Content

- 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]
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### Dual-Fuel applications - References

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
</table>
| **Power Plants**  | DF Power Plant  
57 installations  
225 engines  
Online since 1997 |
| **Merchant**      | LNGC  
121 vessels  
481 engines  
Conversion  
1 Chem. Tanker  
2 engines conv.  
Complete gas train  
Complete design |
| **Offshore**      | PSVs/FPSOs  
20 vessels  
93 engines  
Online from 1994  
New orders:  
Harvey Gulf; the first 5 LNG-PSV to be operated in the Gulf of Mexico! |
| **Cruise and Ferry** | LNG ferries  
1 vessels  
4 engines per vessel  
Complete gas train  
2800 passengers  
In service early 2013 |
| **Navy**          | Coastal Patrol  
DF-propulsion  
DF main and auxiliary engines |
| **Others**        | TUG  
2 vessel  
2 engines each  
Mechanical drive  
FPSO  
1 vessel  
6*18V50DF |

→ 6 segments → 210 installations → > 7’000’000 running hours
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.
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\textsubscript{x}

Big temperature difference → NO\textsubscript{x} formation!
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 comparison

<table>
<thead>
<tr>
<th>Technology in gas mode</th>
<th>Competitor</th>
<th>Wärtsilä Product</th>
</tr>
</thead>
<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>
</tr>
</tbody>
</table>

Wärtsilä supplies the DF technology for marine use.
• Introduction
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Methane slip

- Oxidation of CH$_4$ requires t > 540° C
- Heavier C$_n$H$_m$ do oxidize at lower temperatures
- CH$_4$ is greenhouse gases listed in the Kyoto protocol
- Methane 25 times more harmful than CO$_2$
  - NG produces about 170-200 g/kWh less CO$_2$ than HFO
  - 6 g/kWh CH$_4$ (methane slip) gives 5-10% lower GHG
- Also Diesel engines burning MDO/HFO have a minor CH4 slip
  - <0,5 g/kWh
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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

Scavenging/ compression  Pilot fuel & HP gas injection, ign  Expansion
2-stroke DF-concept LOW PRESSURE

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
   • lower Capex and Opex
   • lower parasitic load/better efficiency

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

3. Dual Fuel capability
   • operation on either gas or HFO
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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Wärtsilä – Your solution provider

SYSTEM INTEGRATION
Dual Fuel installation

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
Gas solution components

Main Engine

Gas Valve

GVU

Pressure build up evaporator

LNGpac

Bunkering line, insulated pipes

Bunkering Station

Water/Glycol system

Bottom tank filling

LNG – gas evaporator
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

Electrical & Mechanical applications

- 17.55 MW
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
Wärtsilä 50DF

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
Convertible products

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

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