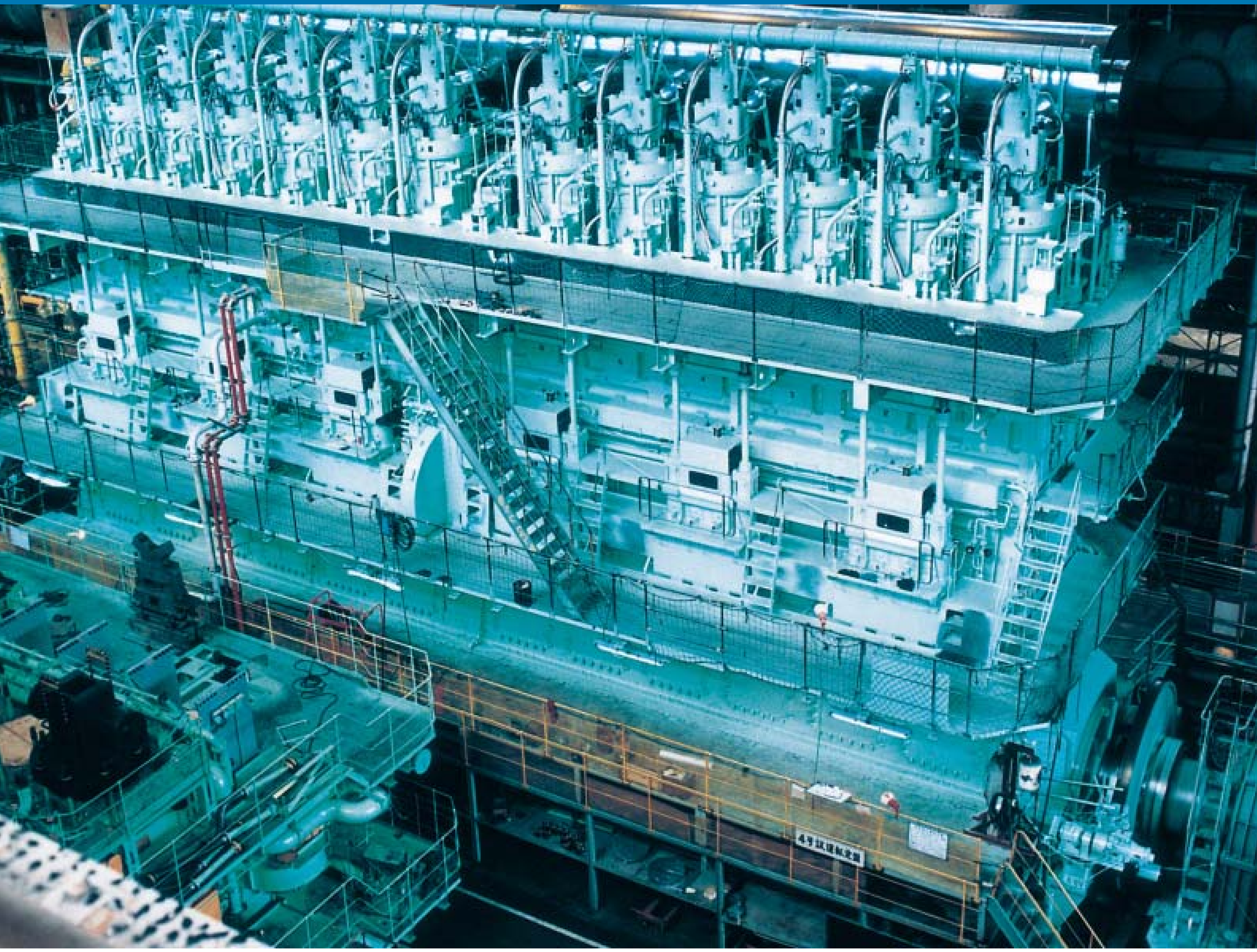
SULZER RTA-C

Technology review



WÄRTSILÄ

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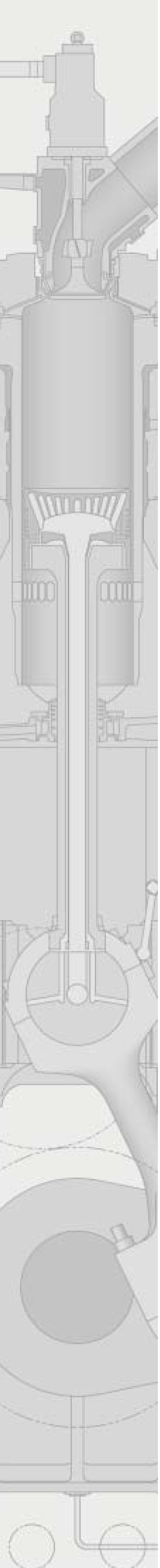
This is a brief guide to the technical features and benefits of the Sulzer RTA84C and RTA96C low-speed marine diesel engines.



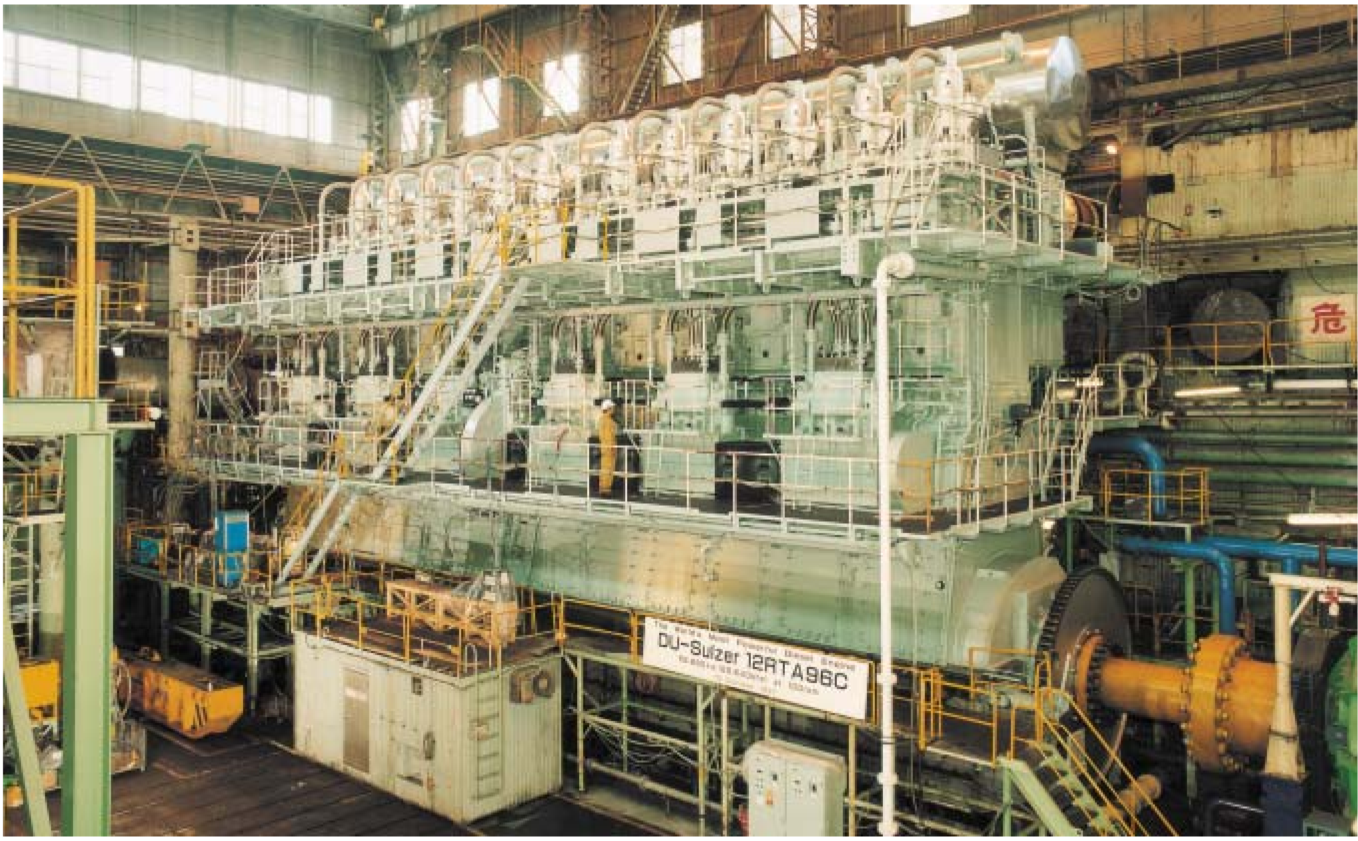
Introduction

Sulzer RTA84C and RTA96C low-speed marine diesel engines are tailor-made for the economic propulsion of large, fast container liners. In this role, they offer clear, substantial benefits:

- High power outputs at optimum shaft speeds
- Competitive first cost
- Economical fuel consumption over the whole operating range
- Three years' time between overhauls
- Low maintenance costs through reliability and durability
- Full compliance with the IMO NO_X emission regulation.

The Sulzer RTA84C two stroke diesel engine was introduced in September 1988 for propelling the then coming generation of larger and faster container ships. It was developed from the RTA84 which was popular for such vessels and with its higher output the RTA84C 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.

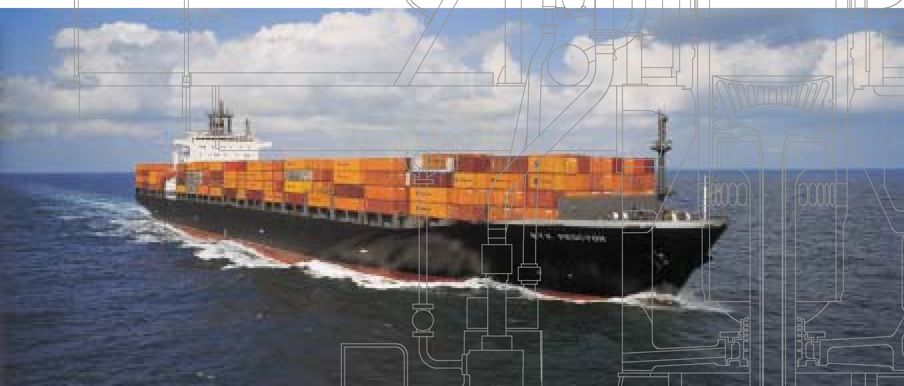
Yet the trend to ever larger container ships continued with a need for considerably more power. A jump in the engine bore size became inevitable, and the Sulzer



12-cylinder Sulzer RTA96C engine giving 68,640 kW (93,360 bhp)

RTA96C engine type was announced in December 1994. It also quickly became established and today powers many of the world's largest container liners.

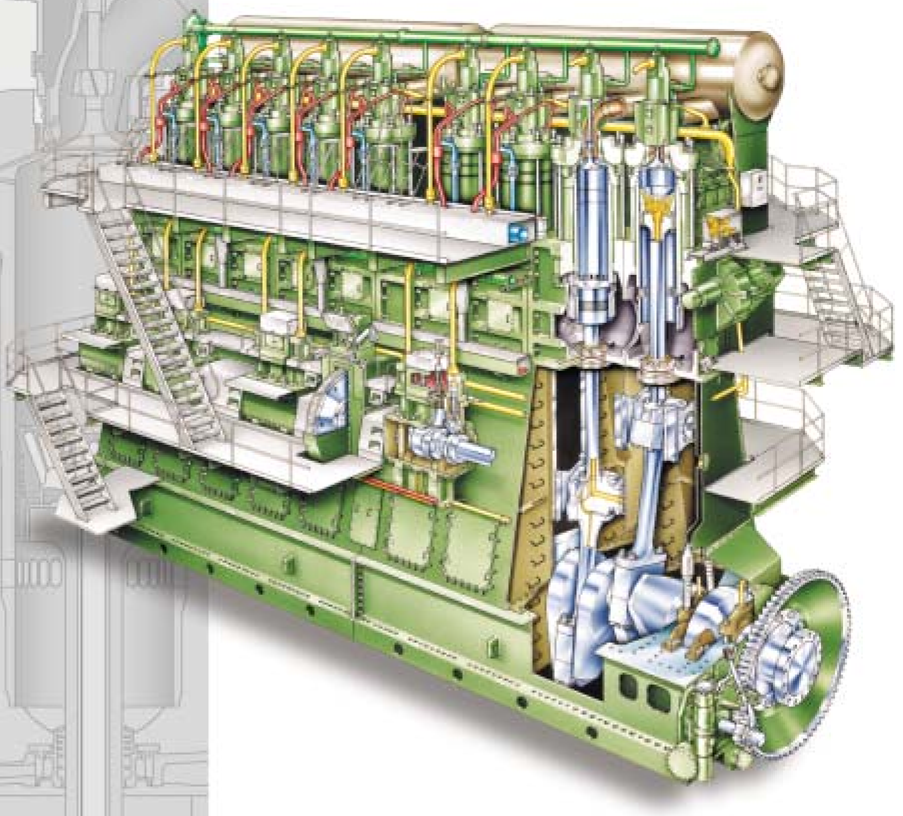
This large-bore engine extends the power spectrum of the RTA series up to 80,800 kW (108,920 bhp) in the 14-cylinder model. Together, the RTA84C and RTA96C two stroke engines provide a comprehensive engine programme for all sizes of large, fast containerships from around 3000 up to 10,000 TEU capacity at service speeds of around 25 knots.



Principal parameters

Type		RTA84C	RTA96C
Bore	mm	840	960
Stroke	mm	2400	2500
Output MCR, R1	kW/cyl bhp/cyl	4050 5510	5720 7780
Speed range, R1–R3	rpm	102–82	102–92
BMEP at R1	bar	17.9	18.6
Pmax	bar	140	145
Mean piston speed at R1	m/s	8.2	8.5
Number of cylinders		6–12	6–12, 14
BSFC:			
at full load, R1	g/kWh g/bhph	171 126	171 126
at 85% load, R1	g/kWh g/bhph	168 124	166 122

Development background



Wärtsilä has a policy of continuously updating its engine designs to adapt them to the latest market requirements and to incorporate the benefits of technical improvements. The Sulzer RTA-C engine types have followed this policy since the RTA84C was introduced in 1988.

In 1993, the power output of the RTA84C was increased by six per cent. At the same time, the cylinder cover was modified, and the number of fuel nozzles was increased from two to three. The thermal load of the combustion chamber could be reduced.

The design of the RTA96C introduced in 1994 is based fully on the RTA84C to take advantage of the wealth of experience in theoretical design, testbed research and operating service from the RTA84C and other previous RTA engines.

In 2000, the cylinder power of the RTA96C was raised by some four per cent. A 14-cylinder model was also added to bring the maximum power up to today's 80,080 kW (108,920 bhp).

Throughout, the increased power outputs were only made possible by the very satisfactory service experience with the large numbers of engines in service.

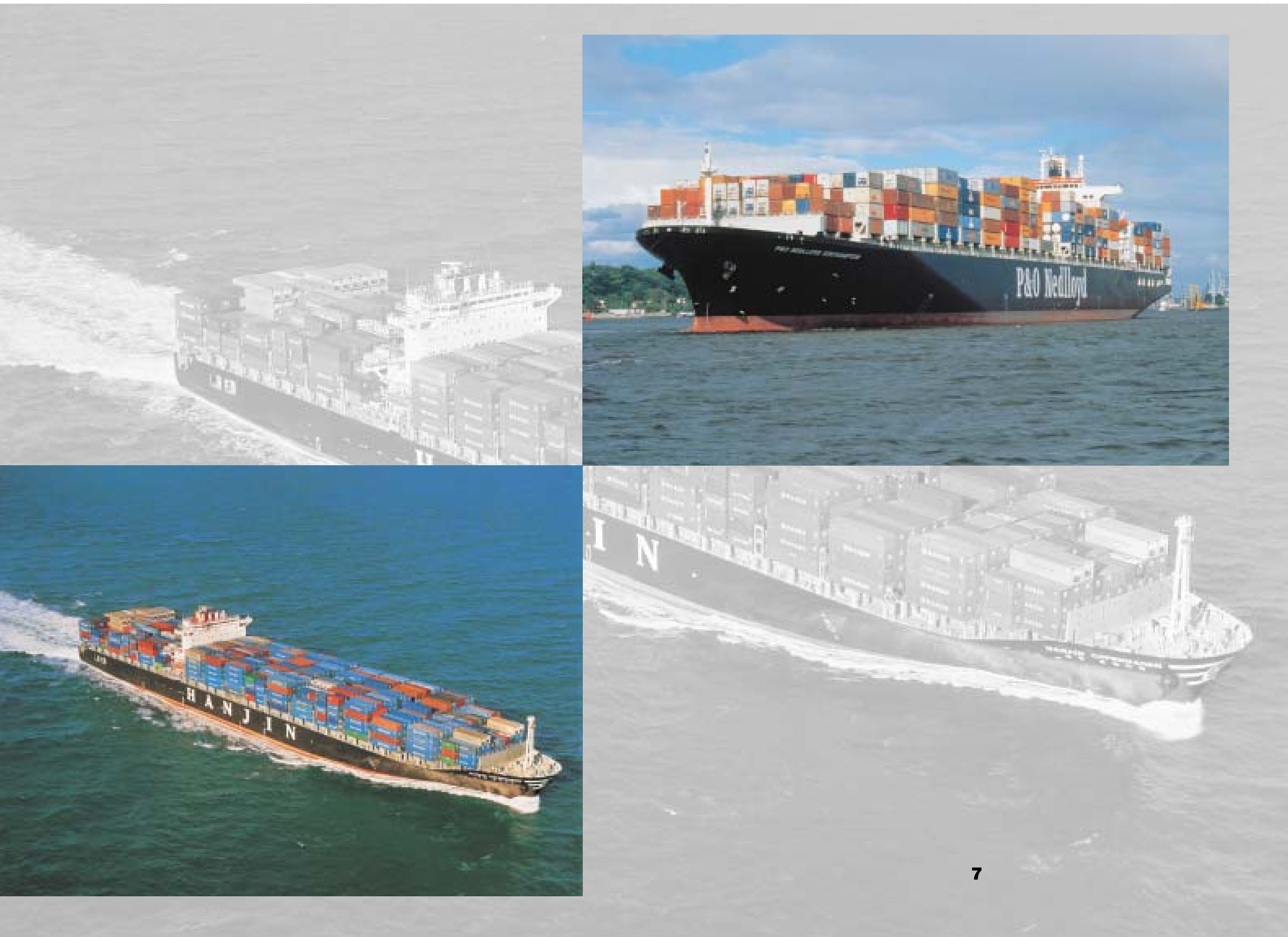
Further improvements are being achieved by the introduction of TriboPack technology in all new engines. By considerably improving piston-running behaviour, the TriboPack design measures are reducing liner and ring wear rates, extending times between overhauls and allowing reduced cylinder oil feed rates.

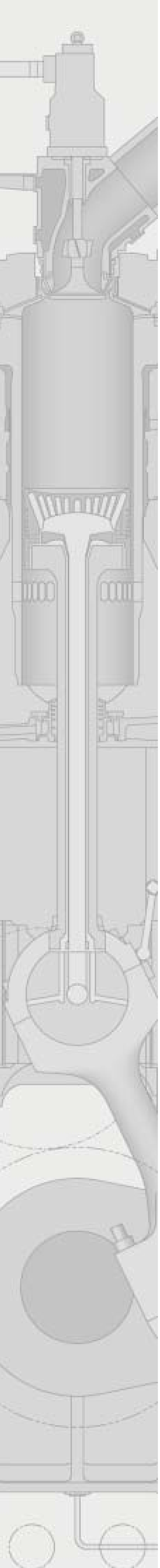
Exhaust emissions

With the current popular concern about the environmental, exhaust gas emissions have become an important aspect of marine diesel engines.

Today, the control of NO_X emissions in compliance with Annex VI of the MARPOL 73/78 convention is standard for marine diesel engines. For Sulzer RTA-C engines, this is achieved without adding any extra equipment to the engines. Instead, NO_X emissions are reduced below the limit set by the MARPOL regulation by Low NO_X Tuning techniques, involving a careful combination of adapted compression ratio, injection and valve timing, and different fuel nozzles to achieve the best results. Low NO_X Tuning is simple and effective yet assures high engine reliability and also keeps the fuel consumption at the lowest possible level.

As further regulations to control other emissions and further lower the NO_X limit are fully expected, Wärtsilä is carrying out a long-term research programme to develop techniques for reducing exhaust emissions, including NO_X, SO_X, CO_2 and smoke.



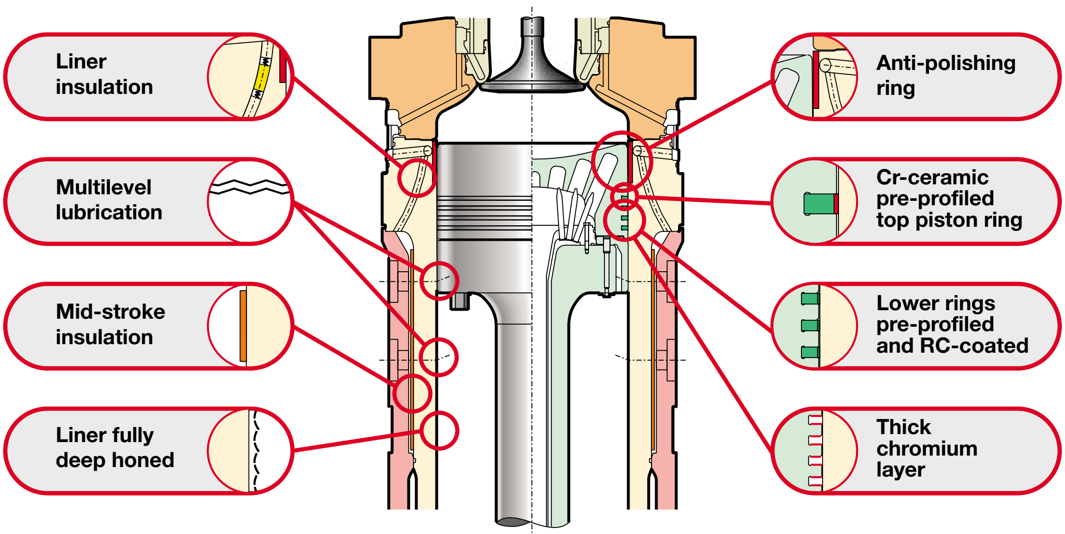


Piston-running behaviour

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, Sulzer RTA-series engines now incorporate TriboPack technology – 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. At the same time, TriboPack allows the further reduction of cylinder lubricating oil feed rate.

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
- Mid-stroke liner insulation, and where necessary, insulating tubes in the cooling bores in the upper part of the liner
- 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.

Pistons of Sulzer RTA96C engines

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 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 adapted to keep the liner surface above the dew point temperature throughout the piston stroke to avoid cold corrosion. Mid-stroke insulation and, where necessary, insulating tubes are therefore employed to optimise liner temperatures over the piston stroke.

Whilst trying to avoid corrosive wear by optimising liner wall temperatures, it is necessary to keep as much water as possible out of engine cylinders. Thus, the highly-efficient vane-type water separators fitted in RTA-C type engines 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 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.

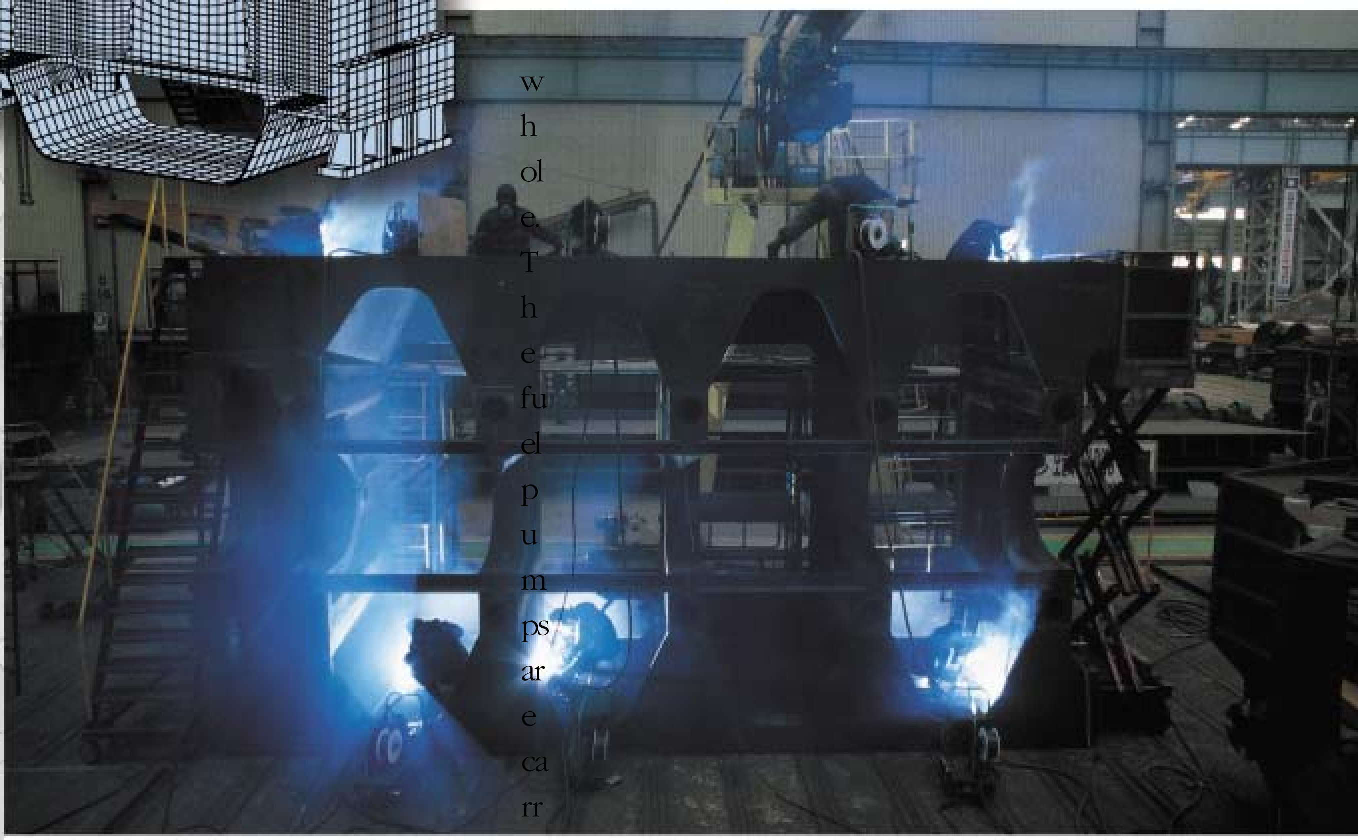
Engine structure

Sulzer RTA84C 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 fuel pumps are carr

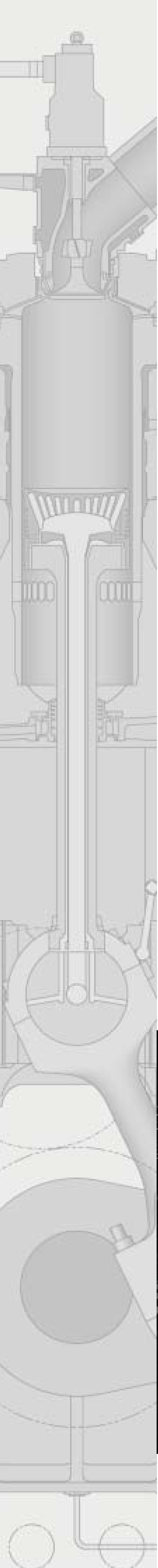
Finite-element model of the RTA96C structure for computer analysis comprising the 'gondola' type bedplate, welded box-type columns and individual cast-iron cylinder blocks



ied 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 fuel pump 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 camshaft drive, the thrust bearing can be very short and very stiff, and can be carried in a closed, rigid housing.

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



Running gear

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

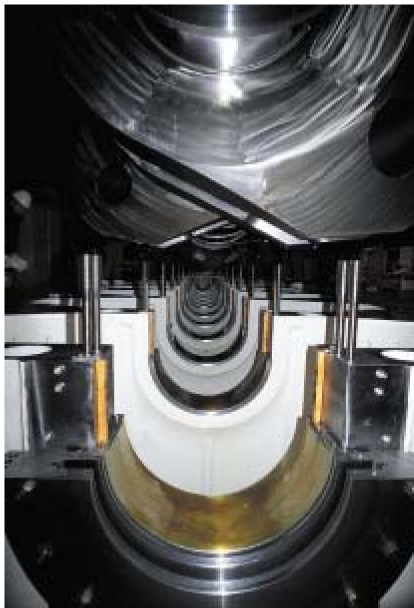
The crankshaft is semi-built comprising combined crank pin/web elements forged from a solid ingot and the journal pins then shrunk into the crank web.

The main bearings have white metal shells. The main bearing caps are held down by a pair of jack bolts in the RTA84C, and by a pair of elastic holding down studs in the RTA96C.

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 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. 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 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



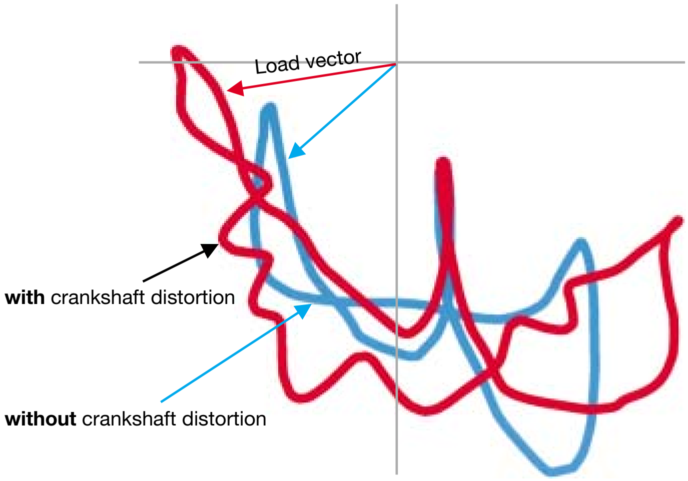
Lowering the crankshaft into the bedplate.

consumption down to a reasonable level and maintaining the quality of the system oil.

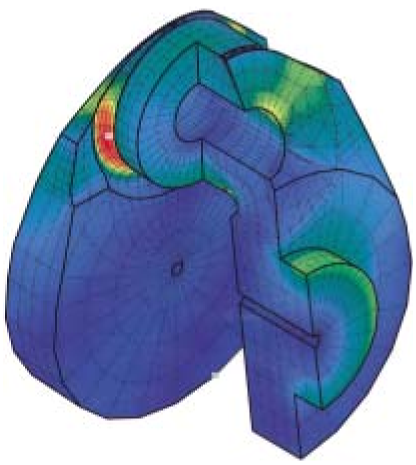
Today's RTA engines employ an improved design of piston rod gland with gas-tight top scraper rings, and large drain areas and channels. Hardened piston rods are now standard to ensure long-term stability in the gland behaviour.

Piston, piston rod and gland box.

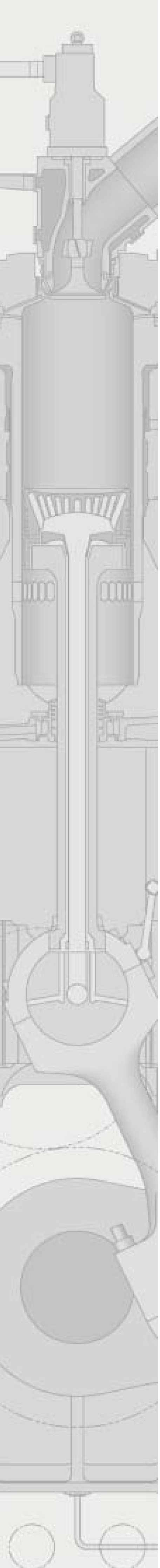
Crosshead pins with guide shoes for Sulzer RTA96C engines.



Taking account of crankshaft distortion is important when calculating main bearing loads.



Finite-element analysis of the crank throw of the RTA96C under full dynamic loading.



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.

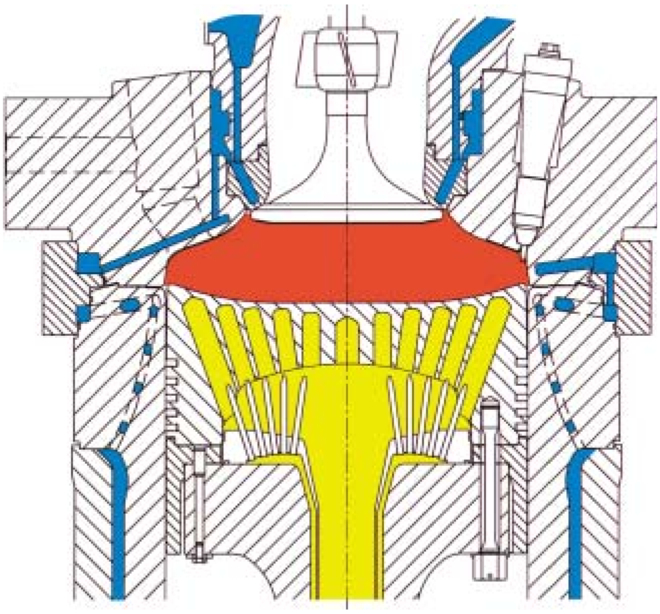
The modern calculation tools were invaluable with the RTA96C which has a rather shallow combustion chamber owing to its comparatively short stroke/bore ratio, and care was needed with the large quantity of fuel injected to avoid impingement on component surfaces.

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.

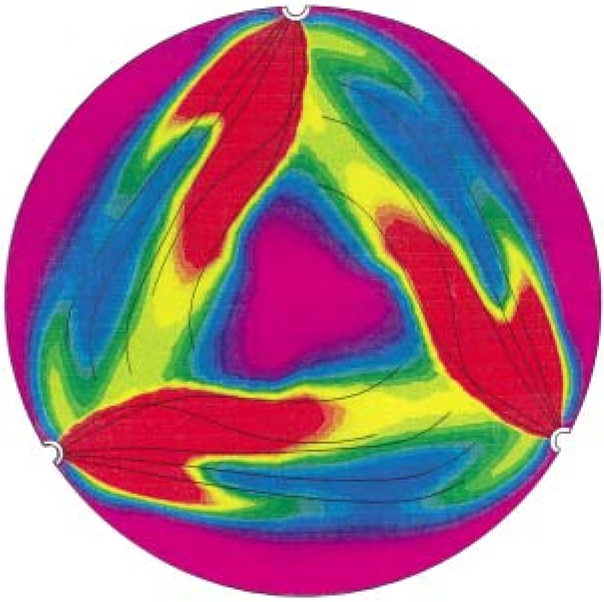
The solid forged steel, bore-cooled cylinder cover is secured by eight elastic studs. It is equipped with a single, central exhaust valve in Nimonic 80A which is housed in a bolted-on valve cage. The engines have three fuel injection valves symmetrically distributed in the cylinder cover. Anti-corrosion 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.

Bore-cooled pistons from the underside.



Fully bore-cooled combustion chamber.



Analysis of fuel distribution and injection trajectories in the RTA96C cylinder. Colours indicate concentration with blue/green for the stoichiometric mixture. No combustion calculated.

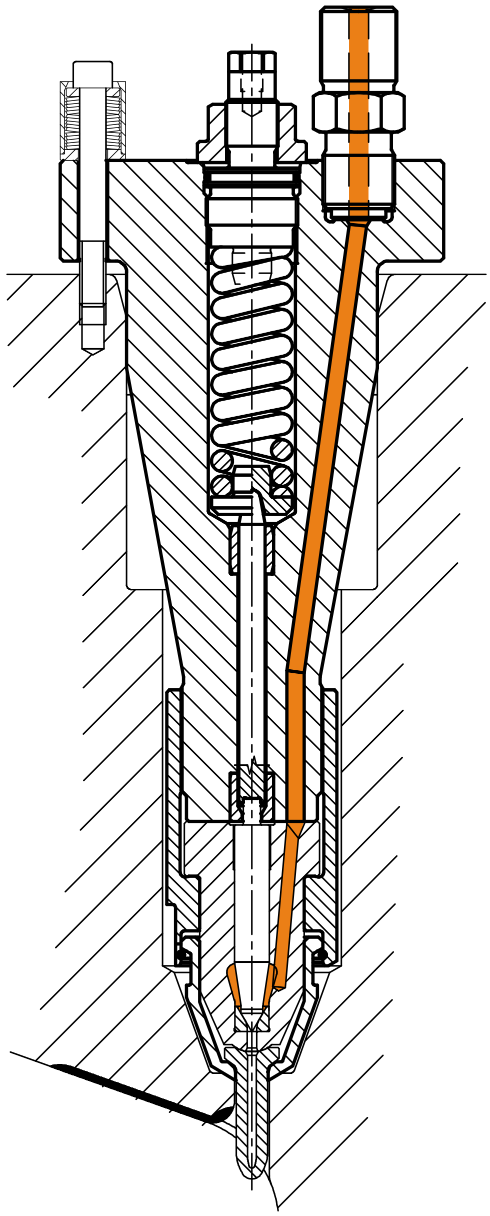
The cylinder liner is also bore cooled. Its surface temperatures are optimised by having a higher coolant entry point so that less of the liner is cooled, applying an insulation bandage around the outside of the liner in the upper mid-stroke region and, where necessary, by employing insulation tubes in the cooling bores.

Cooling oil spray nozzles at top of piston rod

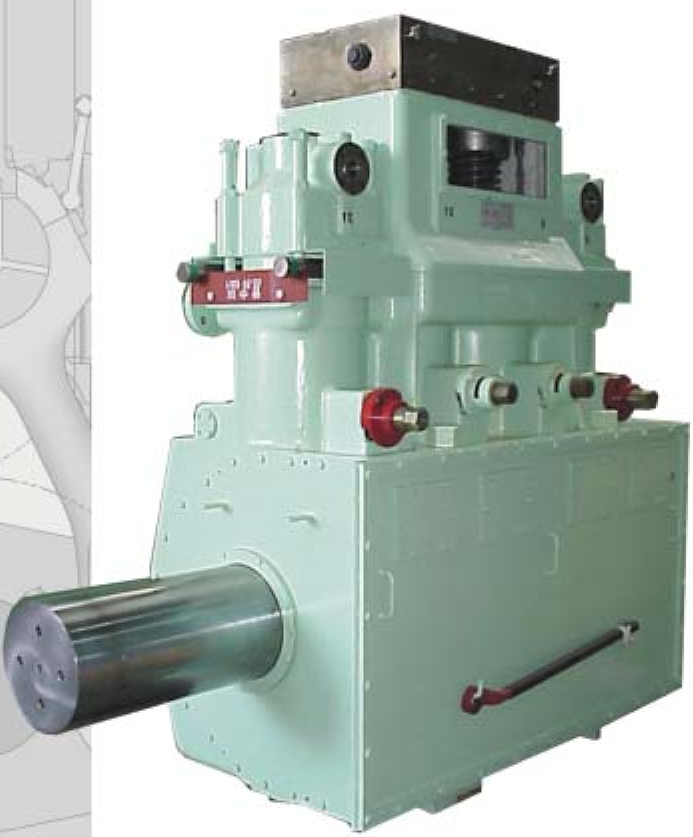
Fuel injection and valve actuation

There are three uncooled fuel injection valves in each cylinder cover. Their nozzle tips are sufficiently long that the cap nut is shielded by the cylinder cover and is not exposed to the combustion space.

The camshaft-driven fuel injection pumps are of the well-proven double-valve controlled type that has been traditional in Sulzer 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,



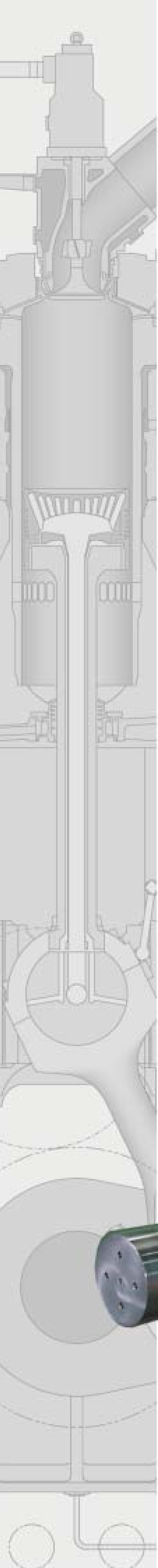
Fuel injection valve. The nozzle cap is not exposed to the combustion space and thereby avoids material being burned off.



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

and for the fuel quality setting (FQS) lever to adjust the injection timing according to the fuel oil quality.

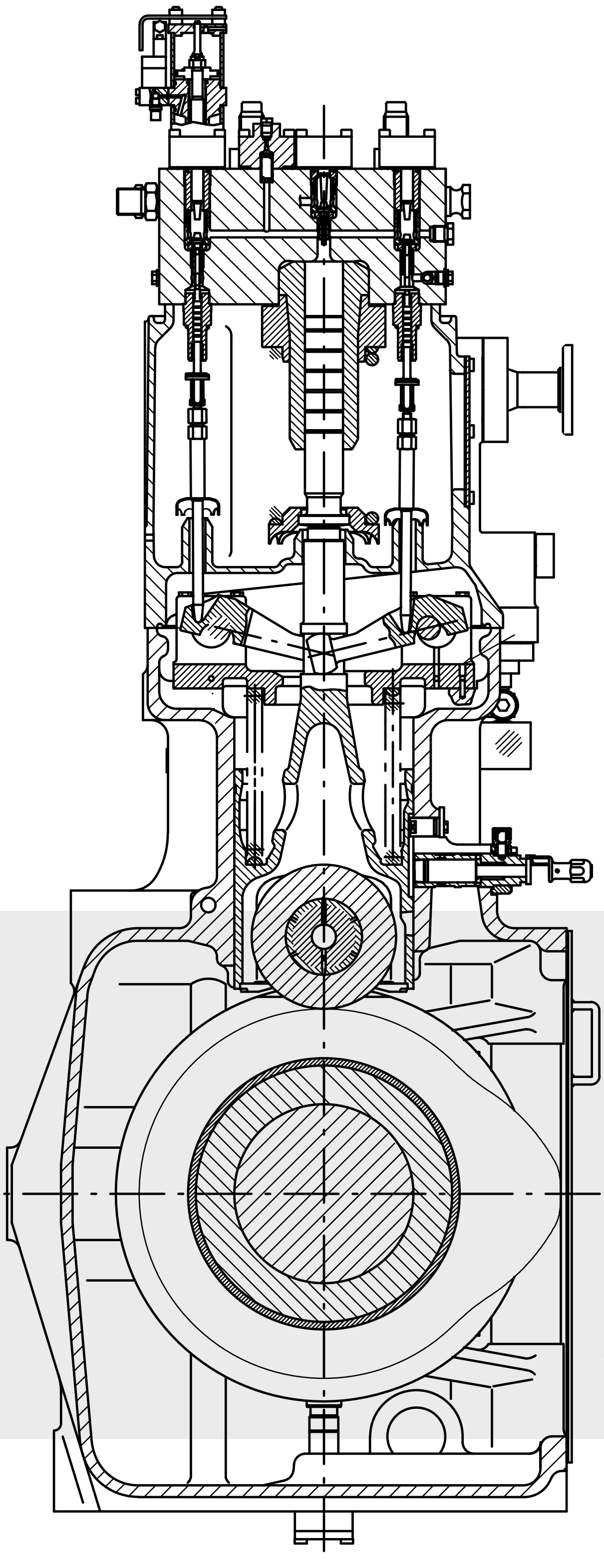
The valve-controlled fuel injection pump, in comparison with a helix type, has a plunger with a significantly greater sealing length. The higher volumetric efficiency reduces the torque in the camshaft. Additionally, injection from a



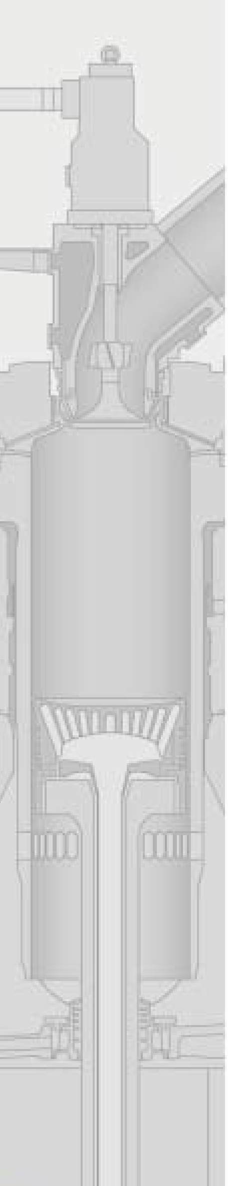
valve-controlled pump is far more stable at very low loads and rotational shaft speeds down to 15 per cent of the rated speed are achieved. Valve control also has benefits of less deterioration of timing over the years owing to less wear and to freedom from cavitation.

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 Sulzer arrangement of gear wheels housed in a double column located at the driving end or in the centre of the engine. There are three gear wheels in the camshaft drive. The main gear wheel on the crankshaft is in one piece and flange-mounted.



Fuel injection pump with double control valves.



Turbocharging and scavenge air system

The RTA84C 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 simplified design and modest size with integral non-return flaps, air cooler, 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 cooler, the scavenge air passes through a highly-efficient water separator which 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 air cooler and separator. This arrangement provides the effective separation of condensed water from the stream of scavenge air which is imperative for satisfactory piston-running behaviour.

Scavenge air cooler with the bend on the duct coming down from the turbocharger.

Installation arrangements

Sulzer RTA-series engines have specific design features that help to facilitate shipboard installation.

The broad layout fields of the Sulzer RTA engines gives the ship designer ample freedom to match the engine to the optimum propeller for the ship.

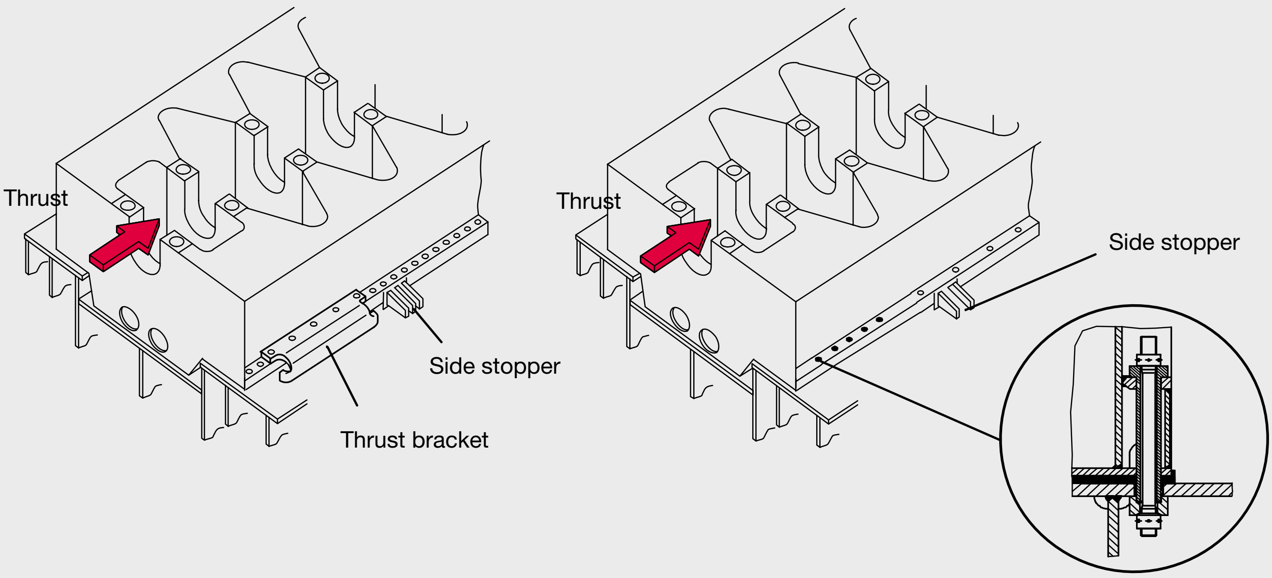
The RTA engines have simple seating arrangements with a modest number of holding down bolts and side stoppers. For a 12-cylinder RTA96C, 14 side stoppers are required. No end stoppers or thrust brackets are needed as thrust transmission is provided by fitted bolts or thrust sleeves which are applied 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.

Sulzer RTA engines have a valuable waste heat recovery potential to generate steam for heating services and for a turbogenerator.

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.



Arrangements for transmitting propeller thrust to the engine seatings for the RTA84C and RTA96C engines. The inset shows the thrust sleeve for the thrust bolts

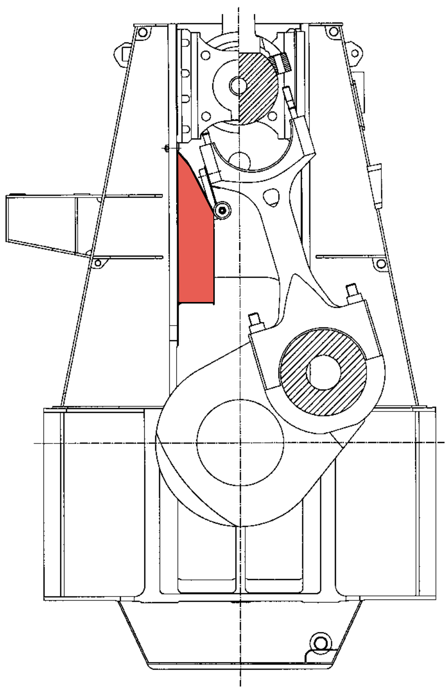
Maintenance

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.

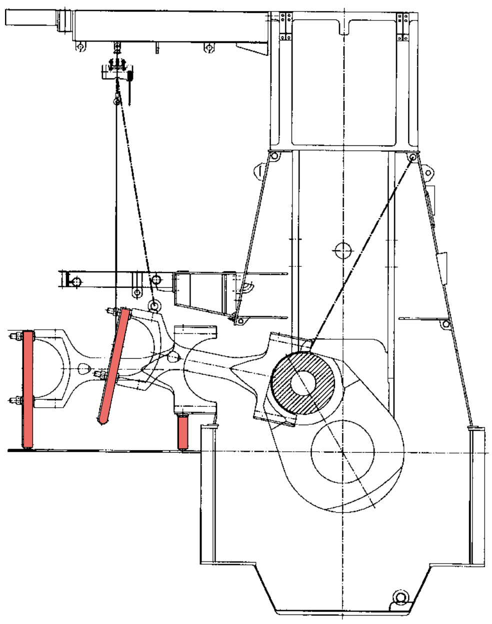
Yet, as maintenance work is inevitable, particular attention is given to ease of maintenance by including tooling and easy access, and by providing easy-to-understand instructions.

For example, all major fastenings throughout the engine are hydraulically tightened. Access to the crankcase continues to be possible through large doors from either one or both sides of the engine. The handling of components within the crankcase is facilitated by ample provision for hanging hoisting equipment. Attention to design details also allows simpler dismantling procedures.

Where possible, the users' views about details that affect operation and maintenance are taken into consideration in the engine design process. One example is the arrangements in the RTA96C for inspection of crosshead bearings and the removal of connecting rods. Discussions between the engine designers and shipowners' technical staffs led to a simple guide tool that is bolted to the crosshead



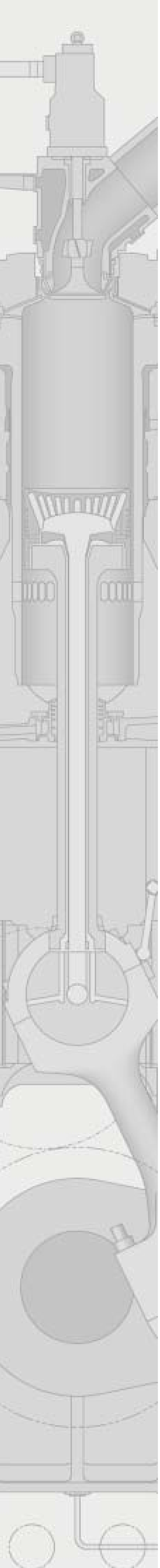
The guiding tool is bolted to the crosshead guides to serve as guide rails which ensure that the top end of the connecting rod and its bolts clear the crosshead pin as the connecting rod is lowered for inspection of the pin and its bearing, or during removal of the connecting rod



If the connecting rod of the RTA96C engine is to be removed from the engine crankcase, the task is facilitated by wheeled frames that can be fixed to each end of the rod.

guides to ensure that the top end of the connecting rod and its bolts clear the crosshead pin as the rod is lowered and raised.

Should a connecting rod need to be withdrawn from the crankcase then the task is facilitated by wheeled frames that are fixed to the ends of the rod. The wheeled frames guide the rod as it comes out of the crankcase and then enable the rod to be wheeled away.



Main technical data

Main data RTA84C

Cylinder bore	840 mm
Piston stroke	2 400 mm
Speed	82 - 102 rpm
Mean effective pressure at R1	17.9 bar
Piston speed	8.2 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							
	102 rpm				82 rpm			
	R1		R2		R3		R4	
	kW	bhp	kW	bhp	kW	bhp	kW	bhp
6	24 300	33 060	17 040	23 160	19 500	26 520	17 040	23 160
7	28 350	38 570	19 880	27 020	22 750	30 940	19 880	27 020
8	32 400	44 080	22 720	30 880	26 000	35 360	22 720	30 880
9	36 450	49 590	25 560	34 740	29 250	39 780	25 560	34 740
10	40 500	55 100	28 400	38 600	32 500	44 200	28 400	38 600
11	44 550	60 610	31 240	42 460	35 750	48 620	31 240	42 460
12	48 600	66 120	34 080	46 320	39 000	53 040	34 080	46 320

Brake specific fuel consumption (BSFC)

	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph
Load 85 %	168	124	162	119	169	124	165	121
Load 100 %	171	126	163	120	172	127	167	123
BMEP, bar	17.9		12.6		17.9		15.6	

Principal engine dimensions (mm) and weights (tonnes)

Cyl.	A	B	C	D	E	F*	G	I	K	Weight
6	11 080	4 320	1 600	11 315	4 749	13 130	2 205	696	920	850
7	12 680	4 320	1 600	11 315	4 749	13 130	2 205	696	920	960
8	15 280	4 320	1 600	11 315	4 749	13 130	2 205	696	920	1 110
9	16 880	4 320	1 600	11 315	4 191	13 130	2 205	696	920	1 230
10	18 480	4 320	1 600	11 315	4 191	13 130	2 205	696	920	1 350
11	20 080	4 320	1 600	11 315	4 191	13 130	2 205	696	920	1 460
12	21 680	4 320	1 600	11 315	4 749	13 130	2 205	696	920	1 570

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

Main data RTA96C

Cylinder bore	960 mm
Piston stroke	2 500 mm
Speed	92 - 102 rpm
Mean effective pressure at R1	18.6 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

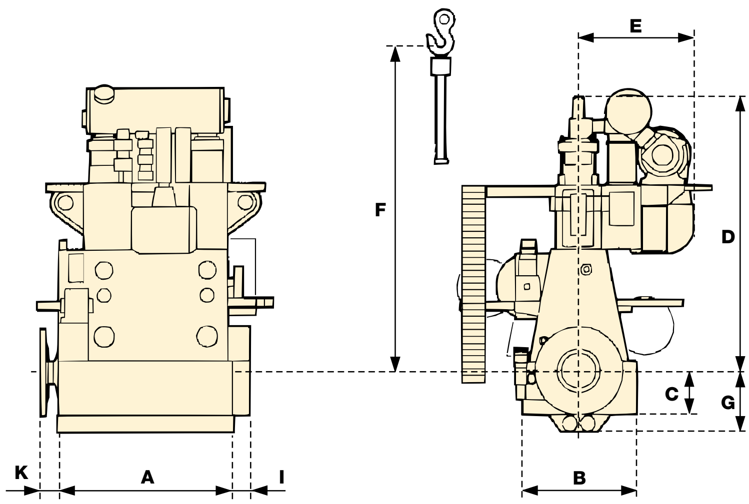
Cyl.	Output in kW/bhp at							
	102 rpm				92 rpm			
	R1		R2		R3		R4	
	kW	bhp	kW	bhp	kW	bhp	kW	bhp
6	34 320	46 680	24 000	32 640	30 960	42 120	24 000	32 640
7	40 040	54 460	28 000	38 080	36 120	49 140	28 000	38 080
8	45 760	62 240	32 000	43 520	41 280	56 160	32 000	43 520
9	51 480	70 020	36 000	48 960	46 440	63 180	36 000	48 960
10	57 200	77 800	40 000	54 400	51 600	70 200	40 000	54 400
11	62 920	85 580	44 000	59 840	56 760	77 220	44 000	59 840
12	68 640	93 360	48 000	65 280	61 920	84 240	48 000	65 280
14	80 080	108 920	56 000	76 160	72 240	98 280	56 000	76 160

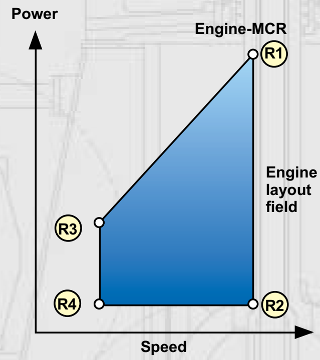
Brake specific fuel consumption (BSFC)

	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph	g/kWh	g/bhph
Load 85 %	166	122	160	118	166	122	160	118
Load 100 %	171	126	163	120	171	126	164	121
BMEP, bar	18.6		13.0		18.6		14.4	

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	5 232	12 880	2 594	723	676	1 160
7	13 244	4 480	1 800	10 925	5 232	12 880	2 594	723	676	1 290
8	15 834	4 480	1 800	10 925	5 232	12 880	2 594	723	676	1 470
9	17 514	4 480	1 800	10 925	5 232	12 880	2 594	723	676	1 620
10	19 194	4 480	1 800	10 925	5 232	12 880	2 594	723	676	1 760
11	20 874	4 480	1 800	10 925	5 232	12 880	2 594	723	676	1 910
12	22 541	4 480	1 800	10 925	5 232	12 880	2 594	723	676	2 050
14	25 914	4 480	1 800	10 925	5 232	12 880	2 594	723		2 300





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%

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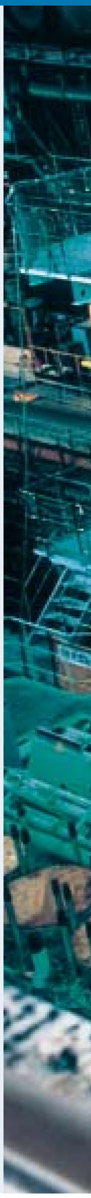

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