Innovative propulsion concepts
June 2016, Volkmar Galke, GM & Head of Global Sales
Introduction WinGD
WinGD HQ in Switzerland (Winterthur) is the centre of excellence and a leading developer for low-speed 2-stroke marine diesel engines.

The company’s target is to set industry standards and to continue the long tradition of the Sulzer Diesel business which started in 1898.

Currently there are more than 350 people from 39 nations working in Winterthur and worldwide located subsidiaries.
Innovation leader with a long heritage

Since 1898

1911 Sulzer opened an experimental turbocharger plant
1915 Büchi's first prototype for turbocharged diesel engine was produced

1905
First reversing 2-stroke marine diesel engine

1912
First 2-stroke marine diesel engines in ocean-going ship

1936
Bore cooling concept invented

1946
First commercial turbocharged 2-stroke engine

2001
First series-built large marine engine in service with electronically-controlled common-rail systems

2011
Generation X Engines introduced with lower fuel consumption, higher power density and high efficiency

2013
First electronically-controlled low-pressure dual-fuel engine introduced: RT-flex50DF


1972
First mechanically-controlled low-pressure dual-fuel 2-stroke engine installed

1982
‘Super-long-stroke’ concept – the Sulzer RTA engine series

1986
High-pressure dual-fuel engine tested

2004
Waste Heat Recovery system with up to 12% recovered power introduced

2005
First 14 cylinder RT-flex96C engine introduced

2001
First series-built large marine engine in service with electronically-controlled common-rail systems

2011
Generation X Engines introduced with lower fuel consumption, higher power density and high efficiency

2013
First electronically-controlled low-pressure dual-fuel engine introduced: RT-flex50DF

2015
First X72DF introduced
Engine building at established licensees

2-stroke engines are manufactured at licensees located in major shipbuilding countries throughout the world.

- 18 licensees → 8 countries
Innovative Propulsion Concepts
Technologies allowing operating flexibility

“Where” flexibility comes from?

- Multi-fuels: MGO, Low Sulphur HFO, etc.
- Wet Technologies
- Exhaust Gas Recirculation
- Dual Fuel Technologies
- Engine Tunings

Engine Inlet

Engine Outlet

Engine Internal

Engine Data

Asset Management Tool

Scrubber
SCR
PTO / PTI
Engine Inlet
Mastering fuel diversity is key for future engines

- What:
  Flexible fuel market:
  - Development of a fuel injection system for **multi-fuel** purposes in most cost-effective manner & comply with regulations
  - 3 partnerships with leading institutions, sharing best practices (PSI, FHNW, OMT)
  - Studies expect HFO share between 50 to 70% by 2030 depending on global sulphur cap. Rest is mostly MDO/MGO and between 5-15% LNG

- Why
  Drivers:
  - Fuel demand to double until 2030 (LR)
  - Shipping industry must stay open for options (environmental legislations (ECAs) vs. sulphur cap vs. pricing vs. fuel availability)
## Future fuels define machinery requirements

### Fuels we are looking into

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Description</th>
<th>Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFO+Scrubber+SCR</td>
<td>Heavy Fuel Oil</td>
<td>Cheap, No technical changes</td>
</tr>
<tr>
<td>MGO+SCR</td>
<td>Marine Gas Oil</td>
<td>SECA compliance</td>
</tr>
<tr>
<td>MDO+SCR</td>
<td>Marine Diesel Oil</td>
<td>SECA compliance</td>
</tr>
<tr>
<td>SVO+SCR</td>
<td>Straight Vegetable Oil</td>
<td>SECA compliance, Small changes to furl system required, only</td>
</tr>
<tr>
<td>DME</td>
<td>Dimethyl ether</td>
<td>Low NOₓ, SOₓ, CO₂ emissions, Moderate changes to engine required, only</td>
</tr>
<tr>
<td>Bio Ethanol</td>
<td></td>
<td>Availability for cars in the US and Brazil</td>
</tr>
<tr>
<td>Bio Methanol</td>
<td></td>
<td>Non-Bio globally available, Simple handling compared to LNG</td>
</tr>
<tr>
<td>Biodiesel (FAME)+SCR</td>
<td></td>
<td>High feasibility for 1st &amp; 2nd generation, Moderate changes to engine required, only</td>
</tr>
<tr>
<td>Bio Methane (LNG)</td>
<td></td>
<td>Abundant, Mature technology, Compliant with NOₓ, SOₓ regulations, Already interest seen in the industry, Global LNG projects starting</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
<td>Safe storage and handling, Less costly and safer infrastructure over LNG</td>
</tr>
<tr>
<td>Pyrolysis Oil</td>
<td></td>
<td>Waste product</td>
</tr>
<tr>
<td>Hybrid Fuels</td>
<td></td>
<td>SECA compliance, Excellent ignition properties</td>
</tr>
</tbody>
</table>
Engine tunings for flexible engine operation and highest efficiency

Internal engine measure:
Tuning options enable specific needs to be met: Tier II compliance and optimal performance for various operational profiles, such as slow steaming, low load, partial load, and steam requirements.

**Standard**: high load tuning, Tier II compliant, optimised for engine loads above 90%.

**Delta**: part load tuning, Tier II compliant, optimised for engine loads between 75% – 90%.

**Delta Bypass**: part load tuning with lower BSFC < 50% load, Tier II compliant, optimised for increasing steam production > 50% engine load.

**Low load**: Tier II compliant, optimised for engine loads below 75%.

**TC cut off**: For multi-turbocharger configuration to reduce the engine’s fuel consumption at low loads.

**HP & LP SCR**: optimized Tier III tuning to minimize fuel consumption and compatible with all SCR suppliers.
Internal measures to optimize external components - hence overall efficiency

Steam Production Control (SPC) instead of switching boiler
Fuel consumption savings of 2-6 g/kWh (50-150 kUSD for std. Capesize)

Graphic showing BSFC effective vs. engine power % with different tuning configurations:
- X-engine Delta bypass tuning + Thermal boiler
- X-engine Delta bypass tuning with variable bypass open
- X-engine Delta bypass tuning reference

Variable exhaust gas bypass
Offering rating fields to operational needs

The X-engines

Flexible ratings for every need!

X35
X40
X52
X62
X72
X82
X92
### Generation X – Reference list

<table>
<thead>
<tr>
<th>X engine type</th>
<th>Vessel type</th>
<th>Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>X35</td>
<td>10-44K dwt Bulk Carriers</td>
<td>39 engines</td>
</tr>
<tr>
<td></td>
<td>11-22K dwt Chemical Tankers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1100 TEU Containerships</td>
<td></td>
</tr>
<tr>
<td>X40</td>
<td>38K dwt Bulk Carrier</td>
<td>1 engine</td>
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<tr>
<td>X52</td>
<td>56–88K dwt Bulk Carriers</td>
<td>27 engines</td>
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<tr>
<td></td>
<td>60K dwt Chemical Tankers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>115K dwt Product Tankers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>115K dwt Crude Oil Tanker</td>
<td></td>
</tr>
<tr>
<td>X62</td>
<td>150-210K dwt Bulk Carriers</td>
<td>46 engines</td>
</tr>
<tr>
<td></td>
<td>158K dwt Crude Oil Tankers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3800 TEU Containerships</td>
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</tr>
<tr>
<td>X72</td>
<td>250K dwt Bulk Carriers</td>
<td>73 engines</td>
</tr>
<tr>
<td></td>
<td>280-310K dwt Crude Oil Tankers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9'400 TEU Containerships</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14'000 TEU Containerships</td>
<td></td>
</tr>
<tr>
<td>X82</td>
<td>9'000 TEU Containerships</td>
<td>28 engines</td>
</tr>
<tr>
<td></td>
<td>11'000 TEU Containerships</td>
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</tr>
<tr>
<td></td>
<td>13'500 TEU Containerships</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20'700 TEU Containerships</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL** 214 X engines (ca. 5.8 GW)
Dual Fuel: The most flexible solution

Low pressure technology sets the standard

The Principle

- Engine operating according to Otto process
- Pre-mixed ‘Lean-burn’ technology => Tier III compliance
- Low-pressure gas admission at ‘mid stroke’ location (<16 bar)
- Ignition by pilot-fuel into pre-chambers
Low pressure technology sets new NO\textsubscript{x} standard

Dual Fuel technology is available today complying Tier III

2015
First factory acceptance test completed

Type Approval testing of first RT-flex50DF engines

2016
Sea trials of first RT-flex50DF engines:
- Small scale LNGC
- Product carriers

2017
Sea trials of first WX62/72DF engines:
- LNGC's

To be continued…
Fast engine reaction to fuel variation

Allows a simple, fast and reliable switching between fuels

- No engine stop needed to switch between the modes!
- No hardware modification required!
- The transfer from gas mode to diesel mode takes place within one revolution
- Transition from diesel to gas requires a gradual change of the fuels (last between 30 seconds and 1 minute)
Low pressure Dual Fuel engine ratings

Clean Combustion = Tier III compliant => The industry standard

![Graph showing engine ratings](image-url)
# Low pressure DF – Reference list

<table>
<thead>
<tr>
<th>DF engine type</th>
<th>Vessel type</th>
<th>Orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT-flex50DF</td>
<td>15K dwt Product Tankers</td>
<td>15 engines</td>
</tr>
<tr>
<td></td>
<td>1400 TEU Containerships</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14K cu.m. LNG Carriers</td>
<td></td>
</tr>
<tr>
<td>X62DF</td>
<td>180k cu.m. LNGC/twin screw</td>
<td>10 engines</td>
</tr>
<tr>
<td></td>
<td>174k cu.m. LNGC/twin screw</td>
<td></td>
</tr>
<tr>
<td>X72DF</td>
<td>174k cu.m. LNGC/twin screw</td>
<td>14 engines</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>39 DF engines (ca. 495 MW)</strong></td>
<td></td>
</tr>
</tbody>
</table>
Engine External
External solutions for variable emission modes

SCR for optimized internal combustion but Tier III compliance

RTA52U:
- 3x RoRo (Wagenborg, SWE), since 1999

RTX-5
- 1x 6RT-flex50 research engine (Wärtsilä, Trieste)

RT-flex58T:
- 1x 22.1kDWT MPP (China Navigation, Singapore)

W-X72:
- 2+2 Suezmax BC (AMPTC, EG)

Total: 5/9 engines delivered/on order
Two offerings for different operating patterns
Depending on NECA exposure duration

**HP SCR:**
pre-turbocharger

**LP SCR:**
post-turbocharger

Solution approved

Solution approved
Engine Data
Engine asset management tool: Value from data

Only collecting and storing data solves nothing

Data analytics

Connect and Collect data

Analyze data

Predict

Self-Learning

Continuous improvement

Machine-learning model

Streaming analytics

Analyze historical data

Connectivity

Standardization

Connect

Collect data
Instant engine support for variable scheduling

Online performance and condition monitoring to optimize the engine according to immediate vessel operation
Summary and conclusions

- The further evolution of environmental regulations in combination with changing market requirements is triggering substantial development efforts.

- Various technologies are applied and developed for achieving improved overall engine and propulsion systems performance and lower emissions with the focus on:
  - Conventional combustion process improvement (increase Pmax, injection system & strategy, etc.)
  - Fuel flexibility
  - SCR / EGR
  - Intelligent engine lifetime management

- The new Generation X Engine series is responding to the market need for highly efficient engines suitable for modern ship designs based on slim hulls and low rated speeds.

- WinGD has developed and delivered a new series of 2-stroke low pressure dual-fuel engines that is inherently Tier III compliant and offers full fuel flexibility.
Thank you