WORKSHOP ON MODERNISATION OF DANUBE VESSEL FLEET

WÄRTSILÄ PORTFOLIO

Wärtsilä Ship Design – 18th April 2018

Krzysztof Czerski – GM Project Development
& Naval Architecture
• **Introduction of Wärtsilä**
  • Increasing public awareness of environmental issues
  • 6L20DF engines
  • Fuel Gas Supply System.
  • LNG Cargo Handling Systems.
  • Wärtsilä Ship Design & LNG Inland Water Tankers
  • Exhaust Gases Cleaning Systems
INTRODUCTION OF WÄRTSILÄ

GLOBAL PRESENCE

Global strategic footprint to meet customers’ demands

Close to the customer anywhere

Leading experts in LNG as cargo and as fuel

Approximately 18,000 professionals

In over 200 locations

In more than 70 countries

Services network
Production facilities (fully owned)
Production facilities (joint ventures)
A Comprehensive product portfolio

<table>
<thead>
<tr>
<th>AUTOMATION</th>
<th>BALLAST WATER MGMT</th>
<th>ENERGY STORAGE</th>
<th>ENGINES &amp; GENERATING SETS</th>
<th>EXHAUST GAS CLEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIFECYCLE SOLUTIONS</td>
<td>GAS SYSTEMS</td>
<td>INERT GAS SYSTEMS</td>
<td>NAVIGATION</td>
<td>POWER ELECTRIC SYSTEMS</td>
</tr>
<tr>
<td>INCL. WÄRTSILÄ GENIUS SERVICES</td>
<td>PUMPS &amp; VALVES</td>
<td>SEALS, BEARINGS &amp; Stern Tubes</td>
<td>SHIP DESIGN</td>
<td>SOLAR</td>
</tr>
<tr>
<td>PROPULSORS &amp; GEARS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THRUSTERS</td>
<td>WASTE, OIL &amp; FRESH WATER MGMT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SERVICES

We create lifecycle services with our customers, enhancing their businesses – whenever, wherever
INTRODUCTION OF WÄRTSILÄ - SERVICES

A broad range of expertise and services

LIFECYCLE SOLUTIONS INCL. WÄRTSILÄ GENIUS SERVICES
SERVICE PROJECTS
ENGINE SERVICES
TURBOCHARGER SERVICES

PROPULSION SERVICES
SEALS & BEARINGS SERVICES
HYDRO & INDUSTRIAL SERVICES
TRAINING SERVICES
ENERGY SOLUTIONS

We are a leading global systems integrator offering a broad range of environmentally sound solutions.

Our flexible and efficient solutions provide superior value to customers and enable a transition to a more sustainable and modern energy system.
ENERGY SOLUTIONS A GLOBAL SYSTEMS INTEGRATOR FOR GREENER AND MORE EFFICIENT ENERGY SYSTEMS

LNG INFRASTRUCTURE

ENGINE POWER PLANTS

SOLAR PV AND ENGINE-SOLAR HYBRID POWER PLANTS
MARINE SOLUTIONS

We are the leading provider of innovative products and integrated solutions in the marine and oil & gas industries. As a leader in our fields, we need to continuously develop and transform ourselves to meet changing customer needs. We have a passion to do right for our customers and the environment.
• Introduction of Wärtsilä
• **Increasing public awareness of environmental issues**
• 6L20DF engines
• Fuel Gas Supply System.
• LNG Cargo Handling Systems.
• Wärtsilä Ship Design & LNG Inland Water Tankers
• Exhaust Gases Cleaning Systems
ENVIRONMENTAL CHALLENGE

**NO\textsubscript{x}**
- Acid rains
  - Tier II (2011)
  - Tier III (2016)

**SO\textsubscript{x}**
- Acid rains
  - Sulphur content in fuel from 2015 worldwide

**Particulate matter**
- Direct impact on humans
  - Locally regulated

**CO\textsubscript{2}**
- Greenhouse effect
  - Energy Efficiency Design Index (EEDI)
ENVIRONMENT: IS SHIPPING CLEAN?

**CO₂ in grams emitted per 1 ton of carried goods per 1 km**

- **Ocean (Avg. ML-owned vessels)**: 8
- **Rail Electric (Global average)**: 18
- **Rail / Diesel**: 21
- **Truck**: 47
- **Air (Boeing 747-400)**: 560

16 largest ships emit as much SOx as all 800 million cars in the world.
One ship can emit as much as 5000 tons of sulphur per year.

Source: The Guardian
• Introduction of Wärtsilä
• Increasing public awareness of environmental issues

**6L20DF engines**
• Fuel Gas Supply System.
• LNG Cargo Handling Systems.
• Wärtsilä Ship Design & LNG Inland Water Tankers
• Exhaust Gases Cleaning Systems
NATURAL GAS AS MARINE FUEL

Carbon content of common fuels

Source: ADEME (2015)
HOW TO BURN THE GAS IN ENGINES

GAS DIESEL
- Not IMOTier III
- HP gas system
- Redundancy

SPARK GAS
- IMOTier III
- LP gas system
- No redundancy

DUAL FUEL
- IMOTier III
- LP gas system
- Redundancy
WARTSILA 20 DUAL FUEL EMISSIONS – CONTINUOUS IMPROVEMENT

Methane emission

- 2014: 67%
- 2019: 20%

NOx emission

- 2014: 30%
- 2019: 30%

Particle Emission

- 2014: 40%
- 2019: 67%

=> Wartsila Dual Fuel Engines – NRMM STAGE V compliant (without after treatment)
LPG CARRIER
Owner: Chemgas Shipping BV
Yard: Chemgas Shipping BV
Capacity: 2620 CBM
Amount of vessels: 2

1 x W8L20DF (ME)

INLAND CARGO VESSEL (IWW)
Owner: Combi International B.V.
Yard: Koedood Dieselservice B.V.
Capacity: 348 TEU
Amount of vessels: 1

2 x W6L20DF (ME) (LNG retrofit)
WÄRTSILÄ 4&6L20 ENGINES – RIVER ICE BREAKERS
• Introduction of Wärtsilä
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• 6L20DF engines

**Fuel Gas Supply System.**

• LNG Cargo Handling Systems.
• Wärtsilä Ship Design & LNG Inland Water Tankers
• Exhaust Gases Cleaning Systems
WÄRTSILÄ LNG PAC – COMPLETE GAS FUEL SYSTEM FOR SHIP

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
Total number of vessels equipped with Wärtsilä LNGPac™*: 83
Total number of LNGPac™*: 92

Total volume: 26,180 m³

Number of vessels in operation: 27
Number of vessels confirmed and/or under construction: 56

**Owner country**

<table>
<thead>
<tr>
<th>Country</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Dredger</td>
</tr>
<tr>
<td>Canada</td>
<td>Fish Feeder</td>
</tr>
<tr>
<td>Germany</td>
<td>Offshore special</td>
</tr>
<tr>
<td>Norway</td>
<td>Passenger</td>
</tr>
<tr>
<td>Sweden</td>
<td>Product Tanker</td>
</tr>
<tr>
<td>UAE</td>
<td>PSV</td>
</tr>
<tr>
<td>USA</td>
<td>RoPax</td>
</tr>
<tr>
<td>UK</td>
<td>RoRo</td>
</tr>
<tr>
<td>Finland</td>
<td>Tug</td>
</tr>
<tr>
<td>Spain</td>
<td>Special vessels</td>
</tr>
<tr>
<td>Denmark</td>
<td>Windfarm</td>
</tr>
</tbody>
</table>

* Includes also LNG fuel gas tank deliveries of Hamworthy as cargo or tank handling system
<table>
<thead>
<tr>
<th>IMO C-type LNG-tank</th>
<th>Double-wall tank</th>
<th>Single-wall tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG Volume</td>
<td>25 – 300 cbm</td>
<td>300 – 5000 cbm</td>
</tr>
<tr>
<td>Dmax (2 &lt; L/D &lt; 7)</td>
<td>6.5 m</td>
<td>10 m</td>
</tr>
<tr>
<td>Design pressure</td>
<td>4 – 9 barg</td>
<td>4 – 7 barg</td>
</tr>
<tr>
<td>Insulation</td>
<td>Vacuum</td>
<td>PUR</td>
</tr>
<tr>
<td>Tank type</td>
<td>Single lobe</td>
<td>Single/Bilobe</td>
</tr>
<tr>
<td>Positioning</td>
<td>Horizontal or Vertical, Top- or Below-deck</td>
<td></td>
</tr>
<tr>
<td>Secondary barrier</td>
<td>Not required</td>
<td></td>
</tr>
<tr>
<td>Bunkering capacity (DN 50-200)</td>
<td>40 – 1000 cbm/h</td>
<td></td>
</tr>
</tbody>
</table>
DOUBLE SHELL TANKS

50m³ to 250 m³
DOUBLE SHELL TANKS

50m³ to 250 m³

Bunkering Station

Process Control Automation & Interfacing

Tank Connection Space

Gas Valve Unit

Gas Valve Unit

Gas Valve Unit

Gas Valve Unit

Evaporator Heating Media Skid
SINGLE SHELL TANKS

250 m³ to 5000 m³
SINGLE SHELL TANKS

250 m³ to 1500 m³
PRISMATIC TANKS

3000 m³ and above

Process Control
Automation &
Interfacing

Bunker station

Gas compressor 8 bar
+ buffer tank (1000 l)
+ gas heater

Svanehoj pumps

Process skid

Gas
Valve
Unit

Glycol-Water
Heating media
skid

Workshop on modernisation of Danube vessel fleet – Wartsila Ship Design Poland - Krzysztof Czerski
Wärtsilä Gas Valve Unit enables:
Efficient space utilisation
Fewer interfaces
Increased reliability
Designs

GVU-ED
- Enclosed design
- Installation in safe area

GVU-OD
- Open Design
- Installation in dedicated area (hazardous area zone 1)

Both type of designs are available for
- 2-stroke engine applications
- 4-stroke engine applications
• Introduction of Wärtsilä
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**LNG Cargo Handling Systems.**
• Wärtsilä Ship Design & LNG Inland Water Tankers
• Exhaust Gases Cleaning Systems
HISTORY

Gas Reference - Highlights

- 50+ years of gas system delivery references of gas handling systems
  - systems and process design
  - Hardware design / manufacture / assembly
  - naval architecture (ship integration)
  - installation, commissioning & start-up

LPG/LEG BUSINESS

- 325 CARGO HANDLING SYSTEMS BETWEEN 1963-2015
- 25 HC BLANKET & FLARE GAS RECOVERY SYSTEMS
- 10 SHIP-PSU BASED VOC RECOVERY SYSTEMS
- 4 SHORE TERMINAL VOC RECOVERY SYSTEMS
- > 150 FLARE GAS IGNITION SYSTEMS

LNG BUSINESS since 2002

- 43 LNG RELIQUIFICATION PLANTS
- 13 REGASIFICATION PLANTS
- 2 TERMINALS
- 4 SMALL SCALE ONSHORE LNG PLANTS

GAS RECOVERY BUSINESS since 1998

- 43 LNG RELIQUIFICATION PLANTS
- 13 REGASIFICATION PLANTS
- 2 TERMINALS
- 4 SMALL SCALE ONSHORE LNG PLANTS

- 25 HC BLANKET & FLARE GAS RECOVERY SYSTEMS
- 10 SHIP-PSU BASED VOC RECOVERY SYSTEMS
- 4 SHORE TERMINAL VOC RECOVERY SYSTEMS
- > 150 FLARE GAS IGNITION SYSTEMS

- BIOGAS LIQUIFICATION PLANT DELIVERED 2013

- SMALL SCALE LNG PLANT DELIVERIES 2003, 2007 and 2010

- 2017 FIRST LNG BUNKERING BARGE w. SHELL
- 2015 1965
- 2010 1970
- 2008 1980
- 2000 1986
- 2012 1990
- 2015 2018
LNG will evaporate at -163°C, and will expand with increasing temperature. Expansion and boil-off gas needs to be handled by onboard systems.

BOG Management Options
1. Pressure build-up; warm LNG and high pressure?
2. Fuel supply to engines; changing composition?
3. Reliquefaction; CAPEX,
4. Gas Combustion Unit; flexible, changing composition, uneconomical?

Considerations
- Required voyage time?
- LNG Quality?
- Supply requirement of LNG (temperature / pressure)?
- Loading limit requirements?
- Size / type / number of engines and fuel demand?
- Tank design pressure?
- Vapour management and vapour return?
## Case study: 3k LNG Bunkering Barge for European Inland Water Ways

<table>
<thead>
<tr>
<th>Owner</th>
<th>LNG Shipping (Victrol and CFT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>LNG Bunkering Barge</td>
</tr>
<tr>
<td>Cargo</td>
<td>LNG</td>
</tr>
<tr>
<td>Financier</td>
<td>Shell</td>
</tr>
<tr>
<td>Ship Size</td>
<td>3 000 CBM</td>
</tr>
<tr>
<td>Shipyard</td>
<td></td>
</tr>
<tr>
<td>Scope of supply</td>
<td>Cargo Handling System</td>
</tr>
<tr>
<td></td>
<td>Cargo Tanks</td>
</tr>
<tr>
<td></td>
<td>LNG Metering system</td>
</tr>
<tr>
<td>Ship design</td>
<td>INEC</td>
</tr>
<tr>
<td>Class</td>
<td>BV</td>
</tr>
<tr>
<td>Ship dimensions (LxBxD)</td>
<td>110 x 15 x 11 m</td>
</tr>
<tr>
<td>Delivery</td>
<td>2018</td>
</tr>
<tr>
<td><strong>Cargo tanks</strong></td>
<td>Cylindrical</td>
</tr>
<tr>
<td></td>
<td>4x750 CBM</td>
</tr>
<tr>
<td><strong>Cargo tanks insulation</strong></td>
<td>Vacuum / perlite</td>
</tr>
<tr>
<td><strong>Tank pressure</strong></td>
<td>4 barg</td>
</tr>
<tr>
<td><strong>Loading limits</strong></td>
<td>MARVS / Trading patterns</td>
</tr>
<tr>
<td><strong>Boil-off rate (BOR)</strong></td>
<td>0.2 %</td>
</tr>
<tr>
<td><strong>BOG Management</strong></td>
<td>Subcooling / pressure build-up</td>
</tr>
<tr>
<td><strong>Loading rate</strong></td>
<td>1000 m3/hr</td>
</tr>
<tr>
<td><strong>Bunkering rate</strong></td>
<td>Up to 660 m3/hr</td>
</tr>
<tr>
<td><strong>Nitrogen system</strong></td>
<td>Membrane / shore</td>
</tr>
<tr>
<td><strong>Custody Transfer</strong></td>
<td>Static + dynamic</td>
</tr>
</tbody>
</table>
The design is a pressure tank allowing Boil-off Gas (BOG) handling by pressure build-up. Tanks are delivered with insulation.

Typical types of tanks:

- C-Type Cylindrical for LNG carriers up to 15000m³
- C-Type Bilobe for LNG carriers up to 30 - 40000m³
- LNGPac solutions - LNG fuel tanks with integrated Tank Connection Space

https://www.youtube.com/watch?v=0WbbfAIC-7I
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• **Wärtsilä Ship Design & LNG Inland Water Tankers**
• Exhaust Gases Cleaning Systems
Wärtsilä Ship Design develops your new **DESIGN CONCEPT** to meet market needs

- Increase crew comfort and safety
- Understanding customers needs and how to improve their business model
- Uses of new technologies
- Challenging status quo in the market perception of ship designs

**VALUE CREATION**

**WSD59 3K**

3,000m³ Coastal LNG Bunkering Vessel

- Wärtsilä 6L20 DF main generators for **maximum fuel savings** and reduced environmental footprint
- **Optimized hull and propulsion design**
- **Efficient cargo handling arrangement and reduced ballast water capacity**
- **Safe and crew friendly environments**
- **Responsibility centralised on a single supplier for equipment and design**
- **Smart maintenance and reduced operating costs**
**LNG RIVER TANKERS**

**Type:**
- WSD50 1.8K
- WSD50 3.6K
- WSD50 4.8K

**Images:**
- LNG River Tankers: WSD50 1.8K
- LNG River Tankers: WSD50 3.6K
- LNG River Tankers: WSD50 4.8K
## Main parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length o.a., LOA</td>
<td>109.90 m</td>
</tr>
<tr>
<td>Length b.p., LBP</td>
<td>107.35 m</td>
</tr>
<tr>
<td>Breadth, B</td>
<td>11.40 m</td>
</tr>
<tr>
<td>Depth, D</td>
<td>5.66 m</td>
</tr>
<tr>
<td>Cargo capacity, 100% fill</td>
<td>1,850 m³</td>
</tr>
<tr>
<td>Draught Design, $T_d$</td>
<td>2.70 m</td>
</tr>
<tr>
<td>Deadweight @ $T_d$</td>
<td>1,050 t</td>
</tr>
<tr>
<td>Main Engine 1x6L20DF</td>
<td>1,665 kW</td>
</tr>
<tr>
<td>Service speed</td>
<td>20 km/h</td>
</tr>
<tr>
<td>@ $T_d$, 90% MCR, 15% SM, no restricted depth</td>
<td></td>
</tr>
<tr>
<td>Daily Consumption LNG</td>
<td>4.2 t</td>
</tr>
</tbody>
</table>
WÄRTSILÄ’S INTEGRATION INTERFACES

Cargo and Ballast Control System
Motor Control Center
Power Control System
NavCom

Azimuth thrusters

Cargo Handling System
Equipment Delivery; Valves, Instruments, Gas Detection, Tank Monitoring, Cargo Piping

LNG Fuel Pumps

Engineering of all piping on deck and gas related systems

Nitrogen / Inert Gas Generator

Gas Fuel Supply System

Cargo Handling System: Arrangement, Design, Supervision & Commissioning

Cargo and Ballast Control System

Reliquefaction/Cargo Cooling Plant (OPTION)

Deepwell Cargo Pumps

Ballast Water treatment, bilge water separator, sewage treatment plant and fresh water generator

Ship Design: Conceptual and Class & Workshop Drawings.
Hull Model Testing Cargo Tank Design, Cargo Tank Delivery

Gas Fuel Supply System

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Gas Fuel Supply System

Cargo Handling System: Arrangement, Design, Supervision & Commissioning
COMPLETE DESIGN SCOPE

Initial Design
- General arrangement
- Building specification
- Hull form and hydrodynamics
- Stability
- Lightship
- Structural arrangement

Basic Design
- Structural drawings
- Arrangement drawings
- Ship common systems
- Final stability

Detail Design
- Production design
- NC cutting info
- Spool drawings
- Coordination drawings
Risk Management & efficiency

**PRODUCT & ENGINEERING**

- Less interface points
- E&A - fully integrated cargo handling & ship control
- Coordinated vessel and product development
- Wide range of BOG management solutions

**PROJECT EXECUTION**

- Avoid change order after contract
- Core competence of Gas Handling Systems within Wärtsilä Ship Design Team
- Wartsila as single project partner
- Save time by optimizing the engineering schedule

**VESSEL OPERATIONS**

- Streamlined digital operating system
- Userfriendly manual operations
- Fully automated engine management and cargo handling online performance reporting
We enable customer success by reducing risks related to time, cost and quality of construction through professional planning, communication and stakeholder management.

Over 50% of Wärtsilä business is run as projects
Over 3,000 projects under execution annually
Over 2,000 people involved in project management
Over 1,700 PMIS / PM Tool users
Over 300 certified project management professionals
Operations in over 70 countries in 300 locations
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SOLUTIONS TO FULFIL THE LIMITATIONS

... running on **HFO/MDO**
(S > 0,1%)

... running on **MGO**
(S < 0,1%)

... running on **LNG**

**DIESEL ENGINE**

**SCR** (NOx reducer)

**SCRUBBER** (SOx reducer)

**SCR** (NOx reducer)

**DF ENGINE**

---

IMO TIER III
SOx compliant
EPA compliant

No need for after treatment devices to be installed
• The Wärtsilä NOx Reducer (NOR) is designed by Wärtsilä and is based on selective catalytic reduction (SCR) technology.

• The NOR is optimized and validated for Wärtsilä medium speed engine portfolio for marine applications in terms of reliability, flexibility and size. It is available for both newbuild and retrofits and is compatible for operation on both distillate and heavy fuel oils.
Short and wide 2 layers vertical reactor

Short and wide 2 layers horizontal reactor

Long and narrow 3 layers vertical reactor

Long and narrow 3 layers horizontal reactor

REACTORS AVAILABLE IN DIFFERENT SHAPES FOR FLEXIBLE AND EASY INSTALLATION
Nitrogen oxides (NO\textsubscript{x}) are reduced into nitrogen (N\textsubscript{2}) and water vapour (H\textsubscript{2}O) using ammonia or urea at a suitable temperature on the surface of the catalyst.
Integrated SCR reactor with silencer

Integrated mixing duct and silencer
- Double pipe containing a reactive silencer element
- Tuned at the ignition frequency of an engine

Benefits:
- Utilizes the mixing duct length for sound attenuation
- Optimize installation and save space
THANK YOU!

Krzysztof Czerski
General Manager Project Development & Naval Architecture

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