Technology Review

This is a brief guide to the technical features and benefits of the Sulzer RTA84T-B and RTA84T-D low-speed marine diesel engines, herein collectively called Sulzer RTA84T engines.

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Introduction

The Sulzer RTA84T low-speed marine diesel engines are tailor-made for the economic propulsion of very large crude oil tankers (VLCCs and ULCCs). In this role, they offer clear, substantial benefits:

- Optimum power and speed
- Competitive first cost
- Lowest possible fuel consumption over the whole operating range from full speed to ‘slow steaming’
- Three years’ time between overhauls
- Low maintenance costs through reliability and durability
- Full compliance with the IMO NOX emission regulation.

When the Sulzer RTA84T type was initiated in 1990, large tankers had become standardised in size, based on standard parcel sizes of multiples of a million barrels (bbl). This has led to the deadweight capacity of a VLCC (about two million bbl) being around 285,000 tonnes at design draught and 300,000 tonnes at scantling draught and in some cases going up to 320,000 tdw.
For newbuildings of 285,000 tdw (design), the average installed power needed is around 27,000 kW (36,000 bhp) for a ship’s service speed of around 15.5 knots. The usually selected propeller speed of some 70 to 79 rev/ min is a direct result of aiming for an ‘optimum propulsion’ installation within the widely accepted MARPOL recommendation for the selection of propeller diameters. These considerations for VLCC newbuildings led to the parameters of the Sulzer RTA84T engine.

<table>
<thead>
<tr>
<th>Principal particulars</th>
<th>Type</th>
<th>RTA84T-B</th>
<th>RTA84T-D</th>
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<tbody>
<tr>
<td><strong>Bore</strong></td>
<td>mm</td>
<td>840</td>
<td>840</td>
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<tr>
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<td>3150</td>
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<tr>
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<td>kW/cyl</td>
<td>3880</td>
<td>4100</td>
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<tr>
<td></td>
<td>bhp/cyl</td>
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<td>5880</td>
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<td>76–61</td>
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<tr>
<td><strong>BMEP at R1</strong></td>
<td>bar</td>
<td>18.0</td>
<td>18.5</td>
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<tr>
<td><strong>Pmax</strong></td>
<td>bar</td>
<td>140</td>
<td>144</td>
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<tr>
<td><strong>Mean piston speed at R1</strong></td>
<td>m/s</td>
<td>7.77</td>
<td>8.0</td>
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<tr>
<td><strong>Number of cylinders</strong></td>
<td>5–9</td>
<td>5–9</td>
<td></td>
</tr>
<tr>
<td><strong>BSFC for low-port version:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>g/kWh</td>
<td>168</td>
<td>168</td>
</tr>
<tr>
<td></td>
<td>g/bhph</td>
<td>123</td>
<td>123</td>
</tr>
<tr>
<td></td>
<td>g/kWh</td>
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<td></td>
<td>g/bhph</td>
<td>121</td>
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<td>g/bhph</td>
<td>120</td>
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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 RTA84T engine type has followed this policy since it was introduced in May 1991.

In 1996, the modernised version B of the RTA84T was introduced, with many new design features for easier manufacturing and improved service behaviour. There was no change in power output.

In July 1998, the fuel consumption of the version B could be improved by 2 g/kWh by the application of ‘low port’ cylinder liners in which the scaveng air inlet ports have a reduced height, in combination with turbochargers of higher efficiency. The result is a full-load fuel consumption of 168 g/kWh (123 g/bhp) for R1-rated engines.

At the end of 1998, the power output of the RTA84T was increased in the version D to 4100 kW/cylinder (5580 bhp/cylinder) at 76 rev/min. This was in response to a market requirement for higher VLCC service speeds to give owners and charterers greater flexibility in economical ship operation to suit the wide variations in charter/freight rates at that time. The power available from a seven-cylinder engine was thereby increased from 27,160 to 28,700 kW (36,960 to 39,060 bhp).
Exhaust emissions

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

Today, the control of NO\textsubscript{X} emissions in compliance with Annex VI of the MARPOL 73/78 convention is standard for marine diesel engines. For Sulzer RTA84T engines, this is achieved without adding any extra equipment to the engines. Instead, NO\textsubscript{X} emissions are reduced below the limit set by the MARPOL regulation by Low NO\textsubscript{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\textsubscript{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\textsubscript{X} limit are fully expected, Wärtsilä is carrying out a long-term research programme to develop techniques for reducing exhaust emissions, including NO\textsubscript{X}, SO\textsubscript{X}, CO\textsubscript{2} and smoke.
Real in-service fuel economy

Sulzer RTA84T engines have a particularly low fuel consumption right across their load/speed range. This is advantageous for large tankers which are called upon to operate over a wide range of ship speeds, from full speed to 'slow steaming', whether fully-loaded or in ballast. With ‘low-port’ liners, RTA84T engines now exceed 50 per cent thermal efficiency at full power, and even more at part load.

An important contribution to the fuel economy of the RTA84T engines is their improved level of setting flexibility compared with other engine types. This is given by a combination of VEC (Variable Exhaust valve Closing) and VIT (Variable Injection Timing). Together, these permit a more comprehensive optimisation of the engine's working process for reduced fuel consumption over the whole load range.

The VIT improves engine efficiency in the upper load range by maintaining the maximum cylinder pressure at the full-load value by injection timing advance. The VEC system is employed in the mid load range to increase the effective compression ratio and thereby lower fuel consumption. The VEC system is a straightforward adaptation of the hydraulic actuation system of the exhaust valve so that the hydraulic pressure can be released earlier than usual.

The ‘low port’ cylinder liners combined with higher efficiency turbochargers give an overall reduction in fuel consumption. There is no penalty in either higher component temperatures or too low exhaust gas temperatures. The low ports give a longer effective expansion stroke in the cycle.

![Graph showing BSFC (g/kWh) for RTA84T-B and RTA84T-D engines with and without VIT/VEC](https://example.com/bsfc-graph.png)

*Influence of variable fuel injection timing (VIT) and variable exhaust valve closing (VEC) on part-load fuel consumption of RTA84T-B and RTA84T-D engines. For maximum continuous rating R1 with low ports.*
Hydraulic actuating arrangement for the exhaust valve. Variable exhaust valve closing (VEC) is provided by a control valve which opens to release the pressure of the hydraulic ‘push rod’ early thereby allowing the exhaust valve to close early.

Exhaust valve lift and cylinder pressure on a common scale of crank angle to show the influence of VEC. With earlier closing of the exhaust valve at part load (dotted curve), the cylinder pressure peak rises higher than if a fixed exhaust valve timing is used (solid line).
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.

Design measures included in Sulzer TriboPack. Together they give improved piston-running behaviour for three years' between overhauls and lower cylinder lubricant feed rates.
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. The load-dependent cylinder liner cooling system plays an important role in ensuring optimum temperature control over the load range. Mid-stroke insulation and, where necessary, insulating tubes are 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 RTA84T engines after the scavange 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.
Sulzer RTA84T 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 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 carried on one side of the
cylinder jacket and the scavenge air receiver on the other. 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.

The compact arrangement around the thrust bearing which acts on the flange of the main gear wheel located here on the crankshaft.

Crankshaft installed in the bedplate of a seven-cylinder engine.

The complete, pre-fitted cylinder block being lifted and mounted on the engine column.
Running gear

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

The semi-built crankshaft of the RTA84T engine has to cater for the longest stroke ever used in a Sulzer engine. To limit the crankshaft weight for production, assembly and transport, the main journals and crank pins are bored.

The design of the crank has a good transverse width at the upper part of the web, allowing the web to be slim longitudinally. The favourable torsional vibration characteristics allow six-cylinder engines to use a viscous damper for many cases instead of a Geislinger damper.

The main bearings have white metal shells. The main bearing caps are held down by a pair of jack bolts for easy assembly and dismantling of bearings.

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 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.
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. However, the large stroke-to-bore ratio of the RTA84T allows a relatively deeper combustion chamber with more freedom in the layout of the fuel spray pattern. Low component temperatures are also desirable to give more freedom for reaching low NOX emissions.

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

The well-proven bore-cooling principle is also employed in 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

Surface temperatures measured on the combustion chamber components of the RTA84T-B at full-load R1 rating. The thickness of the lines represents the circumferential variation in temperature.
a bolted-on valve cage. The RTA84T has 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 piston of the RTA84T comprises 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 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.

Computer simulation of fuel injection spray patterns from the three nozzles of the RTA84T-B to illustrate that the main concentrations in the sprays keep away from the chamber surfaces.

Cylinder liner with the standard mid-stroke insulation in the form of a Teflon band retained by stainless steel cladding.
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, 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 either flange-type couplings or 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 four gear wheels in the camshaft drive. The main gear wheel on the crankshaft is in one piece and flange-mounted.
The RTA84T 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 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 separator. This arrangement provides the effective separation of condensed water from the stream of scavenge air which is imperative for satisfactory piston-running behaviour.

![Simulation by computer fluid dynamics (CFD) of the air flow velocities through the 90-degree bend in the scavenge air duct and the cooler.](image)
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. Only eight side stoppers are required for a seven-cylinder RTA84T. 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 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.

Compensation for second-order forces and moments can be provided by either one or both of a gear-driven Lanchester balancer at the driving end of the engine and an electrically-driven balancer at the free end.

Arrangements for transmitting propeller thrust to the engine seatings. The inset shows the thrust sleeve for the thrust bolts.
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 from 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.
Main technical data

Main data: Version D

- Cylinder bore: 840 mm
- Piston stroke: 3,150 mm
- Speed: 61 - 76 rpm
- Mean effective pressure at R1: 18.5 bar
- Piston speed: 8.0 m/s
- Fuel specification:
  - Fuel oil: 730 cSt/50°C
  - 7,200 sR1/100°F
  - ISO 8217, category ISO-F-RMK 55

The RTA84T-B is available at lower power outputs than the version D shown here, and complies with the IMO NO_x regulation.

### Rated power: Propulsion Engines

<table>
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<tr>
<th>Cyl.</th>
<th>R1 76 rpm kW</th>
<th>R1 61 rpm kW</th>
<th>R2 76 rpm kW</th>
<th>R2 61 rpm kW</th>
<th>R3 76 rpm kW</th>
<th>R3 61 rpm kW</th>
<th>R4 76 rpm kW</th>
<th>R4 61 rpm kW</th>
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<td>5</td>
<td>20,500</td>
<td>14,350</td>
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<td>9</td>
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<td>25,830</td>
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**Brake specific fuel consumption (BSFC)**

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<table>
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<th>Load 100%</th>
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<th>g/bph</th>
<th>g/kWh</th>
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**BMEP, bar**: 18.5

**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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