THE DUAL FUEL TECHNOLOGY

SHIP POWER
Introduction

- Gas Engine technologies
- 4-stroke Dual fuel
- 2-stroke R&D Dual fuel
- Integrated products
- Engine conversion
Shipping until now…
Shipping from now on...

Established Emissions Controlled Areas

Emissions Controlled Areas under consideration

Shipping critical points
Fuel prices

Fuel price [USD/MMBTU]
Content

• Introduction

• Gas Engine Technologies
  • 4-stroke Dual fuel
  • 2-stroke R&D Dual fuel
  • Integrated products
  • Engine conversion
## Dual-Fuel applications - References

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<tr>
<th>Power Plants</th>
<th>Merchant</th>
<th>Offshore</th>
<th>Cruise and Ferry</th>
<th>Navy</th>
<th>Others</th>
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</thead>
</table>
| DF Power Plant:  
  - 57 installations  
  - 225 engines  
  - Online since 1997 | LNGC:  
  - 121 vessels  
  - 481 engines | PSVs/FPSOs:  
  - 20 vessels  
  - 93 engines  
  - Online from 1994  
  - New orders:  
    - 1 Chem. Tanker  
    - 2 engines conv.  
    - Complete gas train  
    - Complete design | LNG ferries:  
  - 1 vessels  
  - 4 engines per vessel  
  - Complete gas train  
  - 2800 passengers  
  - In service early 2013 | Coastal Patrol:  
  - DF-propulsion  
  - DF main and auxiliary engines | TUG:  
  - 2 vessel  
  - 2 engines each  
  - Mechanical drive |
|               | Merchant | Offshore | Cruise and Ferry | Navy | Others |
|               | LNGC:  
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→ 6 segments → 210 installations → > 7’000’000 running hours
Gas burning technologies

Gas-diesel (GD) engines:
- Runs on various gas / diesel mixtures or alternatively on diesel.
- Combustion of gas, diesel and air mixture in Diesel cycle.
- High-pressure gas injection.

Spark-ignition gas (SG) engines:
- Runs only on gas.
- Combustion of gas and air mixture in Otto cycle, triggered by spark plug ignition.
- Low-pressure gas admission.

Dual-fuel (DF) engines:
- Runs on gas with 1% diesel (gas mode) or alternatively on diesel (diesel mode).
- Combustion of gas and air mixture in Otto cycle, triggered by pilot diesel injection (gas mode), or alternatively combustion of diesel and air mixture in Diesel cycle (diesel mode).
- Low-pressure gas admission.

Dual-fuel (DF) engines
Spark-ignition gas (SG) engines
Gas-diesel (GD) engines

20DF
32DF/34DF/50DF
34SG
32GD/46GD

The marine favourite technology?

**DUAL-FUEL (DF)**
Meets IMO Tier III

**SPARK-IGNITION GAS (SG)**
Meets IMO Tier III
No redundancy
No HFO flexibility

**GAS-DIESEL (GD)**
Does NOT meet IMO Tier III
High gas pressure
Otto or Diesel cycles: effects on NO$_X$

Big temperature difference → NO$_X$ formation!

- **Diesel**, max flame temp.
- **Otto**, max flame temp.
Wärtsilä’s choice

DUAL-FUEL (DF)
Meets IMO Tier III

1. IMO Tier III compliant
2. Low pressure gas
3. Fuel flexibility; GAS, MDO and HFO
### Technology in gas mode

<table>
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<tr>
<th>Technology in gas mode</th>
<th>Competitor</th>
<th>Wärtsilä Product</th>
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<tbody>
<tr>
<td>Spark ignited engine (Otto)</td>
<td>Rolls-Royce Bergen C26:33 and C35:40</td>
<td>W34SG and W50SG, not for propulsion applications.</td>
</tr>
<tr>
<td>Lean burn, low pressure, DF engine (Otto/Diesel)</td>
<td>MAN 51/60DF, 35/44DF Caterpillar DF, Himsen</td>
<td>W20DF, W34DF, W50DF Wärtsilä 2-S RT-flex50</td>
</tr>
<tr>
<td>High pressure gas injection (Diesel)</td>
<td>MAN ME G-I</td>
<td>W32GD (and W46GD) 4-stroke engine, not for marine applications.</td>
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Wärtsilä supplies the DF technology for marine use.
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• Engine conversion
Methane slip

- Oxidation of CH₄ requires t > 540° C
- Heavier CₙHₘ do oxidize at lower temperatures
- CH₄ is greenhouse gases listed in the Kyoto protocol
- Methane 25 times more harmful than CO₂
  - NG produces about 170-200 g/kWh less CO₂ than HFO
  - 6 g/kWh CH₄ (methane slip) gives 5-10% lower GHG
- Also Diesel engines burning MDO/HFO have a minor CH4 slip
  - <0,5 g/kWh
Introduction
Gas Engine Technologies
4-stroke dual fuel
2-stroke R&D dual fuel
Integrated products
Engine conversion
2-stroke GD-concept HIGH PRESSURE

Principles:

- Engine operating accordingly to Diesel process
- Injection of gas close to TDC. Air is completely compressed and, therefore, high pressure gas injection (300 bar) is required.
- No significant NO\textsubscript{X} reduction
- Requires SCR or EGR (not proven) in order to meet IMO Tier III levels

Direct injection, diffusion combustion

Scavenging/ compression
Pilot fuel & HP gas injection, ign
Expansion
Principles:

- Engine operating accordingly to Otto process
- Injection of gas at mid-stroke. Low pressure gas injection (<10 bar) sufficient
- High impact on NO\textsubscript{X} reduction
- Meets IMO Tier III without after treatment
Design requirements

1. To meet the Tier III NOx requirements
   • without after treatment of the exhaust gas
   yes!

2. Low pressure gas system (< 10 bar) and avoid compressor or cryogenic pump
   • lower Capex and Opex
   • lower parasitic load/better efficiency
   yes!

3. Dual Fuel capability
   • operation on either gas or HFO
   yes!
Design features:

- Wärtsilä two-stroke DF engines have the same footprint as a conventional HFO engine
- No SCR, Scrubber or EGR required in order to meet upcoming emission regulations
- No parasitic loads introduced thanks to low pressure gas injection
- No expensive installation features (HP cryo-pumps, HP evaporators, “heavy” double wall piping)
- Minimization of hazards thanks to low pressure gas injection
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A complete and modularized solution for LNG fuelled ships

A. Storage tanks
B. Evaporators
C. Dual-Fuel Main engine
D. Dual-Fuel Aux engines
E. Bunkering station(s)
F. Integrated control system
Complete solution – Viking Grace
Gas valve unit

- Regulating the gas pressure to the engine
- One unit per engine
- Enclosed type, no separate room needed
- Vertical and horizontal
- Less than 10m away from the engine
- Compact
- Integrated ventilation with the engine
Wärstila 4-stroke on a conventional ship

- Low pressure
- Simple installation
- Proven technology
- Common automation system
Wärtsilä 2-stroke on a conventional ship

- Low pressure
- Simple installation
- Same technology as 4-stroke
- Common automation system
Dual fuel engine portfolio

High efficiency
Low gas pressure
Low emissions, due to:
- High efficiency
- Clean fuel
- Lean burn combustion

Fuel flexibility
- Gas
- LFO
- HFO

Three existing engine models
- Wärtsilä 20DF
- Wärtsilä 34DF
- Wärtsilä 50DF
The 4-stroke portfolio

Wärtsilä 20DF
- 6L20DF 1.0 MW
- 8L20DF
- 9L20DF

Wärtsilä 34DF
- 6L34DF
- 9L34DF
- 12V34DF
- 16V34DF
- 20V34DF

Wärtsilä 50DF
- 6L50DF
- 8L50DF
- 9L50DF
- 12V50DF
- 16V50DF
- 18V50DF 17.55 MW

Electrical & Mechanical applications
Wärtsilä 20DF

Main data:
- Cylinder bore: 200 mm
- Piston stroke: 280 mm
- Cylinder output: 146/176 kW/cyl
- Engine speed: 1 000/1 200 rpm
- Mean effective pressure: 20.0 bar
- Regulation: IMO tier II & Tier III
- Methane number: > 70

The ideal choice for:
- LNG Feeder
- Jack-up
- Tugs
- Small cargo vessels
- Barges
- Small ferries
- As auxiliary engines combined with W34DF and W50DF-powered vessels
Main data:
Cylinder bore 340 mm
Piston stroke 400 mm
Cylinder output 435/450 kW/cyl
Engine speed 720/750 rpm
Mean effective pressure 20.0/19.8 bar
Regulation IMO Tier II & Tier III
Methane number > 70

The ideal choice for:
- Small LNG / CNG vessel
- Small cargo vessels
- Supply vessel
- Offshore application / Production
- As auxiliary engines combined with W50DF - powered vessels
Main data:
Cylinder bore  500 mm
Piston stroke  580 mm
Cylinder output  950/975 kW/cyl
Engine speed  500/514 rpm
Mean effective pressure  20.0 bar
Regulation  IMO Tier II & Tier III
Methane number  > 70

The ideal choice for:
• LNG / CNG carrier
• Cargo vessels
• Offshore production
• Ferries
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**Engine conversion, Services**
Convertable products

Wärtsilä 20 Diesel → Wärtsilä 20DF
Wärtsilä 32 Diesel → Wärtsilä 34DF
Wärtsilä 46 Diesel → Wärtsilä 50DF
DF conversion – Parts to be exchanged

- Cylinder heads
- Turbochargers modified for DF operation
- Camshaft pieces for DF Miller valve timing
- Control system UNIC
- Dual-needle injection valve
- Connecting rods (upper part)
- Pistons & piston rings
- Cylinder liner & anti-polishing ring
DF conversion – Components to be added

- Exhaust gas waste gate
- Gas rail pipe
- Gas admission valves
- Pilot fuel system:
  - Pilot fuel oil filter
  - Common rail piping
  - Pilot fuel oil pump
Wärtsilä 4-stroke on an LNGC

- Low pressure
- Simple installation
- Proven technology
- Common automation system
Wärtsilä 2-stroke on an LNGC

- Low pressure
- Simple installation
- Same technology as 4-stroke
- Common automation system