The Wärtsilä low-speed, low-pressure dual-fuel engine

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The development path for gas powered Marine Engines

1972 – launching 7RNMD90 Low-Pressure DF Engine for 29,000 m³ LNGC, ‘MV Venator’ Moss Yard, Norway

1986 – testing High-Pressure DF Engine 6RTA84 at IHI, Japan

1992 – Low-Pressure Spark-Ignited Engine

1995 – Low-Pressure Dual-Fuel Engine
Break through in marine segment


1987 – High-Pressure Gas Diesel Engine

2013 – Low-Pressure Dual-Fuel Engine
RTX-5 test engine activities

- 6RT-flex50DF test engine in Trieste, Italy
- Gas trials on one cylinder in 2011 - 2013 for concept development, ~1000 rhs accumulated
- Full-scale testing started in August 2013, ~ 1050 rhs accumulated
- Engine performance confirmed
- Key advantages of the 2s DF technology successfully confirmed
- Exploration of further performance improvements ongoing
X72DF test engine in Diesel United

- **Strong support / interest from Japanese customers in 2sDF engines**
  → Cooperation with Japanese licensee Diesel United Ltd.

- **6X72DF test engine** will be installed at Diesel United’s facilities

- Engine start scheduled for **beginning of 2015**
  (engine production already started)

- **Main objectives:**
  - Additional test engine/facility
  - Further combustion and performance optimization, but on larger bore engine sizes, including fuel sharing mode

6X72, Doosan
Dual-fuel application references – medium-speed

Merchant
- LNG Carrier
  - 160 vessels
- Multigas Carrier
  - 7 vessels
- Ro-Ro
  - 2 vessels
- Bulk Carrier
  - 1 vessel
- Conversion
  - 1 vessel
- ~ 650 engines

Navy
- Coastal Patrol
  - DF-propulsion
- DF main and auxiliary engines

Offshore
- OSV’s
  - 31 vessels
  - 96 engines
- Production
  - 2 platform
  - 9 FPSO’s etc.
  - 1 FSO
  - 40 engines

Cruise & Ferry
- LNG Cruise ferry
  - 1 vessel
  - 4 engines
  - Complete gas train
- LNG ferries
  - 4 ferries
  - 18 engines
  - Conversion
  - 1 ferry
  - 2 engines

Power Plants
- DF Power Plant
  - 67 installations
  - 354 engines
  - Output 4600 MW
  - Online since 1997

Others
- TUG
  - 2 vessel
  - 2 engines each
  - Mechanical drive
- Guide Ship
  - 1 vessel /engine
- IWW
  - 2 vessel
  - 3 engines

→ 6 segments → >1,170 engines → >10,000,000 running hours
A few key technologies make the difference...

- Pilot common-rail system with pre-chamber injector
- Gas admission system
- Engine Control & Automation system
**Concept**

- Engine operating according to the **Otto process**
- Pre-mixed ‘**Lean burn**’ technology
- **Low pressure gas** admission at ’mid stroke’
- Ignition by pilot fuel in **pre-chamber**

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**Principles**

- 'Pre-mixed lean-burn' combustion

![Diagram](image_url)
Gas admission system

- Vent valves (NO)
- Gas admission valve (GAV)
- Shut-off valves (NC)
- DW gas pipes
- Sealing oil system
- Hydraulic pipes for GAV actuation
- Gas in
Pilot fuel system

Pilot injectors

High pressure pipes double walled

Pilot fuel pump module
Engine rating fields

Covered vessel segments:

- **LNG Carriers**
- **Container Vessels**
  1000 – 18000 TEU
- **Tankers**
  - Product
  - Aframax
  - Suezmax
  - VLCC
- **Bulkers**
  - Handysize
  - Handymax
  - Panamax
  - Kamsarmax
  - Capesize
  - VLOC
- **PCTC, CONRO**
Engine output in gas operation – X52DF, X62DF, X72DF

Methane number
- For the DF engine, actual output may be limited by Methane Number of the gas
- The graph is valid for any installation condition, i.e. from winter up to tropical condition

However:
- Typically, the MN of LNG is 70..100
- Typically, operating area for low speed engines is < 85% CMCR
- In case MN is too low, engine control system will automatically make the necessary adjustments or trip to diesel for 100% output
Fuel mode change

Diesel mode
- Running on MDO
- Transfer to gas operation at loads between 5 and 85%
- Pilot fuel injection in operation

Gas mode
- Automatic and instant trip to diesel operation in alarm situations
- Trip to diesel operation on request at any load
‘Port-to-port’ operation on gas

- Entire voyage in gas mode
  - Engine start on diesel for safety check
  - Transfer to gas at low load/idling
  - Transfer to diesel before stop
- In case of FPP, reversing/restart will be done on diesel, then transfer back to gas
- Engine Start/Stop in diesel according to the IGF-code (draft) and IACS rules.
Comparison LP vs HP engine emissions

- $\text{CO}_2$ and $\text{SO}_x$ reduced in gas operation due to fuel composition
- $\text{NO}_x$ very low with LP technology due to lower peak temperature
- PM further reduced by the DF technology with lean-burn Otto combustion with pre-chamber ignition

$\text{NO}_x$ Tier III (2016) and $\text{SO}_x$ level in ECA (2015) are fully met!
Safety aspects - Principles

Goal
Ensure **safe handling of gas fuel under all operating conditions**, to minimize the risk to the ship, persons on board and to the environment.

- **Gas safe machinery space**
  - Single failure will not lead to gas release into machinery space

- **Dilute possible ignitable gas concentrations** to levels below the lower explosion limit (LEL)

- **Limit consequences** of explosions (worst case)
Safety aspects - Principles

Main systems to detect abnormal conditions
- Gas detectors (in double wall pipes, machinery space, on engine)
- Cylinder pressure sensor on each cylinder
- Gas admission valve monitoring
- Knocking sensor on each cylinder

Possible system reactions upon detection of abnormal conditions
- Balancing fuel/air ratio, balancing gas amount
- Trip back to diesel (back-up mode)
  - all gas pipes vented
  - no pressurized gas on engine

Safety principles as stipulated in the IGF-code (draft) and IACS rules
Machinery space concept – Gas safe engine room

- Forced engine room ventilation
- Double wall fuel gas pipe
- Gas venting pipe
- Annular pipe / GVU enclosure venting
- Piston underside gas detection

Engine room: gas safe area
- GVU enclosure
- Gas detector

From fuel gas supply system
Gas admission system

- Precise gas admission control – from full load to ‘idling’
- Valve operation monitored
- Inspection interval: 6,000 RH
- Overhaul/replacement: min. 18,000 RH
  Final value not yet defined, prolonged intervals are expected
Engine / exhaust system ventilation

Prevent accumulation of gas in the engine and exhaust system

- After emergency stop / shut down in gas mode
- Purging with engine auxiliary blowers
- Exhaust valves automatically opened
Dual-fuel engine machinery for Merchant Vessels

Low-speed DF main engine

- Single wall pipe on open deck
- Ventilated double wall piping following class rules for 'inherently safe engine room'
- Purging system for piping, GVU, tank,....

LNGPac
Cyl. tank IMO C-type

‘Tank room’ with 16 bar low-pressure pumps, evaporator, heater, valves, etc

Gas valve unit

Wärtsilä Package..... a complete and modularized solution for LNG fuelled ships

DF auxiliary engines

Gas valve unit

Low electrical energy consumption for gas feed
Gas supply system, type C DW tank

- Bunkering Station
- IMO type C <10 bar
- LNG tank < 700 m³ Double walled Vacuum insulated
- Cryogenic pumps
- LNG vaporizer & heater
- BOG heater
- Pressure reduction
- Shut off valve
- Tank connection Space

Low electrical energy consumption for gas feed

2SDF Main engine

16 barg 0-60°C

6 barg 0-60°C

22 © Wärtsilä

Low electrical energy consumption for gas feed
Gas Valve Unit

- Wärtsilä standardized and proven design applied
- Pressure regulation, gas filtering and safety valves included
- Emergency venting procedure and leakage test features introduced

(1) Gas inlet valve
(2) Gas filter
(3) Automatic shut-off valve
(4) Gas regulating valve
(5) Inert gas connection
(6) Venting line
Control layout

Propulsion control system

Engine safety system | Remote control system

Alarm and monitoring system

DENIS specification

Engine control system UNIC

Gas valve unit

FGSS

Project specific
Example: EEDI calculation for 50 ktdw Product Tanker

- Engine type: **5X62** (conventional engine) vs **5X62DF** (LNG-fuelled)
- CMCR - power: 9000 kW
- Vessel design speed: 14.5 kn (90% CMCR)

Energy Efficiency Design Index

- **5X62**: 5.532 g/kWh, HFO operation
- **5X62DF**: 4.501 g/kWh, LNG operation

18% lower with DF engine

Required EEDI: 5,586

Compliance Index: 99.9

Calculation ref: 202277
INTO the FUTURE - Baltic SO\(_2\)lution

- **Ship type**: 4 x 15,000 dwt Chemical Tankers, 14.5 kn (\(v_{\text{DES}}\))
- **Owner**: Terntank Rederi AS, Sweden
- **Shipyards / Class**: AVIC Dingheng Shipbuilding Co, China / BV
- **Vessel delivery**: Q2, 2016
- **Engine type**: Wärtsilä 5RT-flex50DF, CMCR of 5850 kW
  Wärtsilä CPP and PTO (PTI for 3 ships)
First coastal LNG Carrier with 2sDF engine

- **Ship type**: 14,000 m³ LNG Carrier, 15 kn \(v_{\text{DES}}\)
- **Owner**: Zhejiang Huaxiang Shipping Co., Ltd
  - Private shipping company
  - Major player in LPG transportation market
  - One of the operators of LNG transportation in China domestic water
- **Shipyards / Class**: Qidong Fengshun Ship Heavy Co., Ltd, / CCS
- **Vessel delivery**: 2015
- **Engine type**: Wärtsilä 5RT-flex50DF, CMCR of 6000 kW
First LNG-fuelled Container Feeder Vessel for Baltic Sea operation

- **Ship type**: 3 (+1+2) x 1400 TEU C/V, 18.5 kn ($v_{DES}$), iceclass 1A
- **Owners**: GNS Shipping / Nordic Hamburg, Germany
- **Charter**: Containerships, Finland
- **Shipyards / Class**: Yangzhou Guoyu Shipbuilding, China / ABS
- **Vessel delivery**: Q3, 2016

- **Engine type**
  - Wärtsilä 7RT-flex50DF
  - CMCR of 10070 kW
  - 6L20DF generating set
  - MCR of 1055 kW

CPP, PTO
First LNG Carrier with low-speed LOW-PRESSURE DF engines

- **Ship type**: 2 x 180,000 m³ LNG Carrier, 19.5 kn (v_{DES})
  Twin-skeg, twin-screw
- **Owners**: SK Shipping, Korea
  Marubeni Corporation, Japan
- **Charter**: Total SA, France
- **Shipyard / Class**: Samsung Heavy Industries, Korea / BV
- **Vessel delivery**: Q1, 2017
- **Engine type**: Wärtsilä 2 x 6X62DF main engines
  CMCR of 13450 kW each
  Wärtsilä 4 x L34DF gensets
Why to choose a Wärtsilä LP DF engine?

1) **Meets IMO Tier III** requirements **without** exhaust gas after-treatment due to lean burn Otto combustion process.

2) **Low CAPEX** due to **low pressure** gas supply system
   - Low pressure equipment (pumps, compressor, evaporator, piping, sensors, …)
   - No exhaust gas after treatment required

3) **Low OPEX** due to **high overall efficiency**
   - Lower electrical power demand
   - Lower maintenance cost
   - Lower gas leakage risk

4) **Full Wärtsilä Package** - Complete and modularized **solutions** for LNG fuelled ships

5) **Low pressure** - **The industry standard** with 4s gas engines: MAN, Cat/MAK, Rolls Royce, MTU, Mitsubishi, …
THANK YOU!

Wärtsilä
Leading gas applications in the marine market