-flex: Concept and benefits

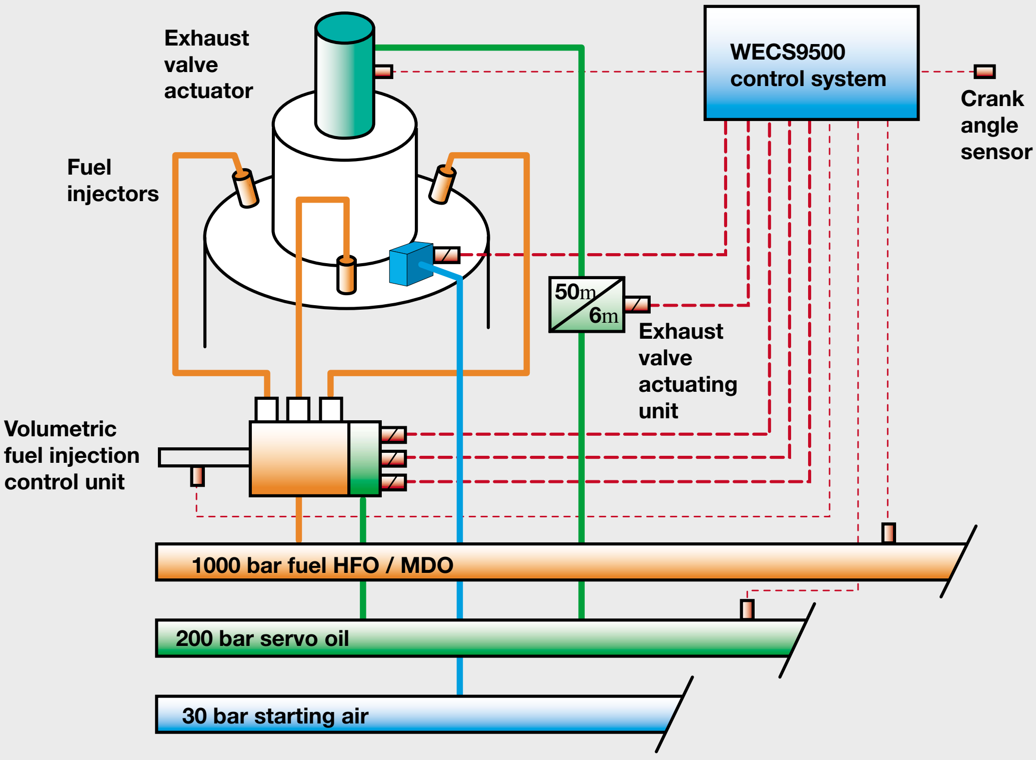
The Sulzer RT-flex system is the result of a long project since the 1980s to develop Sulzer low-speed marine engines without the constraints imposed by mechanical drive of fuel injection pumps and valve actuation pumps but with far greater flexibility in engine setting to reach future requirements. The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

The resulting Sulzer RT-flex60C is basically a standard Sulzer 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 and exhaust valve actuation, 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 Sulzer RTA-series engines.

The Sulzer RT-flex engine offers a number of interesting benefits to shipowners and operators:

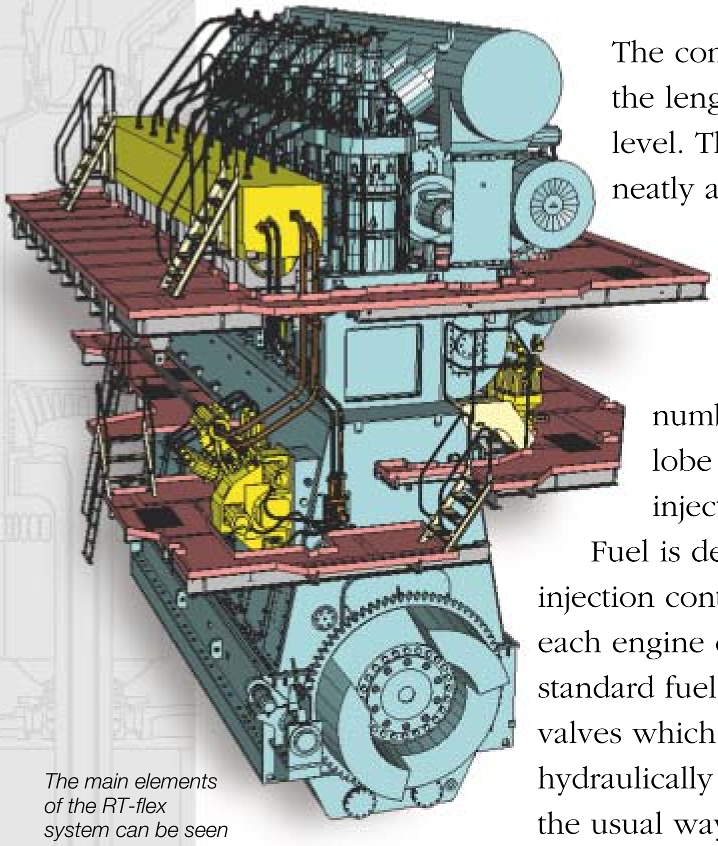
- Smokeless operation at all operating speeds
- Lower steady running speeds, in the range of 10-12 per cent nominal speed, obtained smokelessly through sequential shut-off of injectors while continuing to run on all cylinders



Schematic of the Sulzer RT-flex system with electronically-controlled common-rail systems.

- 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, and use of fuel supply pumps based on well-proven Sulzer four-stroke fuel injection pumps
- Higher availability owing to the integrated monitoring functions
- High availability also given by the built-in redundancy, as full power can be developed with one fuel pump and one servo oil pump out of action. High-pressure fuel and servo-oil delivery pipes, and the electronic systems are also duplicated for redundancy.

Sulzer RT-flex system applied

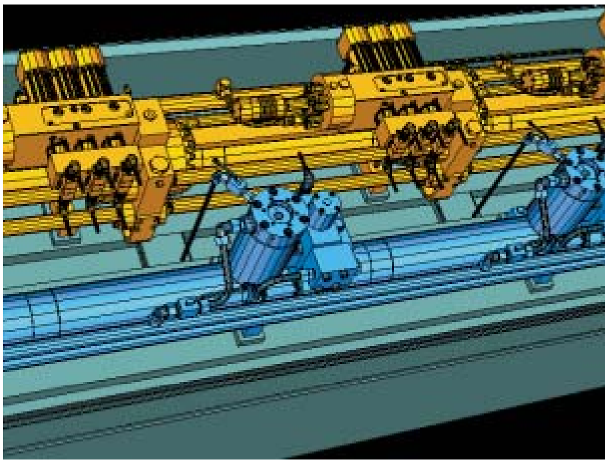


The main elements of the RT-flex system can be seen in yellow: the supply unit with fuel and servo oil pumps, the rail unit alongside the cylinders, and the servo oil filter on the other side.

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 pipework are neatly arranged on 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. The pump design is based on the proven injection pumps used in Sulzer four-stroke engines.

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 Sulzer 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.

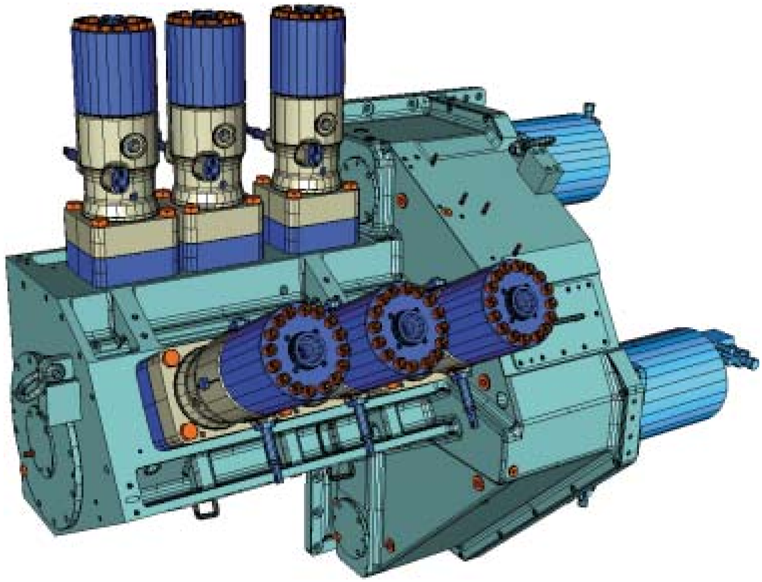


CAD drawing of the rail unit open to show the common-rail systems for fuel (brown) and servo oil (yellow).

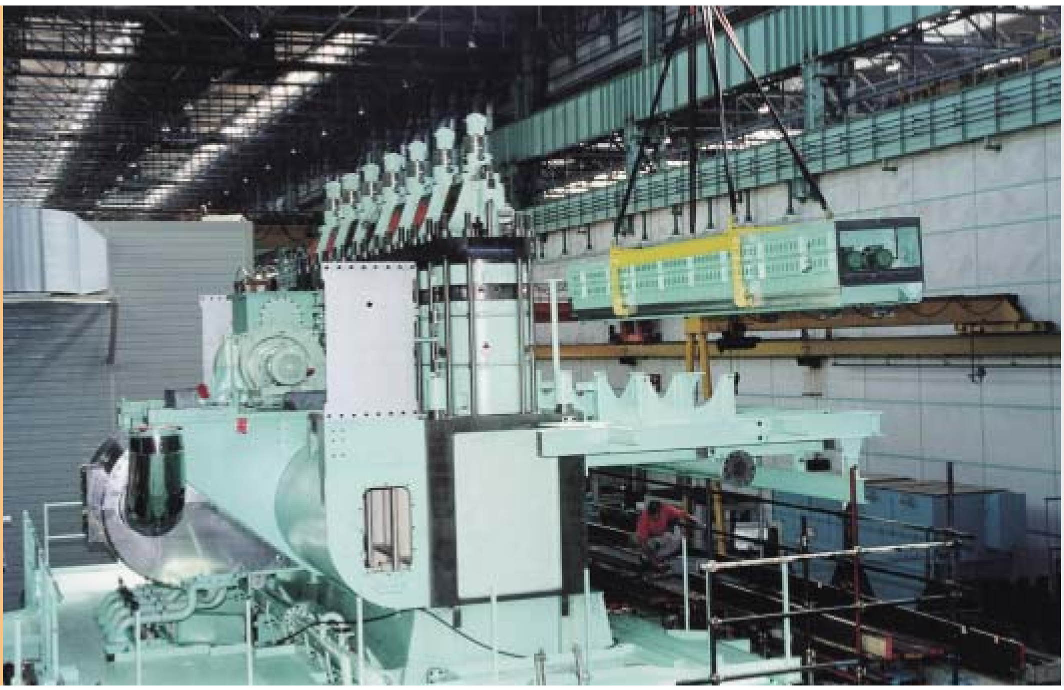
The key features of the Sulzer common-rail system are:

- 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 Sulzer 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 hydraulic pumps incorporated in the supply unit with the fuel supply pumps. The electronically-controlled actuating unit for each cylinder gives full flexibility for valve opening and closing timing.


Supply unit with fuel pumps on left and servo oil pumps on right.

All functions in the RT-flex system are controlled and monitored through the integrated Wärtsilä WECS-9500 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.


Installing the rail unit.

Real in-service fuel economy

Although Sulzer RTA-series engines have excellent fuel consumption in general, the Sulzer RT-flex system enables further improvements in the part-load range. The full-load efficiency of the RT-flex60C remains the same as equivalent conventional RTA engines.

The RT-flex system offers advantages because of the freedom allowed 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 closing as the load/speed is reduced. This is not only advantageous for fuel consumption but also limits component temperatures, which 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-flex60C engines is the capability to adapt easily the injection timing to various fuel properties having a poor combustion behaviour. Variable injection timing (VIT) over load has been a traditional feature of Sulzer low-speed engines for many years, using a mechanical arrangement primarily to keep the cylinder pressure high for the upper load range. This is much easier to arrange in an electronically-controlled engine. Yet the settings for compliance with the NO_X limit have to be maintained.

An important contribution to the overall fuel consumption can come from exhaust heat recovery. The RT-flex60C offers a clear advantage in this respect with an exhaust gas temperature of 285 °C for an unsurpassed high potential for waste heat recovery. High exhaust temperatures are traditional for Sulzer low-speed engines. They are obtained by efficient scavenging processes.

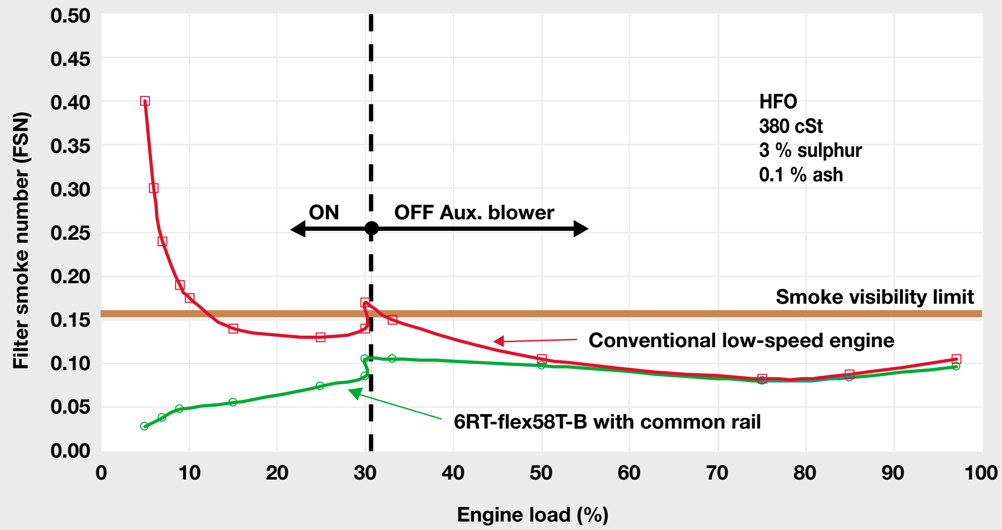
The Gypsum Centennial is powered by a Sulzer 6RT-flex58T-B engine and was delivered in September 2001.

Cleaner in the environment

With the current popular concern about the environment, exhaust gas emissions have become an important aspect of marine diesel engines. All Sulzer RTA engines comply with the NO_X emissions limit of Annex VI of the MARPOL 73/78 convention as standard.

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. This is achieved by the superior combustion gained with the common-rail system. It enables the fuel injection pressure to be maintained at the optimum level irrespective of engine speed. In addition, at very low speeds, individual injectors are selectively shut off and the exhaust valve timing adapted to help to keep smoke emissions below the visible limit. In contrast, engines with the traditional jerk-type injection pumps have increasing smoke emissions as engine speed is reduced because the fuel injection pressure and volume decrease with speed and power, and they have no means of cutting off individual injection valves and changing exhaust valve timing.



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

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.

For example, one possibility for future development would be to offer different modes for different emissions regimes. In one mode, the engine could be optimised for minimum fuel consumption while complying with the global NO_X limit. Then to satisfy local emissions regulation the engine could be switched to an alternative mode for even lower NO_X emissions while the fuel consumption may be allowed to increase.

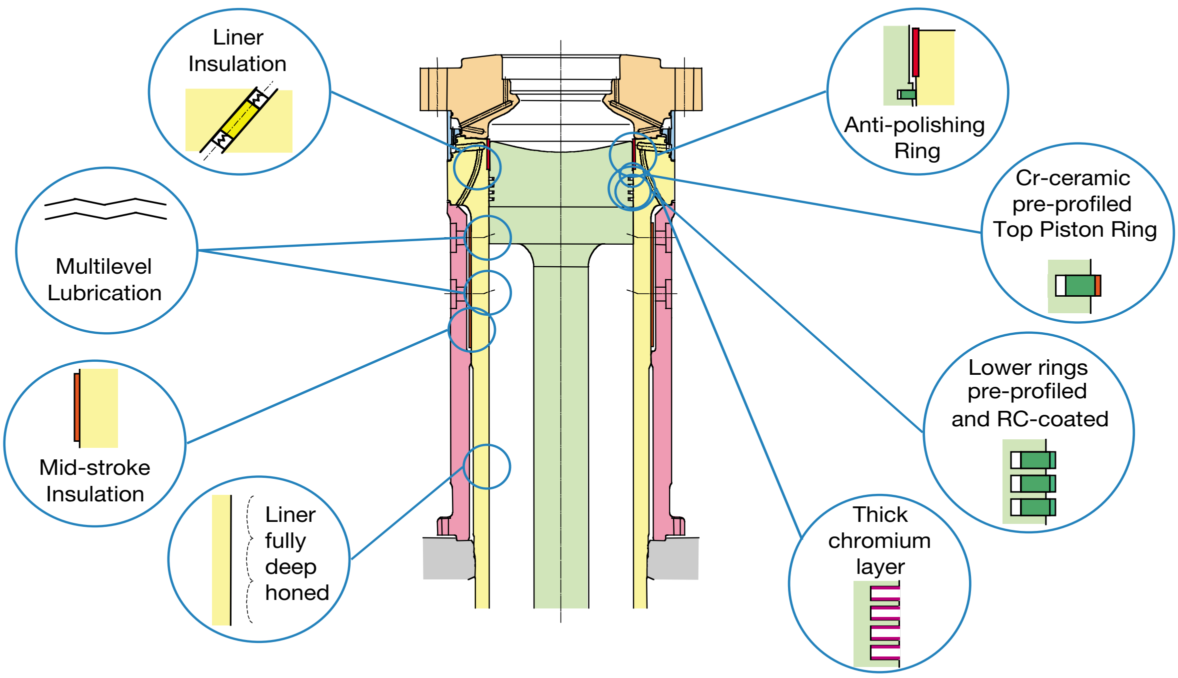
As well as investigating the scope of possibilities of the RT-flex system, Wärtsilä is carrying out a long-term research programme to develop techniques for further reducing exhaust emissions, including NO_X, SO_X and CO_2.

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, today's Sulzer RTA-series engines incorporate TriboPack technology - a combination of design measures that enable the TBO of the cylinder components, including piston ring renewal to be extended to at least three years. At the same time, TriboPack offers more safety for piston running under adverse conditions and thus allows standard cylinder lubricating oil feed rates to be as low as 1.0 g/kWh and even less.

The design measures incorporated in TriboPack are:

- Multi-level cylinder lubrication
- Liner of the appropriate material, with sufficient hard phase
- Careful turning of the liner running surface and deep-honing of the liner over the full length of the running surface
- Insulating tubes in the cooling bores in the upper part of the liner
- Mid-stroke liner insulation
- Pre-profiled piston rings in all piston grooves.
- Chromium-ceramic coating on top piston ring
- 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.



Sulzer TriboPack is a package of design measures giving much improved piston-running behaviour, lower wear rates, three years' time between overhauls, and lower cylinder lubricant feed rates.

Most of the design measures in TriboPack have been employed in Sulzer RTA engines for several years. They are now combined systematically as a standard package. Although each individual measure of TriboPack improves piston-running behaviour, only the application of the complete package delivers the full benefits to the shipowners.

A key element of TriboPack is the deep-honed liner. Careful machining and deep honing gives the liner an ideal running surface for the piston rings, together with an optimum surface microstructure. The RT-flex60C has four piston rings, all 16 mm thick and of the same geometry.

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

Whilst trying to avoid corrosive wear by appropriate optimising of liner wall temperatures, it is necessary to keep as many water droplets as possible out of engine cylinders. Thus, a newly developed, highly-efficient vane-type water separator after the scavenge air cooler and the effective water drainage arrangements are absolutely essential for good piston running.

Load-dependent cylinder lubrication is provided by the well-proven Sulzer multi-level accumulator system. The lubricating pumps are driven by frequency-controlled electric motors. On the cylinder liner, oil distributors bring the oil to the different oil accumulators. For ease of access, the quills are positioned in dry spaces instead of in the way of cooling water spaces.

Deep-honed liners soon achieve a mirror surface.

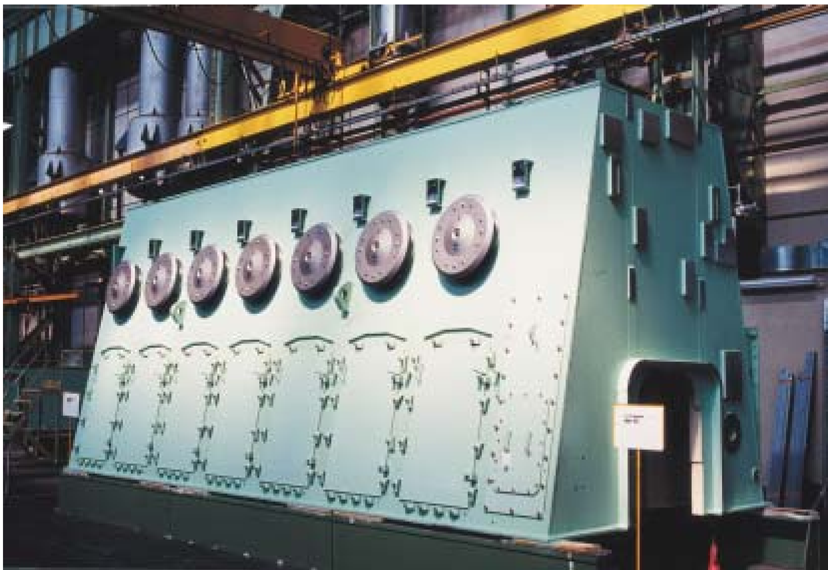
Piston of the RT-flex60C.

Engine structure

The structure of the RT-flex60C engine is similar in concept to those of previous Sulzer RTA-series engines with the well-proven, sturdy 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 that are also designed for minimum machining.

Bedplate stiffness is one of many prerequisites for a sound bearing performance. A stiff bedplate can, to some extent, limit the adverse influence of excessive flexibility in some modern ship designs.

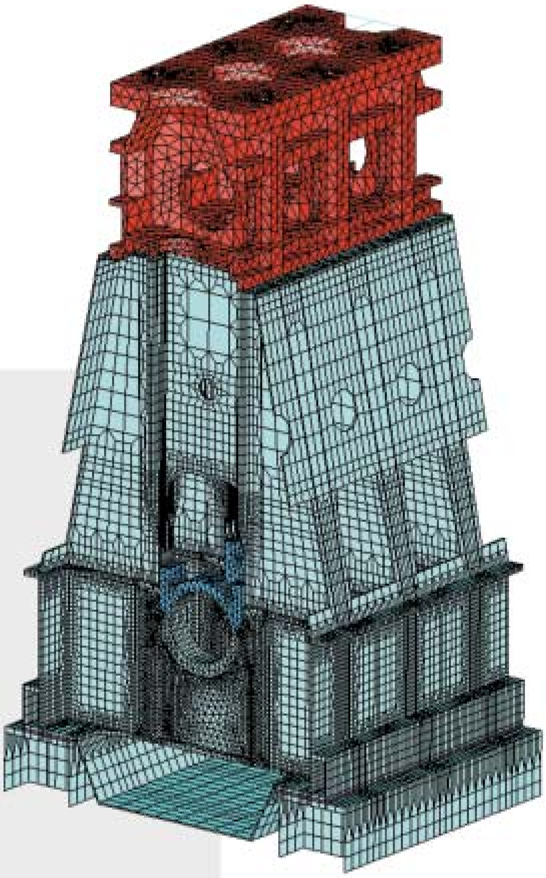
A high overall structural rigidity is of major importance. Accordingly the design is based on extensive stress and deformation calculations carried out by using a full three-dimensional multi-cylinder finite-element computer model for different column designs to verify the optimum frame configuration.



Column of 7RT-flex60C engine.

Cylinder block of 7RT-flex60C engine.

The cylinder jacket is a single-piece iron casting. The height of the cylinder jacket is determined by the space required for the scavenge air receiver. Access to the piston under-side is possible from the receiver side of the engine, to allow for maintenance of the piston rod gland and also for inspecting piston rings. On the fuel side, one door per cylinder can be opened for inspection and to support in-engine work from outside



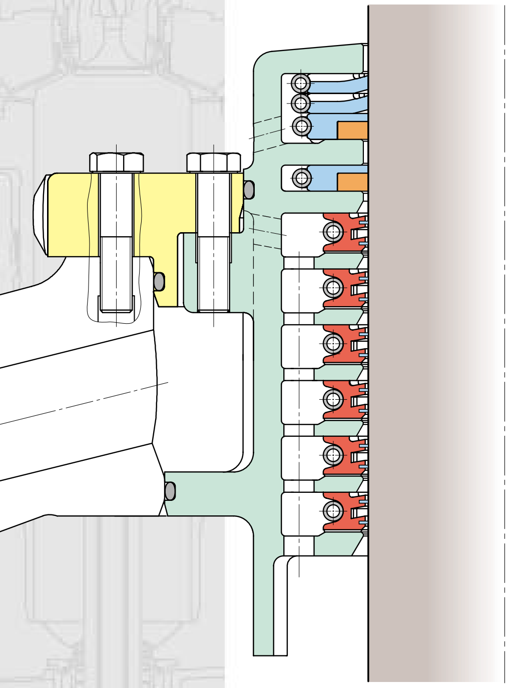
The tilting-pad thrust bearing is integrated in the bedplate. The pads are arranged to ensure a safe, uniform load distribution. The thrust-bearing girder consists of only two steel cast pieces, omitting welding seams in critical corners. The girder is clearly stiffer than in previous designs.

Finite-element model of the RT-flex60C structure for computer analysis.

Bedplate of 7RT-flex60C engine.

Bedplate of the 7RT-flex60C with main bearing caps in place.

Running gear



Section of the piston rod gland of the RT-flex60C.

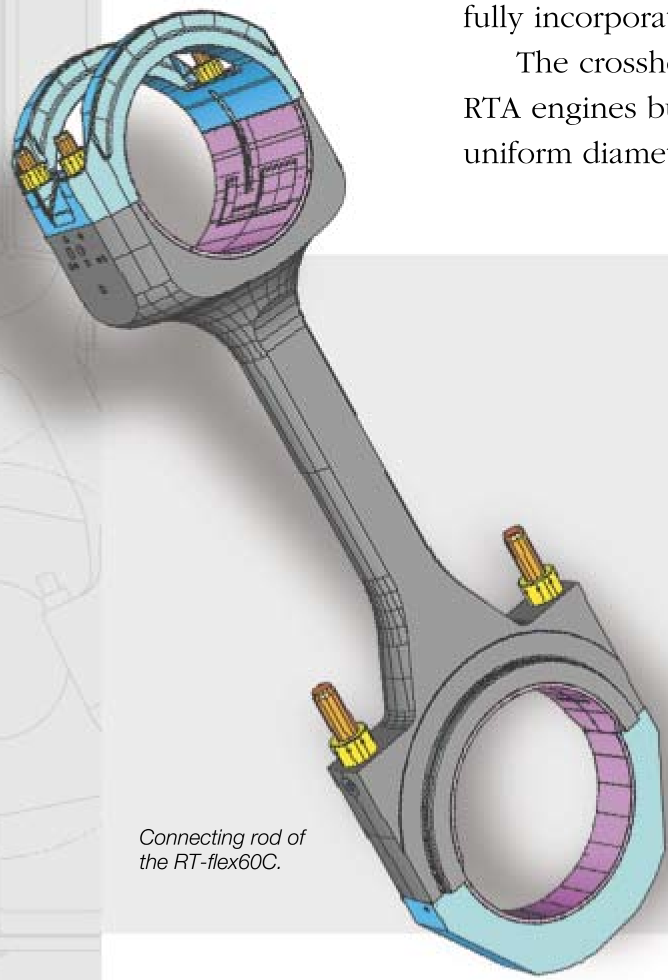
The running gear comprises the crankshaft, connecting rods and piston rods together with their associated bearings and piston rod glands.

The semi-built crankshaft of the RT-flex60C engine was carefully optimised by three-dimensional finite-element analysis. Special care was taken for the fillet areas and the shrink fits to cope with the compact cylinder distances.

The main bearings are of white metal on thin steel shells. To achieve greater precision in the geometry of the mounted bearing shells and thereby improved running safety, the main bearing bores are co-machined with the bearing caps mounted and tightened.

A much improved understanding of the real behaviour of main bearings and their loads was obtained by combining the latest finite-element analysis and elasto-hydrodynamic calculation techniques considering the whole engine structure including shaft vibrations. This remarkable gain in knowledge, which could be verified with service results, was fully incorporated in the RT-flex60C engine.

The crosshead has a full-width lower bearing as in other RTA engines but is simplified in design. The pin is of a uniform diameter and the two guide shoes are made in



Connecting rod of the RT-flex60C.

Thrust bearing of 7RT-flex60C engine with the supply unit drive gear on the thrust collar. The flywheel is to the right.

single steel castings with white metal-plated running surfaces. Special care was taken to give the guide shoe ample flexibility to adapt well to the natural deformation of the guide rails under load. The crosshead bearing design features a full-width shell for the lower half bearing. Sulzer 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 bearing at every revolution. This ensures that sufficient oil film thickness is maintained under all circumstances. 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 RT-flex60C uses a new gland design which is already employed in the RTA68T-B and in some RTA84C engines. It combines the well proven and highly effective dirt scraping top part with an effective system oil scraping ring design in the lower part. The oil scraping is provided by six spring-loaded grey cast-iron segments which run on a hardened piston rod. Oil can flow back to the crankcase through many large vertical holes. The result is that there is practically no flow from the neutral space. Instead there is a complete internal re-circulation of the scraped-off oil into the crankcase and the system oil consumption is expected to stabilise.

Crankshaft of 7RT-flex60C engine.

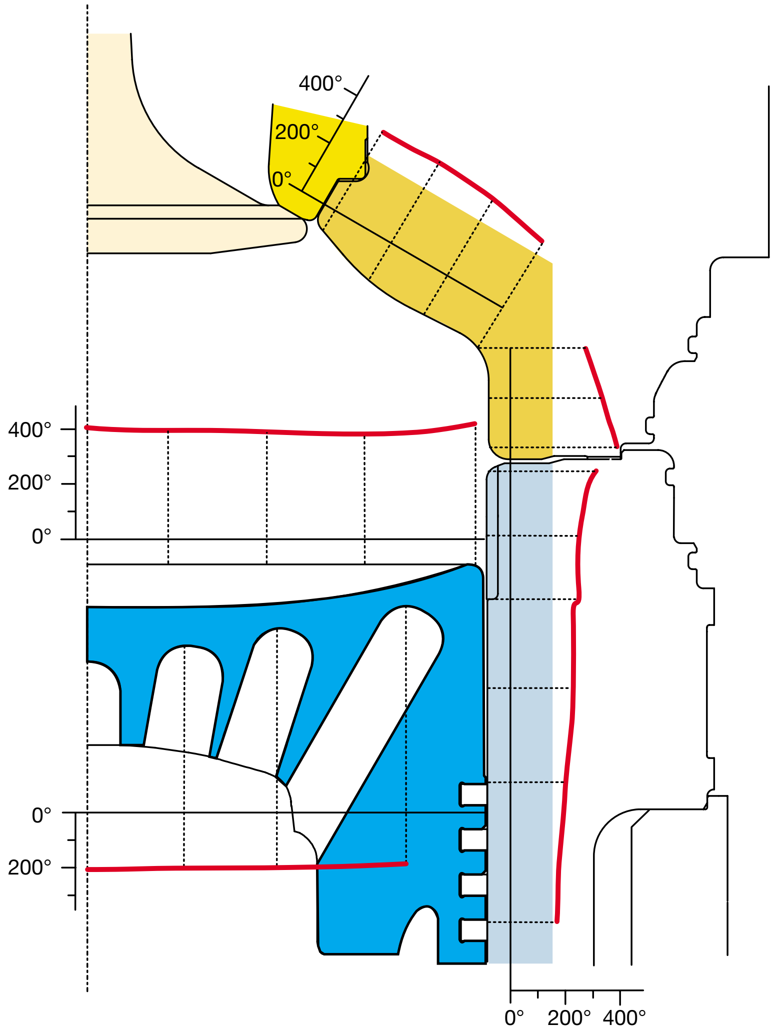
Piston and piston rod equipped with gland box.

Combustion chamber

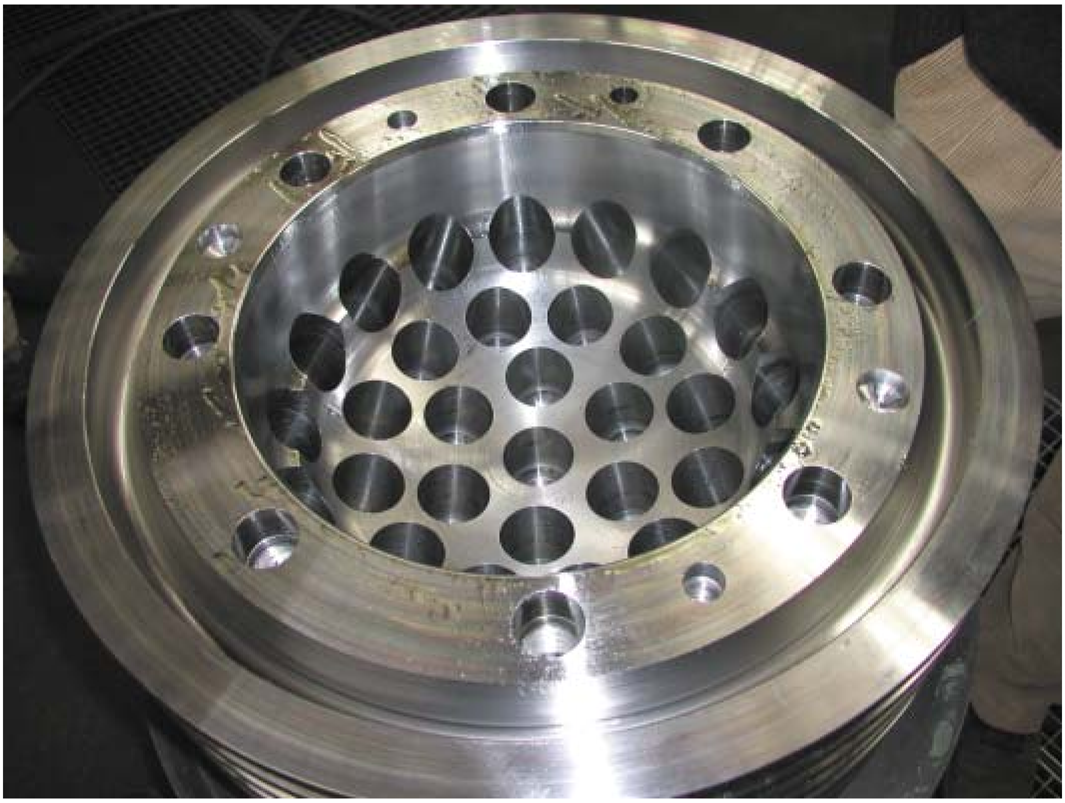
The combustion chamber is a key issue for an engine's reliability. Careful attention is needed for the piston cooling, as well as for the layout of the fuel injection spray pattern to achieve moderate surface temperatures and to avoid carbon deposits. Low combustion chamber temperatures are not only responsible for long times between overhauls but also desirable to have a higher degree of freedom to reach low NO_X emissions.

At Wärtsilä, the optimisation of the fuel injection is simulated with modern calculation tools, such as CFD (computerised fluid dynamics) analysis and then is confirmed on the engine.

The well-proven bore-cooling is also adopted in all combustion chamber components, together with shaker cooling in the piston, to achieve high heat transfer coefficients over a long time and thus to control temperatures and thermal strains as well as mechanical stresses of the components.



Surface temperatures of the combustion chamber components calculated for full-load conditions.



Cooling bores on the underside of the piston crown.

The bore-cooled steel cylinder cover is secured by eight elastic studs arranged in four pairs. It is equipped with a single, central exhaust valve in Nimonic 80A which is housed in a bolted-on valve cage. There are three fuel injection valves symmetrically distributed in each cylinder cover. This arrangement of injection valves helps to equalise the temperature distribution on the piston crown over the circumference around the liner and 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 piston comprises a forged steel crown with a very short skirt. The compact piston contains four rings of the same height, as part of the TriboPack.

The cylinder liner is bore cooled which has been proven to meet necessary high demands on temperature distribution. Although insulation tubes are criticised as being complicated, they do allow an invaluable adjustment of the temperature distribution in the liner. Yet only local insulation with physically correct heat conduction parameters, together with a proper geometry can lead to the desired temperatures and, at the same time, limit thermal stress.

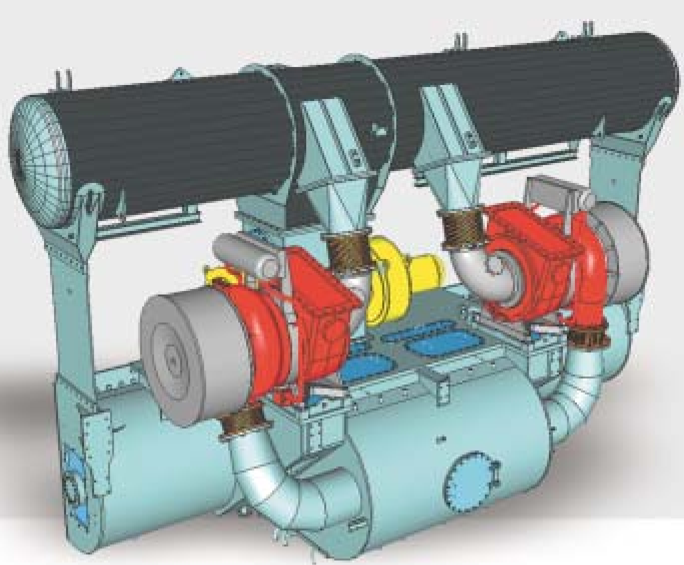
Turbocharging and scavenge air system

The RT-flex60C is 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 number 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 a simplified and modular design with integral non-return flaps, hanging cooler bundles and two auxiliary blowers. The cooler is dismantled vertically. The cooler bundles are made of high-efficient tubes and fins for compact dimensions, circulated with fresh water.

The turbochargers are mounted on very stiff brackets. The receiver carries the fixed foot for the exhaust manifold. The fixed foot contains the two auxiliary blowers including the whole channelling and auxiliary flaps needed for low-load operation.

Special attention is given to removing all water condensate before the air enters the cylinder as this is vital for satisfactory piston running. Immediately after the cooler, the scavenge air passes a newly developed water separator of high efficiency. There are ample drainage provisions to remove completely the condensed water collected at the bottom of the air cooler and separator. To avoid blow-back through the drains from the higher pressure areas, all the drains are collected at the bottom of a vertically mounted pot which is filled with water and kept under scavenge air pressure. Drain water then leaves from the top of the pot with an orifice controlling the discharge. This arrangement has no moving parts.



Complete scavenging system for a seven-cylinder RT-flex60C engine, comprising exhaust manifold at top, two turbochargers, auxiliary blowers, scavenge air cooler and scavenge air manifold.

Installation aspects

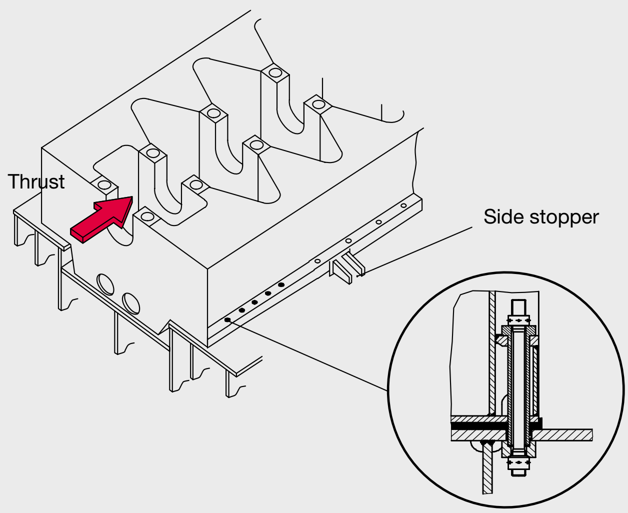
Sulzer RTA-series engines have specific design features that help to facilitate their installation on board ship.

The RTA engines have simple seating arrangements with a modest number of holding down bolts and side stoppers. No end stoppers, thrust brackets or fitted bolts are needed as thrust transmission is provided by 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 engine's electrical power requirement for the ancillary services, including auxiliary blowers, cooling water, lubricating oil, fuel supply, etc., is kept down to a minimum.

Sulzer RTA engines have a valuable waste heat recovery potential to generate steam for heating services and for a turbogenerator. The exhaust gas temperature of an RT-flex60C is some 25°C higher than competitors' engines, which almost doubles the possible steam production. A two-stage scavenge air cooler is also possible for waste heat recovery purposes.

The RT-flex60C has a standard all-electric interface for engine management systems - known as DENIS (Diesel Engine Interface Specification) - to meet all needs for control, monitoring, safety and alarm warning functions. An electronically-equipped local control stand for manual engine operation is standard.



Arrangements for transmitting propeller thrust to the engine seatings for RT-flex60C engines. The inset shows the thrust sleeve for the thrust bolts.

Maintenance

Primary objectives in the design and development of Sulzer RTA 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-flex60C, 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 Sulzer 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 Sulzer 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.

Main technical data

Cylinder bore	600 mm
Piston stroke	2 250 mm
Speed	91 - 114 rpm
Mean effective pressure at R1	19.5 bar
Piston speed	8.5 m/s
Fuel specification: Fuel oil	730 cSt/50°C 7 200 sR1/100°F ISO 8217, category ISO-F-RMK 55

Rated power: Propulsion Engines

Cyl.	Output in kW/bhp at							
	114 rpm				91 rpm			
	R1		R2		R3		R4	
	kW	bhp	kW	bhp	kW	bhp	kW	bhp
5	11 800	16 050	8 250	11 200	9 400	12 800	8 250	11 200
6	14 160	19 260	9 900	13 440	11 280	15 360	9 900	13 440
7	16 520	22 470	11 550	15 680	13 160	17 920	11 550	15 680
8	18 880	25 680	13 200	17 920	15 040	20 480	13 200	17 920

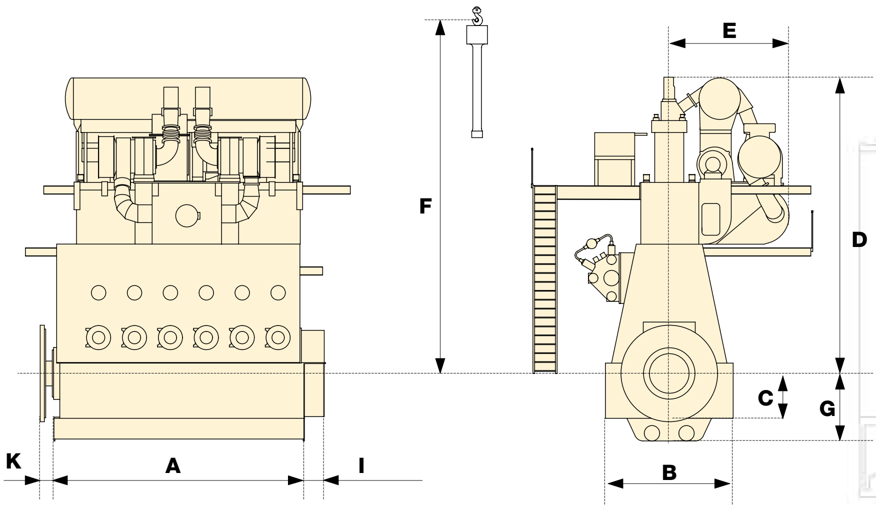
Brake specific fuel consumption (BSFC)

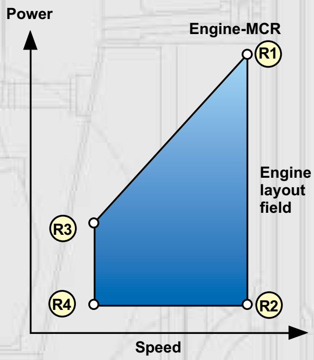
	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph
Load 85 %	167	123	164	120	167	123	165	121
Load 100 %	170	125	164	120	170	125	166	122
BMEP, bar	19.5		13.7		19.5		17.0	

Principal engine dimensions (mm) and weights (tonnes)

Cyl.	A	B	C	D	E	F*	G	I	K	Weight
5	6 213	3 700	1 300	8 520	3 960	10 400	1 955	400-650	405	290
6	7 253	3 700	1 300	8 520	3 960	10 400	1 955	400-650	405	330
7	8 293	3 700	1 300	8 520	3 960	10 400	1 955	400-650	405	375
8	9 333	3 700	1 300	8 520	3 960	10 400	1 955	400-650	405	415

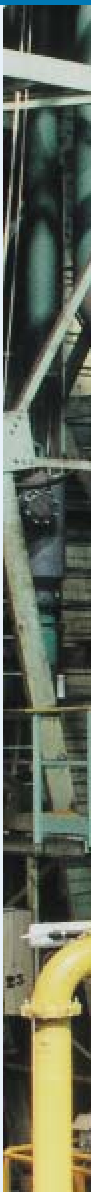
* Standard piston dismantling height, can be reduced with tilted piston withdrawal.





Definitions:

- R1, R2, R3, R4 = power/speed ratings at the four corners of the RTA 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 RTA layout field.
- BSFC = brake specific fuel consumption. All figures are quoted for fuel of net calorific value 42.7 MJ/kg (10 200 kcal/kg) and ISO standard reference conditions (ISO 3046-1). The BSFC figures are given with a tolerance of 5%, without engine-driven pumps.
- The values of power in kilowatts and fuel consumption in g/kWh are the official figures and discrepancies occur between these and the corresponding bhp values owing to the rounding of numbers.
- ISO standard reference conditions
  Total barometric pressure . . . . 1.0 bar
  Suction air temperature . . . . 25 °C
  Scavenge air cooling-water temperature . . . 25 °C
  Relative humidity 60%



Wärtsilä Corporation is the leading global ship power supplier and a major provider of solutions for decentralized power generation and of supporting services.

In addition Wärtsilä operates a Nordic engineering steel company Imatra Steel and manages a substantial shareholding to support the development of its core business.

For more information visit www.wartsila.com

Wärtsilä Corporation
P.O.Box 196
FIN-00531 Helsinki

Tel: +358 10 709 0000
Fax: +358 10 709 5700

WÄRTSILÄ