

New high-economy engines for panamax containerships and large tankers

Kaspar Aeberli
Senior Director, Marketing & Project Development
Wärtsilä Switzerland Ltd, Winterthur

Summary

The paper presents the four new 820 mm-bore low-speed marine engine types introduced by Wärtsilä Corporation for a wide range of applications in panamax containerships and large tankers, such as VLCCs and ULCCs, as well as in very large ore carriers. The first engines of these new types have been ordered and are due for delivery in 2008 onwards. The engines have been designed according to the platform concept with two different strokes to suit the respective ship applications but with as many components as possible of the same design to give economies of scale in manufacture, storage and logistics.

With a piston stroke of 2646 mm, the “-C” versions will suit panamax container ships, with powers between 21,720 and 54,240 kW, while the “-T” versions of 3375 mm stroke will be ideally suited for large tankers (VLCCs, ULCCs) and very large ore carriers, with powers of 21,720 to 40,680 kW. The paper focuses on the RT-flex82C and RT-flex82T engines which will incorporate the latest electronically-controlled common-rail systems. They are also built in RTA versions with mechanically-controlled camshaft systems.

Introduction

The new Wärtsilä family of 820 mm-bore marine low-speed engines arose from a need to provide more modern engines in this size range to provide shipowners and shipbuilders with the benefits of recent developments in operating economy, manufacturing, electronically-controlled common-rail systems, etc., as well as increased unit power outputs.

In the envisaged applications, the key requirements are highly economical operation, high reliability, long times between overhauls (target three years), low fuel and lubricating oil consumptions, low exhaust emissions, low, stable running speeds, compactness, and optimised industrialisation.

There has been a clear need to replace the RTA84C which, although it has served well as a propulsion engine for panamax container ships, cannot meet the power demand of such ships today which are notably larger now, carrying as much as 5000 TEU. Studies have thus led to the choice of 4520 kW/cylinder as the maximum continuous power of the new RT-flex82C and RTA82C engines, compared with the output of 4050 kW/cylinder developed by the RTA84C.

A broadly similar situation of increased power requirement is also anticipated for the next generation of large crude oil tankers known as VLCCs and ULCCs which have capacities of larger than 200,000 tdw and 350,000 tdw respectively. The need for greater installed power could thus be provided by the development of new RT-flex82T and RTA82T engines with a maximum continuous power of 4520 kW/cylinder, compared with

4200 kW/cylinder given by the RTA84T-D. Similar considerations apply to the propulsion of very large ore carriers in the range of 300,000 tdw for which these engines are equally applicable.

The possibility of meeting the requirements of two distinctly different market segments with engines of the same 820 mm cylinder bore and the same cylinder power of 4520 kW/cylinder opened the way for the development of new engine types according to the platform concept (Fig. 1). This is well practised in the car industry where cars of completely different brands are designed and built using a common platform with as many parts as possible, even engines and body panels, being shared to reduce costs.

The same idea is being employed for the new Wärtsilä RT-flex82C, RTA82C, RT-flex82T and RTA82T engines. Parameters are standardised as far as possible so that many components can be same for both engine types, allowing benefits of rationalisation in the design and manufacturing, lowering manufacturing costs, and rationalising also spare parts stocks.

These engines are all of 820 mm cylinder bore but with two different piston strokes appropriate for the ship applications envisaged. The ‘-C’ versions are intended to be ideal prime movers for container ships of panamax size with capacities up to around 5000 TEU and service speeds typically of about 24 knots. They will have a stroke of 2646 mm and will be available with six to twelve cylinders to cover a power range of 21,720 kW to 54,240 kW at 87 to 102 rpm (Fig. 2 & Table, page 3).

The second pair, the ‘-T’ versions for tankers and ore

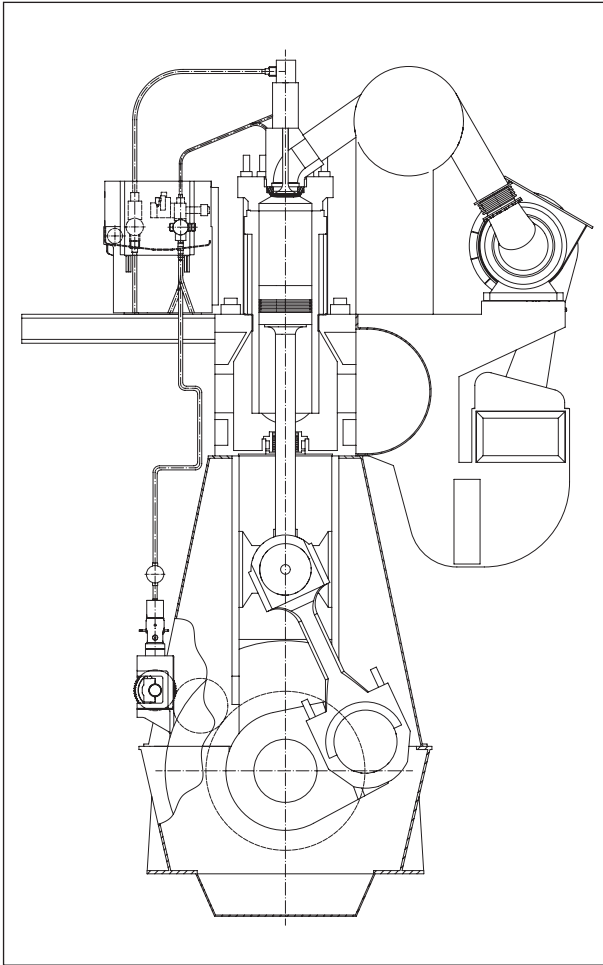


Fig. 1: Above, cross section of the Wärtsilä RT-flex82C is representative of the four new engine types. [06#076]

carriers, will have a stroke of 3375 mm to suit the shaft speeds for the propulsion of such large vessels of 200,000 tdw to more than 350,000 tdw. The engines will be built with six to nine cylinders to cover a power range of 21,720 kW to 40,680 kW at 68 to 80 rpm (Fig. 2 & Table, page 3).

The RT-flex82C and RT-flex82T versions will have the very latest electronically-controlled common rail systems while the corresponding RTA versions will have traditional, mechanical camshaft systems. Otherwise the RT-flex and RTA versions have the same principal characteristics and design features.

The first orders have been received for these new engine types and the first engines are expected to be completed in mid 2008, in cooperation with Hyundai Heavy Industries Co Ltd supporting in engine production design and testing by utilising their existing facilities and manpower.

Extended layout fields

During the initial studies for the new 820 mm-bore family of engines it became clear that, although the required power could be readily identified, single running speeds could not be identified as optimum for the two principal markets for these engines. The solution was found to widen the layout fields to provide a range of speed at the given maximum continuous rated power output.

The engine layout fields, usually defined by the power/speed ratings R1, R2, R3 and R4, are thus extended to higher speeds defined by the additional points R1+ and R2+ at the same powers as R1 and R2 respectively but with 5% greater shaft speed (Fig. 3). Any power and speed within this whole engine layout field may be selected as the contracted maximum continuous rating (CMCR)

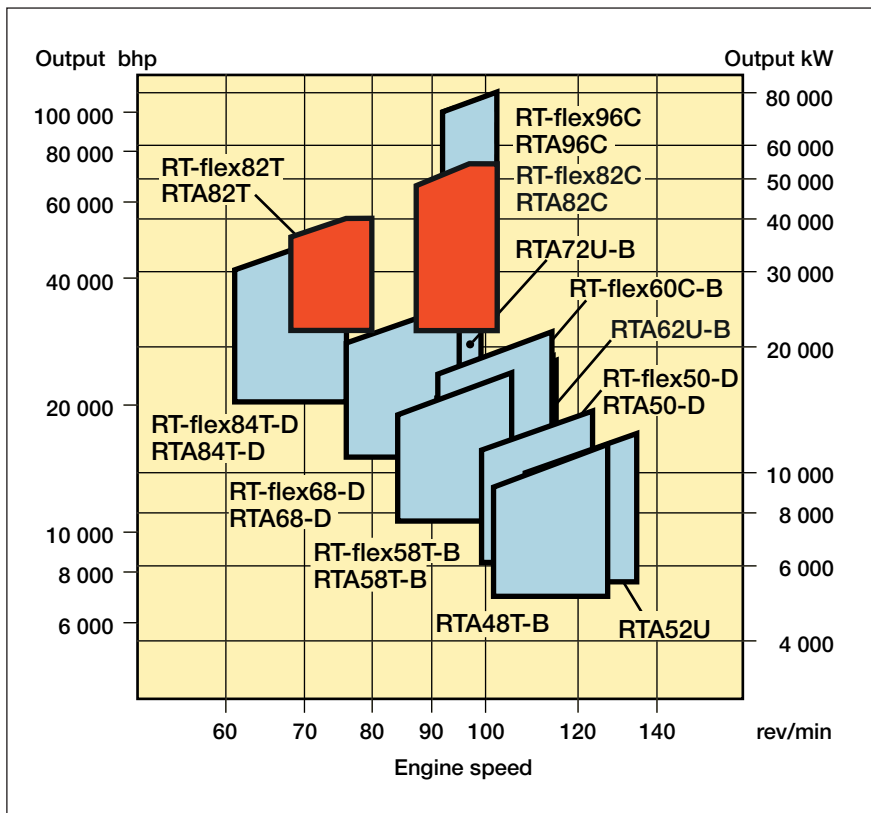


Fig. 2: Power/speed layout fields for the new 820mm-bore engines superimposed on the fields for the Wärtsilä low-speed engine programme. [06#110]

Table: Principal particulars of Wärtsilä RT-flex82C, RTA82C, RT-flex82T and RTA82T marine engines:

Engine type	RT-flex82C		RT-flex82T		
	RTA82C	RTA82T	RTA82T	RTA82T	
Cylinder bore:	820	820	820	820	mm
Piston stroke:	2646	3375	3375	3375	mm
Stroke/bore ratio:	3.2	4.1	4.1	4.1	—
Power/cylinder, R1 & R1+:	4520	4520	4520	4520	kW
	6150	6150	6150	6150	bhp
Speed range, R1+ to R3/R4:	102-87	80-68	80-68	80-68	rev/min
Maximum cylinder pressure:	159	159	159	159	bar
Mean effective pressure, R1/R1+:	20.0/19.0	20.0/19.0	20.0/19.0	20.0/19.0	bar
Mean piston speed, R1/R1+:	8.6/9.0	8.6/9.0	8.6/9.0	8.6/9.0	m/s
Numbers of cylinders:	6 to 12	6 to 9	6 to 9	6 to 9	—
Power range:	21,720–54,240	21,720–40,680	21,720–40,680	21,720–40,680	kW
	29,520–73,800	29,520–55,350	29,520–55,350	29,520–55,350	bhp
BSFC at full load, R1/R1+:	171/169	167/165	167/165	167/165	g/kWh

point for an engine.

With the 5% increase in shaft speed at the R1+ point at the same power as at the R1 point, the engine is running at five per cent lower mean effective pressure (BMEP). The reduced BMEP at the unchanged maximum combustion pressure (Pmax) gives this R1+ point the benefit of a reduced specific fuel consumption compared with the R1 point.

Seen from the point of view of the ship installation, the increased running speed at the R1+ point offers the possibility of a freedom to select a smaller propeller diameter but at the same time the vessel would also sail at the same daily fuel consumption (in tonnes per day) as with R1 using a larger propeller diameter.

The extended layout field also allows the appropriate propeller diameter to be selected in the case of vessels with reduced draught such as container vessels in the broad size range of around 3000 to 5000 TEU.

To summarise, the extended field offers usefully widened flexibility to select the most efficient propeller speed for lowest daily fuel consumption, and the most economic propulsion equipment, namely the propeller, shafting, etc.

RT-flex common-rail and its benefits

Electronically-controlled Wärtsilä RT-flex common-rail engines are proving to be very popular with shipowners, and this is expected to be the case for the new 820 mm-bore engines. The RT-flex versions have added benefits for shipowners and operators, including smokeless operation at all engine speeds, lower stable running speeds, lower fuel consumption, and consistent engine settings for reduced maintenance. The RTA versions with mechanically-controlled fuel injection pumps and exhaust valve drives will be available for those shipowners preferring the traditional concept.

In the RT-flex electronically-controlled common-rail system, fuel oil and servo oil are delivered at regulated pressures to rail pipes arranged in a rail unit along the side of the cylinders (Fig. 4). Heated fuel oil is delivered, ready for injection, at pressures up to 1000 bar. Servo oil

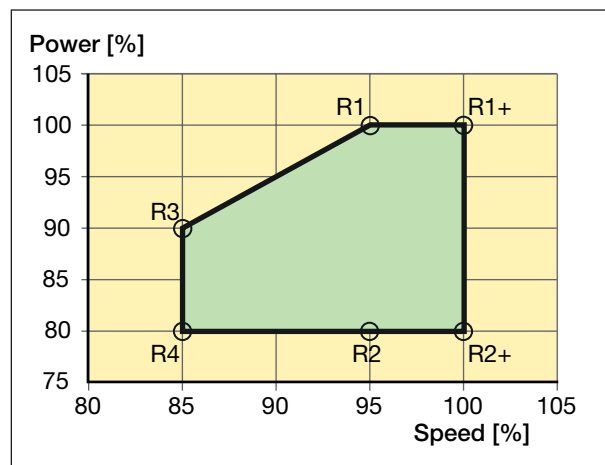


Fig. 3: Greater layout flexibility is provided in the RT-flex82C, RTA82C, RT-flex82T and RTA82T engines. The usual power-speed layout field for Wärtsilä low-speed engines defined by the points R1, R2, R3 and R4 is extended to the points R1+ and R2+. The contracted maximum continuous power and speed can be freely selected within the area defined by R1+, R2+, R3 and R4. [06#111]

is drawn from the engine lubrication system through an automatic self-cleaning fine filter and delivered at pressures up to 200 bar.

Fuel injection and exhaust valve operation are controlled by individual control units for each cylinder. The control units are directly mounted on the single-piece rail pipes and are controlled using servo oil through Wärtsilä electro-hydraulic rail valves.

Fuel oil and servo oil are supplied to the common-rail system pumps mounted in a very compact arrangement at the after end of the engine (Fig. 5). The fuel supply pumps are of the reciprocating plunger type designed by Wärtsilä while the servo oil pumps are of proprietary make. The pumps are driven through gearing from the crankshaft. The number of pumps depends upon the number of engine cylinders and engine power output. The fuel supply pumps make several strokes during each crankshaft revolution owing to the drive gear ratio. Fuel delivery

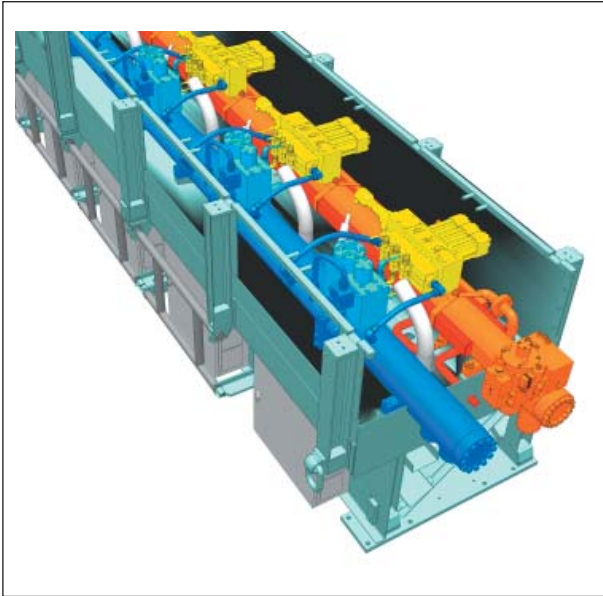


Fig. 4: Drawing of the rail unit with covers removed showing the fuel rail (orange) and servo oil rail (blue) both surmounted by the respective control units for injection and exhaust valves respectively for individual cylinders. [06#079]

volume and rail pressure are regulated through suction control of the fuel supply pumps.

RT-flex electronic control

All functions in the RT-flex system are controlled, monitored and executed through the integrated Wärtsilä WECS-9520 electronic control system which triggers the electro-hydraulic rail valves for the respective functions. This is a modular system with separate microprocessor control modules for each cylinder, which are all connected together by a CANbus. Devices such as actuators or servo oil pumps are directly connected to and controlled from these modules. The crankshaft position is detected by a crank angle sensor and provided through a redundant SSI bus directly to each control module. Provision is also made in the control system for access for monitoring, maintenance, adjustments, and troubleshooting.

The control modules are housed in cabinets mounted on the side of the rail unit.

All control functions are distributed between the control modules in such a way that if one module fails, the engine remains in operation. The WECS-9520 thus has benefits of a single module type, simple wiring, few control boxes of standardised design, good communication within the system, integration with the ship alarm systems, redundancy and easy troubleshooting.

The WECS-9520 offers unmatched flexibility for interconnectivity between the RT-flex engine control system and the ship's integrated remote control and safety systems according to the DENIS-9520 interface specification.

Reliability and safety have had the utmost priority in the RT-flex system. There is also extensive duplication in the system for redundancy, in the supply pumps, main delivery pipes, crank angle sensors, electronic control

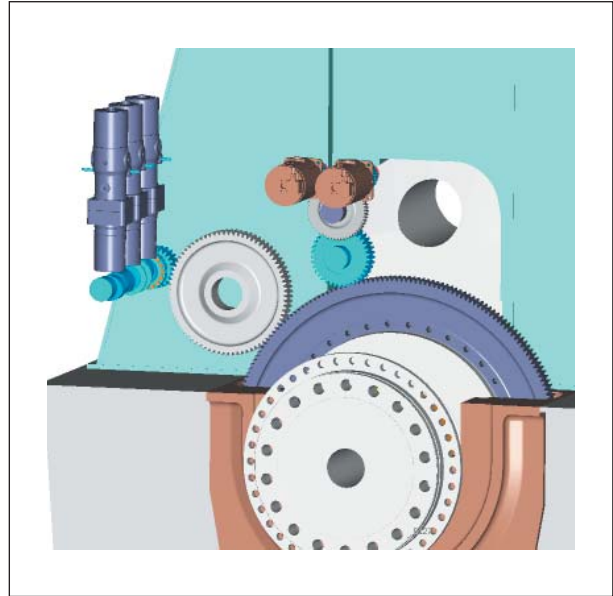


Fig. 5: Arrangement of RT-flex fuel supply pumps (left), servo oil pumps right (right) and their gear drive from the crankshaft without the housings. [07#261]

units, etc.

Fuel consumption flexibility

RT-flex engines have lower fuel consumption at part loads compared with conventional camshaft-type engines. In addition, an alternative fuel consumption curve is available as standard, through Delta Tuning, to give even lower brake specific fuel consumption in what is for many ships the main operating range.

Delta Tuning takes advantage of the complete flexibility in engine setting provided by the common-rail system to optimise fuel injection pressures and timing, and valve timing at all loads to lower specific fuel consumption in the mid- and low-load operating range below 90 per cent engine power. The consequent increase in NO_x in that operating range is compensated by reducing NO_x emissions in the high load range.

Environmental compliance

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

In addition, the flexibility of the RT-flex system in optimising the fuel injection and exhaust valve processes facilitates the ready compliance of the engines with the current NO_x regulation of Annex VI of the MARPOL 73/78 convention, together with enabling the engines to use Delta Tuning for improved part-load fuel saving.

Very slow running

RT-flex engines are able to run very stably at very low speeds, slower than camshaft-type engines. They can run without smoking at about 10–12% nominal speed. This is made possible by precise control of injection, optimised injection pressures, optimised valve timing, and shutting off individual injectors at low speeds.

Design summary

The engine structures of the new 820 mm-bore engines are based on well-proven concepts, with a 'gondola'-type bedplate surmounted by a very rigid, monobloc double-walled column and a cast-iron monobloc cylinder block, all secured by pre-tensioned vertical tie rods. The whole structure is very sturdy with low stresses and high stiffness. Both bedplate and column are welded fabrications which are also designed for minimum machining.

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

The double-walled column has thick guide rails for greater rigidity under crosshead shoe forces.

The dry cylinder jacket is a single-piece cast-iron cylinder block with a high rigidity. The cylinder liners are seated in the cylinder block, and are sufficiently robust to carry the cylinder covers without requiring a support ring. A light sleeve is applied to upper part of each liner to form a water jacket around the respective liner. Access to the piston under-side in the cylinder jacket is normally from the front 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 in a very compact and thus stiff housing. Owing to the use of gear wheels for the supply unit drive in the RT-flex engines, the thrust bearing can be very short and very stiff.

Running gear

The main, bottom-end and crosshead bearings are all of white metal on steel shells. Each main bearing cap is held down by four hydraulically-tensioned elastic holding down studs. The main bearings have thin shells with thick white-metal layers, whereas the thin shells of the connecting rod bottom-end bearings have thin white-metal layers.

The crosshead bearing is designed to the same principles as for all other RTA and RT-flex engines. It also features a full-width a lower half bearing with the crosshead pin being of uniform diameter. The crosshead bearings have a lower thin shell lined with white metal for a high load-bearing capacity whilst the bearing covers themselves are lined with white metal. The two guide shoes are single steel castings with white metal-lined running surfaces.

The piston rod gland is of a proven design with highly-

effective dirt scraping action in the top part and system oil scraping ability in the lower part. The glands are provided with large drain areas and channels. System oil losses are minimised as there is substantially a complete internal recirculation of scraped-off oil back to the crankcase. Hardened piston rods ensure long-term stability in the gland behaviour.

RT-flex common-rail supply system

In the RT-flex82C and RT-flex82T engines, the fuel supply pumps and servo oil pumps are arranged on the after side of the aftermost column. They are driven by gearing from the crankshaft in two separate groups. The crankshaft gearwheel is mounted on the thrust collar. Separating the gear drives splits the drive torque, and thereby reduces the sizes of the intermediate gearwheels and their inertias. There are three to six fuel supply pumps vertically mounted in-line and driven at a multiple of the crankshaft speed with a single intermediate gearwheel from the crankshaft gearwheel. The numbers of fuel supply pumps and servo oil pumps depend on an engine's number of cylinders.

Bore-cooled combustion chamber

The well-proven bore-cooling principle is employed in the cylinder cover, exhaust valve seat, cylinder liner and piston crown to control their temperatures, as well as thermal strains and mechanical stresses (Fig. 6). The surface temperatures of the cylinder liner are optimised for good piston-running behaviour.

The solid forged steel, bore-cooled cylinder cover is secured by eight hydraulically-tensioned elastic studs. It is equipped with a single, central exhaust valve in Nimonic 80A alloy which is housed in a water-cooled, bolted-on valve cage of grey cast iron. The exhaust valve is hydraulically actuated and has an air spring. The cylinder cover also carries the electronically-controlled air starting valve.

Three fuel injection valves are symmetrically arranged in each cylinder cover. Each fuel injection valve is separately supplied and controlled from the common-rail system. 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 very short skirt. The pistons each have three piston rings, all of which are pre-profiled and have a chrome-ceramic coating (Fig. 7). The short skirt is equipped with two bronze rubbing bands. The piston and its short skirt are secured to the piston rod from below by hydraulically-tightened bolts. The pistons continue with the well-proven combined jet-shaker oil cooling of the piston crown which provides optimum cooling performance. It gives very moderate temperatures on the piston crown with an even temperature distribution right across the crown surface.

Piston-running features

The time between overhaul (TBO) of low-speed marine diesel engines is today largely determined by the piston-

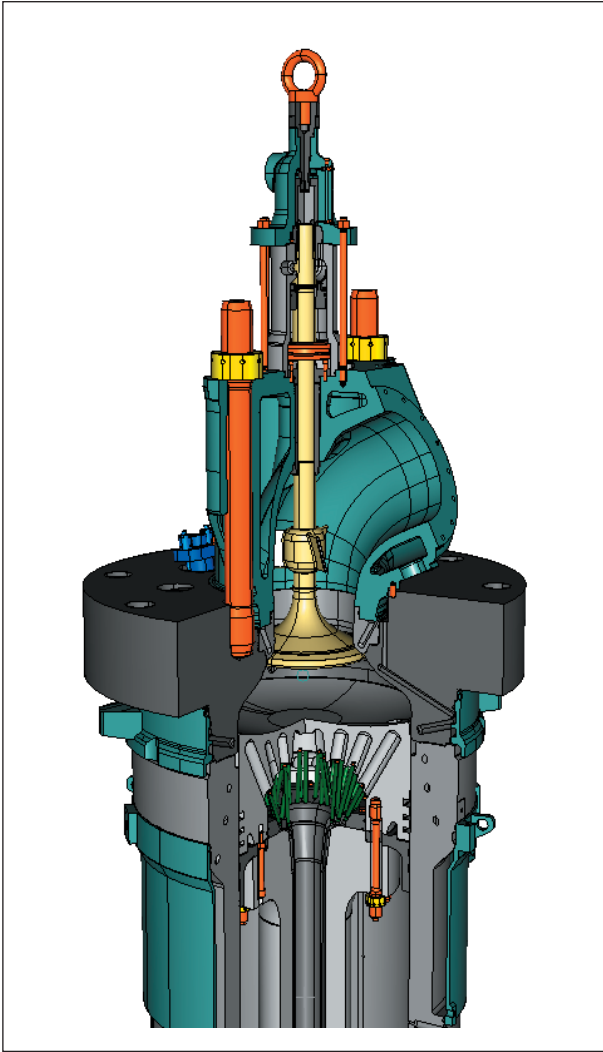
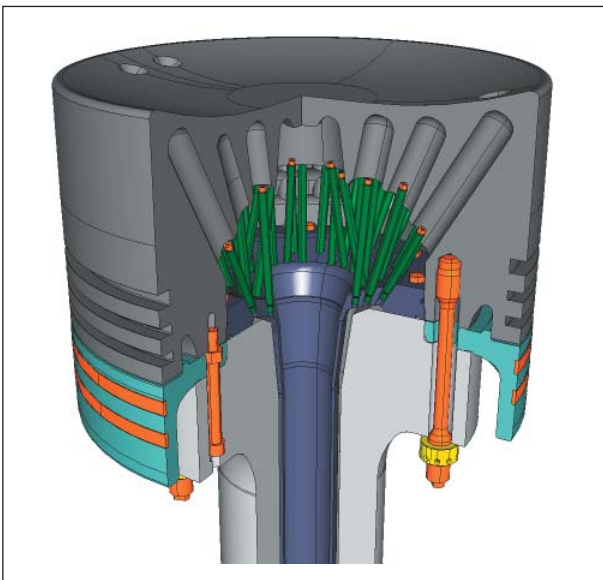


Fig. 6: Cutaway view of the combustion space showing bore-cooled exhaust valve seat, cylinder cover, cylinder liner and piston crown.
[07#259]

Fig. 7: Cutaway of piston showing the arrangement of oil spray nozzles and cooling bores for jet-shaker cooling.
[07#260]



running behaviour and its effect on the wear of piston rings and cylinder liners. For this reason, the new 82 cm-bore engines incorporate a package of proven design measures that enable the TBO of the cylinder components, including piston ring renewal, to be extended to at least three years, while allowing a low cylinder lubricating oil feed rate.

The standard design measures applied to these engines for excellent piston-running behaviour include:

- Liner of the appropriate material
- Careful turning of the liner running surface and deep, plateau honing of the liner over the full length of the running surface
- Chromium-ceramic coated, pre-profiled piston rings in all piston ring grooves
- Anti-Polishing Ring (APR) at the top of the cylinder liner
- Ample thickness of chromium layer in the piston-ring grooves
- Wärtsilä Pulse Lubricating System for cylinder lubrication.

A key element is the deep-honed liner. Careful machining and deep, plateau 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 would otherwise damage the oil film on the liner and cause bore polishing.

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

Wärtsilä Pulse Lubricating System

Cylinder lubrication is provided by the Wärtsilä Pulse Lubricating System (PLS) which provides the timely quantity of lubricating oil for good piston-running behaviour (Fig. 8). The lubricating oil feed rate is controlled according to the engine load and can also be adjusted according to engine condition. The guide feed rate with PLS is 0.7–0.8 g/kWh for engine loads of 50–100% and all fuel sulphur contents above 1.5%.

PLS is a new, electronically-controlled lubricating system to meet the demand from owners and operators for lower cylinder oil feed rates. It delivers reduced cylinder oil consumption without compromising piston-running reliability. As well as reducing operating costs, reduced cylinder oil feed rates are beneficial also for their significant influence on reducing air-polluting emissions in terms of particulate matter.

The cost savings achievable with PLS are significant. In the case of a Wärtsilä 12RT-flex82C engine of 54,240 kW maximum continuous output running at 85 per cent load

for 7000 hours a year with oil costing US\$ 1700/tonne, the reduction from the guide feed rate of 1.1 g/kWh (0.8 g/bhph) with the existing accumulator system to the PLS guide feed rate of 0.7 g/kWh (0.5 g/bhph) can generate cost savings of some US\$ 220,000 a year.

The reduction in cylinder oil feed rate allowed by PLS, compared with the existing accumulator system, is made possible through the improved distribution of cylinder lubricating oil to the cylinder liner, and the fully flexible, precise timing of oil delivery.

The key feature of the Pulse Lubricating System is that it delivers accurately metered, load-dependent quantities of lubricating oil to the cylinder liner running surface at the precise timing required. Electronic control ensures the accurate dosage and timing, with full flexibility in settings.

The 820 mm-bore engine types are equipped with eight lubricator quills. These deliver lubricating oil directly into the piston ring pack. Cylinder lubricating oil is supplied under pressure to the lubricators by a newly-developed dosage pump which is driven by pressurised servo oil, either from the RT-flex engine servo oil rail or, in RTA engines, a separate servo oil supply. The feed rate and timing of the cylinder oil are electronically controlled through a solenoid valve at the dosage pump. There is full flexibility in the volumetric metering of the cylinder oil delivery across the engine's load range. The dosage is

precisely regulated even for low feed rates.

Service experience with the Pulse Lubricating System has been very successful with excellent liner and piston ring conditions. Trials have been carried out both on the Wärtsilä RTX-3 research engine in Winterthur and on shipboard engines. The first production engine fully fitted with PLS successfully passed its shop test in May 2006, with other engines following. Since then, the PLS has been employed in newbuildings and retrofitted in existing engines.

The first PLS test started on the RTX-3 research engine in June 2003. Shipboard testing began with a Wärtsilä RTA58T engine in September 2004, followed by an RT-flex96C engine. Throughout, the outstanding performance of the Pulse Lubricating System was confirmed, with all testing being at or below the guide feed rate of 0.7–0.8 g/kWh.

Turbocharging and scavenging

The 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 two or three high-efficiency exhaust gas turbochargers depending on the numbers of cylinders. For starting and during slow running, the scavenge air delivery is augmented by

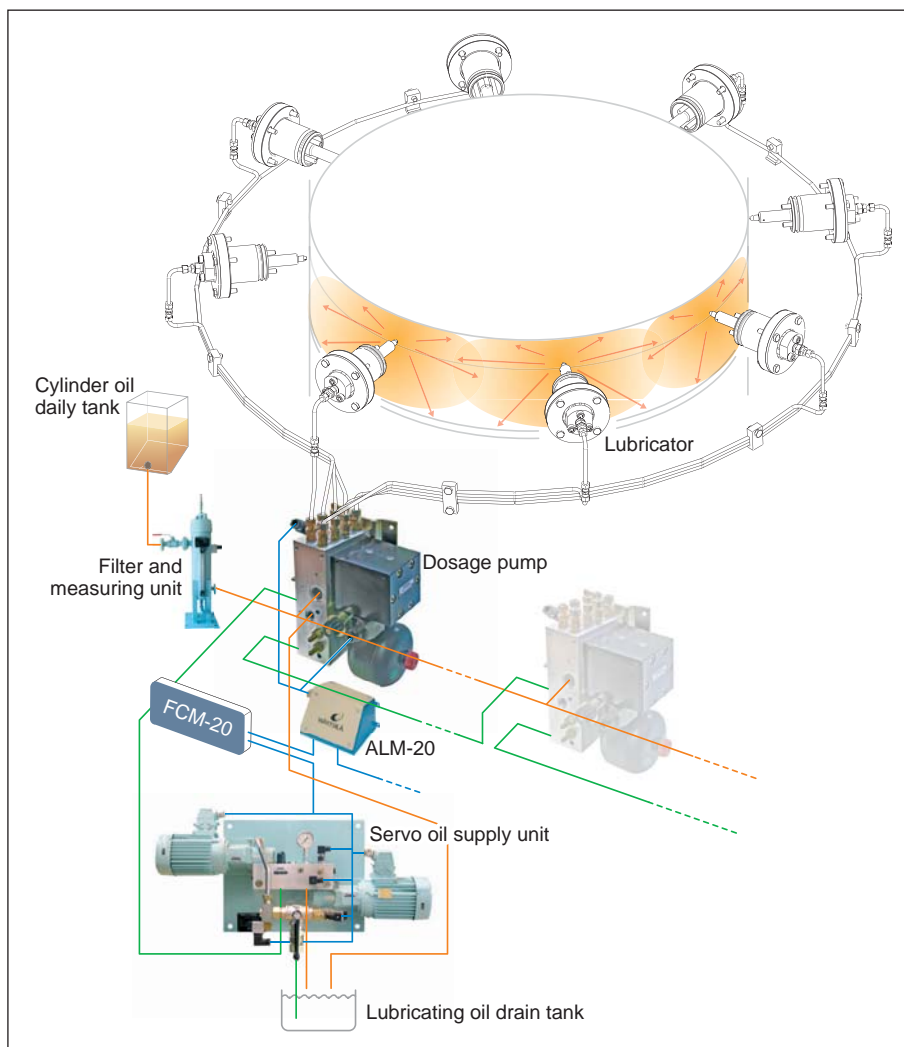


Fig. 8: General arrangement of the Pulse Lubricating System on one engine cylinder. The system shown is for RTA engines, with motor-driven servo oil pumps. In RT-flex engines, servo oil is drawn from the RT-flex servo oil supply. [07#269]

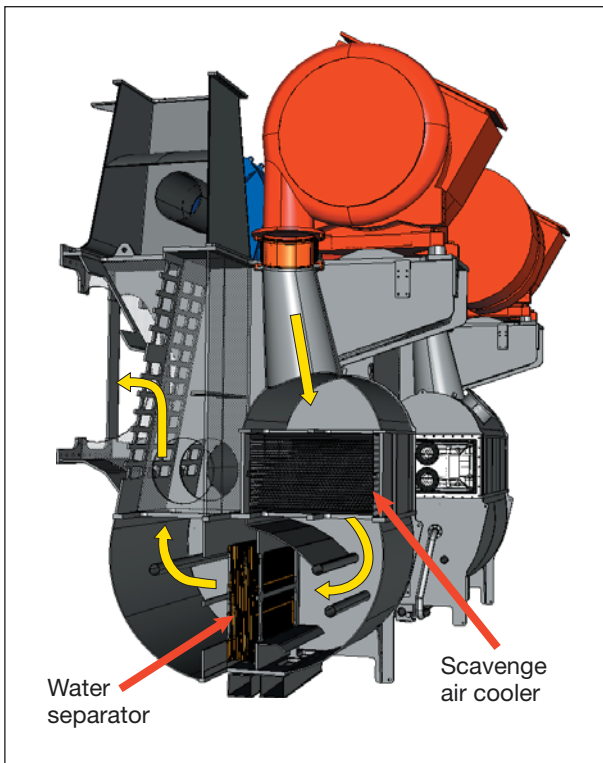


Fig. 9: General arrangement of scavenge air receiver, showing the air flow (yellow arrows) from the turbocharger and through the scavenge air cooler and water separator. [07#263]

electrically-driven auxiliary blowers.

The scavenge air receiver is of an underslung design with integral non-return flaps, air cooler, water separator and the auxiliary blowers (Fig. 9). The turbochargers are mounted on the scavenge air receiver which also carries the support for the exhaust manifold. The turbochargers, air coolers and air receiver are in a compact arrangement that allows optimum gas flows while minimising engine width.

Special attention has been given to removing water condensate before the scavenge air enters the cylinder. The high-efficiency water separator is provided with ample drainage. Immediately after the horizontal air cooler, the scavenge air is swung round 180 degrees to the engine cylinders, in the process passing through the vertically-arranged water separator. The highly-efficient water separator comprises a row of vanes which divert the air flow and collect the water. There are ample drainage provisions to remove completely the condensed water collected at the bottom of the separator. This arrangement

provides the effective separation of condensed water from the stream of scavenge air which is imperative for satisfactory piston-running behaviour.

Installation features

Careful attention has been given to facilitating installation of the engine in the ship. The seating involves a modest number of holding-down bolts and side stoppers, and there are no end stoppers, thrust brackets or fitted bolts. Thrust transmission is by thrust sleeves on a number of holding-down bolts. All ancillaries and their arrangement are optimised to reduce installation time and operating costs, with minimum electrical requirements.

First orders

By mid September 2007, the order book for the new 820 mm-bore engines had reached 70 engines with an aggregate power of about 2470 MW.

The orders include "82C" engines for panamax container ships as well as "82T" engines for very large tankers and ore carriers. They are split between about two-thirds as RT-flex versions and about one-third as RTA versions, and include seven-, eight- and ten-cylinder engines.

Conclusion

The new RT-flex82C and RT-flex82T common-rail engines, together with their more traditional RTA counterparts, are tailor-made as optimum prime movers for specific ship types. The extended layout fields also give the engines valuable additional flexibility to match them to the specific ship application. Yet as the engine designs are based on a 'platform concept' they will draw the significant benefits from sharing components between the two, '-C' and '-T' versions.

The engines will meet the market needs for highly economical operation, outstanding reliability, high efficiency, compactness, optimised industrialisation, and environmental requirements. As with all new marine engines nowadays, they will be fully compliant with the current NO_x emission regulation of Annexe VI of the MARPOL 1973/78 convention.

Particular attention is drawn to the new Pulse Lubricating System which brings major cost savings to ship owners and operators and is thus an important improvement for Wärtsilä low-speed marine engines. It is also an example of how electronic control can be applied to engine operation to give both improved engine performance and flexibility.



Published September 2007 by:
Wärtsilä Switzerland Ltd
PO Box 414
CH-8401 Winterthur
Tel: +41 52 262 49 22
Fax: +41 52 262 07 18
www.wartsila.com