LPG and Wärtsilä’s Power Generation Applications

WLPGA Oceania Regional Summit

Suraj Narayan
Sales Director (MEA), Wärtsilä - Energy Solutions
LPG as fuel in Wärtsilä Gas Engine Power Plants

Our flexible, efficient and environmentally advanced energy solutions provide superior value to customers and enable a transition to a more sustainable and modern power system.
### Engine technology as a function of gas quality

**Methane Number relation to Gas Composition; Methane number is not the same as methane content!**

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>100%</td>
<td>97%</td>
<td>93%</td>
<td>90%</td>
<td>87%</td>
<td>85%</td>
<td>85%</td>
</tr>
<tr>
<td>Ethane</td>
<td>3%</td>
<td>5%</td>
<td>6%</td>
<td>7%</td>
<td>7%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>3%</td>
<td>97%</td>
<td></td>
</tr>
<tr>
<td>Butane</td>
<td>1%</td>
<td>2%</td>
<td>2%</td>
<td>1%</td>
<td>3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pentane</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Heptane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td></td>
</tr>
</tbody>
</table>

**Methane Number**

<table>
<thead>
<tr>
<th>Methane Number</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>...</th>
</tr>
</thead>
</table>

**Values presented for guidance only**

Exact values to be calculated by Methane Number calculator

If gas content of >C4 exceeds 1 vol-% contact Wärtsilä

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**SG engines**

- MN 100 ...55
- NG

**LPG**

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WÄRTSILÄ PROPRIETARY INFORMATION
Otto cycle combustion

Optimum performance for all cylinders

Knocking LPG

Operating window

Misfiring

BMEP Brake Mean Effective Pressure [bar]

Air / Fuel ratio

Thermal efficiency [%]

NOx emissions [g / kW h]

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LPG AS FUEL IN WÄRTSILÄ GAS ENGINE POWER PLANTS

WÄRTSILÄ 34LPG ENGINE

1. W9L34LPG, W16V34LPG, W20V34LPG approved for running on propane, efficiency >42% *) [fuel: propane minimum 97%; rest butane]
2. W34LPG can be run full power on natural gas with higher engine efficiency

<table>
<thead>
<tr>
<th>W34LPG</th>
<th>Power_{electrical} 50 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20V34LPG 7300 kW</td>
</tr>
<tr>
<td></td>
<td>16V34LPG 5840 kW</td>
</tr>
<tr>
<td></td>
<td>9L34LPG 3280 kW</td>
</tr>
<tr>
<td>Power_{electrical} 60 Hz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20V34LPG 7000 kW</td>
</tr>
<tr>
<td></td>
<td>16V34LPG 5600 kW</td>
</tr>
<tr>
<td></td>
<td>9L34LPG 3150 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>W34SG</th>
<th>Power_{electrical} 50 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20V34SG 9730 kW</td>
</tr>
<tr>
<td></td>
<td>16V34SG 7740 kW</td>
</tr>
<tr>
<td></td>
<td>9L34SG 4340 kW</td>
</tr>
<tr>
<td>Power_{electrical} 60 Hz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20V34SG 9340 kW</td>
</tr>
<tr>
<td></td>
<td>16V34SG 7430 kW</td>
</tr>
<tr>
<td></td>
<td>9L34SG 4170 kW</td>
</tr>
</tbody>
</table>

*) efficiency at gen terminals 0% tol
Fuel system - LPG

LPG storage tank
- Pressure vessel without thermal insulation
- Pressure as function of ambient temperature

Gas vents
- New location. Hazardous area to ground level.

Scope limit

Insulation
- Depending on ambient temp.

Main Shut-off valves

LPG vaporizers
- Primary heat source HT water

LPG pumps and pressure control

HT water

LPG and Wärtsilä’s Power Generation Applications
Proven Technology
211 plants with 874 engines producing 7670 MW

**Largest Plants**

- **Aliaga Industrial Park**
  - Aliaga Izmir, Turkey
  - 250.9 MW - 28xW20V34SG

- **UTE Linhares**
  - Linhares-Espirito Santo, Brazil
  - 204.0 MW - 24xW20V34SG

- **Pearsall Power Plant**
  - Pearsall, Texas, United States
  - 202.5 MW - 24xW20V34SG

- **United Ashuganj 200**
  - Ashuganj, Brahmanbaria, Bangladesh
  - 200.0 MW - 20xW20V34SG

- **PLN Arun**
  - Lhokseumawe, Aceh, Indonesia
  - 190.0 MW - 19xW20V34SG

- **Sasolburg**
  - Sasolburg, South Africa
  - 175.0 MW - 18xW20V34SG

- **Central Termica de Ressano Garcia (CTRG)**
  - Ressano Garcia, Mozambique
  - 174.6 MW - 18xW20V34SG

- **Antelope Station**
  - Abernathy, Texas, United States
  - 168.1 MW - 18xW20V34SG

- **Pltmg Bangkanai**
  - Karendan Village, Lahai District, Indonesia
  - 160.0 MW - 16xW20V34SG

- **Dedeli Enerji Afyon**
  - Afyon, Turkey
  - 126.5 MW - 13xW20V34SG
Press release

Wärtsilä’s first propane-fired project using two 20V34SG gas engines in El Salvador

Wärtsilä power plants now capable of running on propane

Wärtsilä Corporation, Trade press release, 6 November 2015 at 9:30 AM E. Europe Standard Time

Wärtsilä is expanding its Smart Power Generation portfolio by introducing the capability of using propane as fuel for power generation.
Applications
APPLICATIONS

Typical load profile

• Varying load demand => power plant will have to operate at varying loads; generating units would have to be started and stopped to optimize fuel efficiency.

• Effect of renewable generation => uncertainty!

Source: www.aemo.com.au
Characteristics of Smart Power Generation plants

**Multimode operations**
- Baseload
- Load following, peaking
- Regulation
- Fast reserve

**Agility of dispatch**
- Megawatts to grid in <1 minute from start
- <5 minutes to full load from start
- Fast shut down <1 minute
- Fast ramp rates up & down
- Unrestricted up/down times
- High starting reliability
- Remote operator access including start & stop
- Black start capability

**Low generation costs**
- High electrical efficiency
  - Quick dispatch with low CO2 emissions
- Wide economic load range
  - Multiple units
  - Any plant output with high efficiency
- No derating – higher dispatch
- Low maintenance costs, not influenced by cyclic operation
- Low/no water consumption

**High plant reliability and availability**
- Firm n-2 availability (n = no. of units)
- Typical unit availability > 97%
- Typical unit reliability ~ 99%
- Typical unit starting reliability > 99%

**Optimum plant location and size**
- Industrial outlook to the plant enables location inside load pockets i.e. cities
- Flexible, stepwise expandable plant size
  - Same high performance independent of plant size
- Low pipeline gas pressure requirement (5 bar)

**Low environmental impact**
- Low CO2 and local emissions even when ramping and on part load
- The best thermal technology to provide sustainable grid stability
Smart Power Generation technology enables transition to a sustainable power system
This is Wärtsilä

A global leader in advanced technologies and complete lifecycle solutions for the marine and energy markets
Our business areas

ENERGY SOLUTIONS

MARINE SOLUTIONS

SERVICES
A Comprehensive product portfolio

<table>
<thead>
<tr>
<th>AUTOMATION</th>
<th>BALLAST WATER MANAGEMENT</th>
<th>ENGINES &amp; GENERATING SETS</th>
<th>EXHAUST GAS CLEANING</th>
<th>GAS SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>INERT GAS SYSTEMS</td>
<td>NAVIGATION</td>
<td>OIL SEPARATION</td>
<td>POWER ELECTRIC SYSTEMS</td>
<td>PROPULSORS &amp; GEARS</td>
</tr>
<tr>
<td>PUMPS &amp; VALVES</td>
<td>SEALS, BEARINGS &amp; Stern Tubes</td>
<td>SHIP DESIGN</td>
<td>THRUSTERS</td>
<td>WASTE, OIL &amp; FRESH WATER MANAGEMENT</td>
</tr>
</tbody>
</table>
# Financial highlights

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2014</th>
<th>2013(^2)</th>
<th>2012(^3)</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order intake</td>
<td>4,932 MEUR</td>
<td>5,084 MEUR</td>
<td>4,821 MEUR</td>
<td>4,940 MEUR</td>
<td>4,516 MEUR</td>
</tr>
<tr>
<td>Order book at the end of the period</td>
<td>4,882 MEUR</td>
<td>4,530 MEUR</td>
<td>4,311 MEUR</td>
<td>4,492 MEUR</td>
<td>4,007 MEUR</td>
</tr>
<tr>
<td>Net sales</td>
<td>5,029 MEUR</td>
<td>4,779 MEUR</td>
<td>4,607 MEUR</td>
<td>4,725 MEUR</td>
<td>4,209 MEUR</td>
</tr>
<tr>
<td>Operating result (^1)</td>
<td>612 MEUR</td>
<td>569 MEUR</td>
<td>557 MEUR</td>
<td>517 MEUR</td>
<td>469 MEUR</td>
</tr>
<tr>
<td>% of net sales (^1)</td>
<td>12.2 %</td>
<td>11.9 %</td>
<td>12.1 %</td>
<td>10.9 %</td>
<td>11.1 %</td>
</tr>
<tr>
<td>Earnings/share, EUR</td>
<td>2.25 EUR</td>
<td>1.76 EUR</td>
<td>1.98 EUR</td>
<td>1.72 EUR</td>
<td>1.44 EUR</td>
</tr>
</tbody>
</table>

1) Figures exclude non-recurring items
2) Figures related to the statement of income in the comparison period 2013 have been restated due to the two-stroke business being classified as discontinued operations.
3) The figures in the comparison period 2012 have been restated during year 2013 according to the revised IAS 19.
Focus on research and development

• Strong emphasis on product and solution innovation, particularly in the areas of efficiency improvement, fuel flexibility, total cost of ownership, and the reduction of environmental impact
• Long-term co-operation with research institutes and partners
• R&D investments in 2015 EUR 132 million, representing 2.6% of net sales
• In 2015 Wärtsilä made 56 patents for new inventions

"Our market driven investments in R&D and our focus on digitalisation create a strong foundation for securing and strengthening our position at the forefront of technological innovation."

LPG and Wärtsilä’s Power Generation Applications
Production and services globally

- Services network
- Production facilities (fully owned)
- Production facilities (joint ventures)
RECAP

• Wärtsilä’s technology to run on LPG
• Proven references
• Smart Power Generation – high operational flexibility with high efficiency and low lifecycle cost
• Investment in R&D - forefront of technological innovation
• Wärtsilä’s lifecycle power solutions
• Global presence for local support