



Faster Freight – Cleaner Air

February 25-27, 2008
Los Angeles

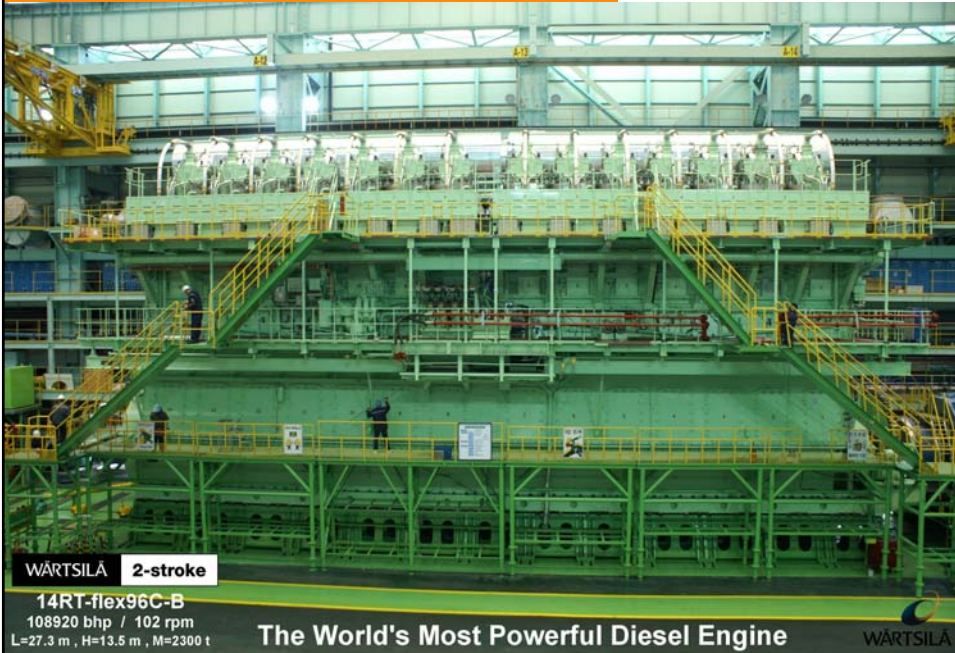
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Making the switch to low sulfur fuel

Agenda:

- Fuels of today
- Incompatibility of fuels
- Change – over between different fuels (high Sulfur - low Sulfur)
- Fuel Viscosity / Density
- Correlation between low sulfur fuel – Cylinder Lub. Oil BN and Cylinder Lub. oil feedrate
- Summary

Making the switch to low sulfur fuel



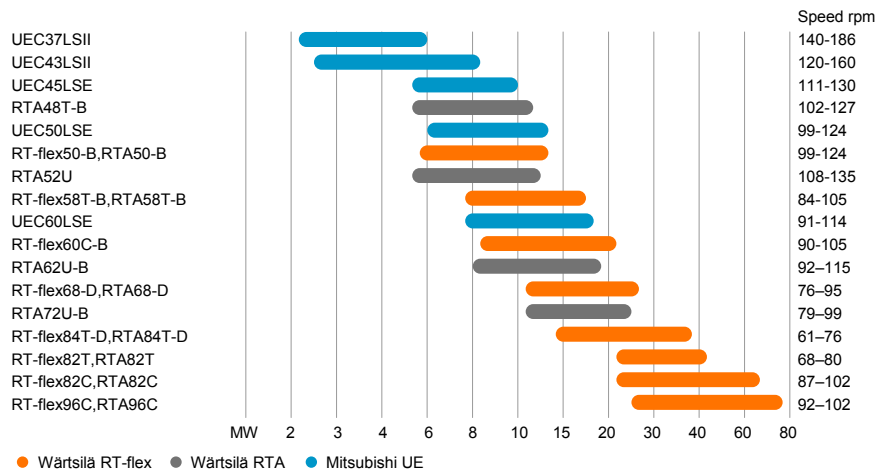
WÄRTSILÄ 2-stroke
14RT-flex96C-B
108920 bhp / 102 rpm
L=27.3 m, H=13.5 m, M=2300 t

The World's Most Powerful Diesel Engine

WÄRTSILÄ

Wärtsilä low-speed engines

Power range for low-speed engines



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50 bore DF Engine, 950 KW/Cylinder



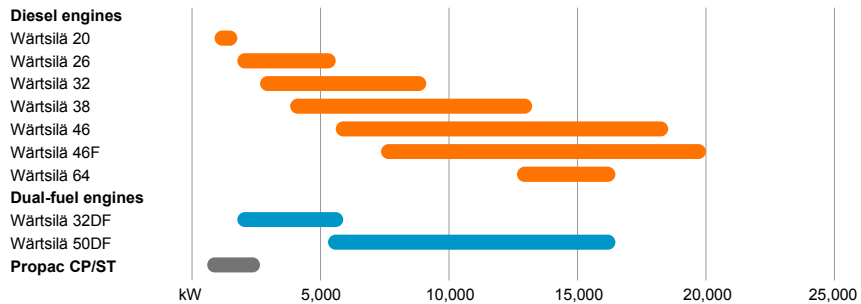
32 bore Engine, 500 KW/Cylinder



26 bore Engine, 340 KW/Cylinder

Wärtsilä medium-speed engines

Power range for medium-speed engines



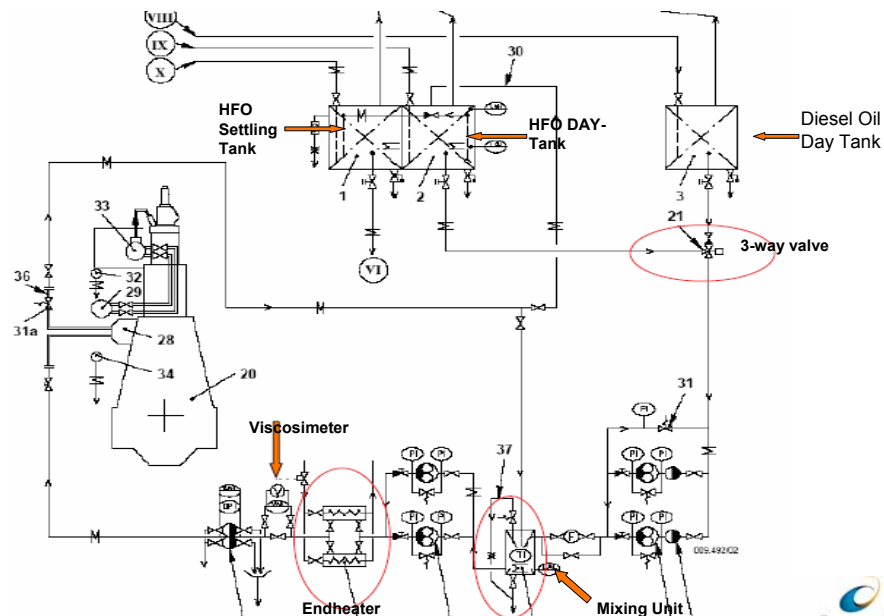
Wärtsilä diesel and dual-fuel medium-speed mechanical and diesel electric main engines and generating sets from 520 – 20,000 kW.

Making the switch to low sulfur fuel

As globally standardised terminology does not exist, the following abbreviations are used: ed:

Fuel type	Denomination	Other names	Sulphur content % m/m
HFO	Heavy Fuel Oil	Residual fuel oil, Intermediate fuel oil, Bunker oil	>1.5
LSHFO	Low Sulphur Heavy Fuel Oil	Residual fuel oil, Intermediate fuel oil, Bunker oil	<1.5
LFO	Light Fuel Oil	Marine Diesel Oil, Marine Gas Oil	0.2 ... 2.0
LSLFO	Low Sulphur Light Fuel Oil	Low Sulphur Marine Diesel Oil, Low Sulphur Marine Gas Oil	0.01 ... 0.2
ULSLFO	Ultra Low Sulphur Light Fuel Oil	Marine Gas Oil	< 0.01

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Incompatibility of Fuels

- Switching Fuel from HFO to a distillate fuel with low aromatic hydrocarbon contains the risk of incompatibility
- The asphaltenes contained in the HFO are likely to separate as heavy sludge, resulting in clogged up filters and possibly stuck fuel pump plungers
- Action to avoid problems
 - Use compatibility test kits on board
 - Guarantee from Fuel supplier that fuels used can be blended

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From the Operation Manual for Sulzer Type engines:

SULZER RT-flex96C	Operation	0270-1/A1
Operation Changing Over from Diesel Oil to Heavy Fuel Oil and Vice Versa		

- Continuous operation with heavy fuel oil is recommended....
- Changing over from HFO operation to MDO operation may only be undertaken when absolutely necessary for example by:
 - Flushing the engine before maintenance work
 - Heating plant switched off in the drydock
 - Environmental requirements

To ensure a safe change over, consider the following items:

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Changing over from heavy fuel oil to diesel oil

Plant side:

To change over from normal heavy fuel oil service to diesel oil, the three way valve 21 has first of all to be repositioned accordingly. This results in a mixture of heavy fuel and diesel oil in the mixing unit 24. The viscosity of the circulating mixture at a certain temperature drops quickly corresponding to the increasing share of diesel oil. After a short period the heating can be shut off.

Engine side:

- The trace heating on the engine (supply unit and fuel rail) must be shut off at the same time when changing over from heavy fuel oil to diesel oil in the plant.
- A complete change over takes appropriately longer if the engine is running at low load.



Attention! Running on diesel oil and with turned on trace heating is extremely dangerous for the engine!

- Before stopping the engine, changing over must be completely finished, avoiding a mixture of diesel oil and heavy fuel oil in the fuel rail which may cause viscosity problems during the next start.

It is recommended to change over from heavy fuel oil to diesel oil operation at less than 50% CMCR power.

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Plant side:

Changing over from MDO to HFO

After changing over the three-way valve 21 the result is a mixture of diesel oil and heavy fuel oil in the mixing unit 24. The viscosimeter controls the end-heater 26 in such a way that the required viscosity (preheating temperature) of the mixture is maintained. This preheating should be done only slowly (temperature rise max. 15°C/min.). Sudden temperature changes can lead to seizing of the fuel pump plungers.

The heating for the fuel filter 27 as well as for the fuel delivery and return pipes should be kept on, at least until the 'required preheating temperature' (read off at the thermometer before inlet to the fuel pumps) is reached.

Check fuel pressure after low pressure feed pump and at fuel pump inlet (see Operating Data Sheet 0250-1).

Engine side:

- The trace heating on the engine (supply unit and fuel rail) must be turned on at the latest when changing over from diesel oil to heavy fuel oil in the plant. All covers of the rail unit must be closed.
- If the engine room is completely cold the trace heating shall be turned on about one hour before changing over.
- Before stopping the engine, changing over must be completely finished, avoiding a mixture of diesel oil and heavy fuel oil in the fuel rail which may cause viscosity problems during the next start.

It is recommended not to exceed 75% CMCR load during changing over and until the required preheating temperature has been reached.

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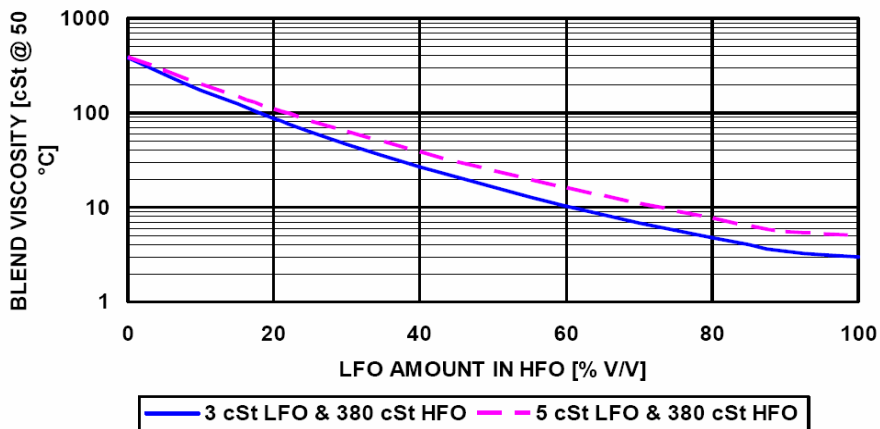
Engine Output / Engine speed relation

Propeller law, fix pitch propeller

Engine Output (%)	Engine Output / Engine speed Engine rpm (%)
100	100
90	96
75	91
50	79
40	74
30	67

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Fuel Viscosity versus blending ratio



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Low injection viscosity 4-stroke engines:

Normally not a problem, however when operating on a too low viscosity

- Injection equipment
 - Cavitations and lower structural damping, in worst case increased wear of components and increased risk for seizure of fuel injection pump
- Engine performance, minor predictable effects
 - Increased leak between the plunger and the barrels leads to changes in the running parameters, such as delay in the dynamic injection
 - prolonged injection, lower max pressures, lower NOx emissions
 - higher soot and CO2 emissions
 - higher exhaust gas temperatures, higher fuel consumption and higher amounts of leakage fuel
- Engine performance, less predictable effects
 - In exceptional cases increased vaporization of lighter fuel fractions
 - Reduced injection pressures and injected quantities
 - Increased pressure oscillation
 - Risk of cavitation damages in injection pumps and pipes and fuel nozzles
 - Risk for loss of capability to produce full power and possibly stalling, black out or starting problems

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Injection Viscosity

2- and 4-stroke engines

Engine type	Minimum fuel injection viscosity, cSt
Wärtsilä 20	1.8
Wärtsilä 26	2.0
Wärtsilä Vaasa 32/32LN	2.0
Wärtsilä 32	2.0
Wärtsilä 38	2.0
Wärtsilä 46	2.8
Wärtsilä 64	2.8
Sulzer S20	3.0
Sulzer Z40, ZA40, ZA40S	2.0

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Low Injection Density:

Energy content of the fuel, effect on automation settings:

- 4-stroke engines:
 - reduced energy content per stroke of fuel pump resulting in reduced output at any fuel rack position
 - Depending on engine type, the actual difference between LFO and HFO can typically be approximately 6-15%
- 2-stroke engines:
 - In general pump index limitations are not an issue
 - Under normal circumstances the torque – and charge air limiter have sufficient margin
 - Under severe condition such as a combination of an old engine with worn injection pumps, inappropriate adjustments, extreme weather conditions and operated on distillate fuel these limiting devices may limit the available engine power. We strongly recommend to check the engine condition if operation in rough sea areas on distillate fuel is foreseen (Maintenance)

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Low Lubricity:

- Based on Wärtsilä's experience, lubricity is not considered a problem for 4-stroke fuel injection components as long as the Sulfur content is above 100ppm (0.01%)
- At the time of writing documented experience about fuels with lower S-content than 100ppm is not available. However in extreme cases a lubricity additive can be added to very low Sulfur fuels by the fuel manufacturer
- For two stroke engines it has not been considered an issue by itself

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Effect on Engine Performance

2-stroke engines

LSHFO + high BN

- LSHFO + 70BN ▶ risk for hard calcium carbonate deposits on piston crown land
- ▶ sudden sever wear

HFO + low BN

- HFO + 40BN ▶ risk of corrosion

Mitigation

- Different lubricant for > and < 1.5% S
- Tribopack
 - APR against high BN
 - Liner wall temperature optimized along full stroke, reduce sensitivity for low BN
- Change of feed rate justified in some cases

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Effect on Engine Performance

4-stroke engines

LSHFO + high BN

- LSHFO expected to have low amounts of ash constituents (vanadium, sodium, nickel)
 - ▶ deposits unlikely, especially with APR
- LSHFO expected to have high amounts of ash constituents + high specific lubricating Oil consumption
 - ▶ risk for deposits

HFO + low BN

- ▶ risk of corrosion

Mitigation

- Suitable BN (not too high, definitely not too low)
- Fuel and lubricating oil flexibility to avoid unsuitable combinations
- Monitor BN

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Summary:

- Exhaust gas emissions from marine engines will be further regulated, engine builders are developing and testing new technologies
- Low Sulfur fuel operation in sensitive areas will remain an alternative to other technologies once fully developed
- All Wärtsilä engines can be operated on low Sulfur fuel oil, minor difference in engine performance between low Sulfur fuel, Diesel Oil, Gas Oil and HFO
- Necessary precautions have to be taken by the operators, guidelines to operate on low Sulfur fuels are established, change over procedures and processes may have to be enforced depending the skills of the crew
- Quality of fuel remains an issue, the further development of low Sulfur fuel to ensure good quality needs to be monitored

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?? Questions??

