Technical Innovation for Floating LNG

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Snøhvit LNG barge
A precursor to FLNG
Extending current skills
Combining the experience

Snøhvit LNG - Hammerfest
- Process facilities built on floating barge – an FLNG precursor
- Compact layout
- Modularized and prefabricated facilities

Global floating production operations
- Floating production units in operation worldwide
- Offshore offloading in harsh conditions
- Gas processing and acid gas removal on floating unit
Snøhvit technology learning
Supporting FLNG development

- Snøhvit field development and Hammerfest plant – a full LNG value chain
- Direct feed to LNG plant from subsea wells
- Use of LM6000 aero derivative gas turbines
- Reinjection of CO₂ from feed gas
- Mixed refrigerant liquefaction process with sea water cooling
- Operation in harsh environment
Statoil FLNG concept development history

- **Kelp Deep** 4 Mtpa
- **Fylla/Snøhvit** 5 Mtpa
- **NnwaDoro** 6-8 Mtpa
- **Shtokman** 3 x 5 Mtpa
- **NnwaDoro** 6 Mtpa (incl. oil)

Timeline:
- 1985
- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011

Projects:
- **Snøhvit** 3 Mtpa
- **NnwaDoro** 6 Mtpa
- **Generic/Angola** 1 Mtpa
- **Generic HLG** 1.5 Mtpa
- **Feasibility** 2.5 Mtpa
- **Pre-FEED** 3.3 Mtpa
Statoil FLNG

- Developed to pre-FEED level
- Varying feed gas composition
- DMR liquefaction process with mechanical compressor drivers
- Side-by-side or tandem offloading
- External or internal turret
- Alternative lay-outs
- Developed in cooperation with major engineering contractor
- Supplier group participation

Statoil FLNG, base concept

<table>
<thead>
<tr>
<th>LNG Capacity</th>
<th>3.0 - 3.5 Mtpa</th>
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<tr>
<td>Overall length</td>
<td>425 m</td>
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<tr>
<td>Beam</td>
<td>65 m</td>
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<tr>
<td>LNG storage</td>
<td>225 000 – 275 000 m³</td>
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Acid gas removal
Sensitive to tilt and motions

Specification:
< 50 ppm CO\textsubscript{2} in treated gas

Example:
• 10 mole % CO\textsubscript{2} in the feed gas
• Bypass of more than 0.05% of gas flow gives off spec composition
Acid gas removal
Statoil safeguarding solution for FLNG

Standard Amine plant

Safeguarding solution (patent pending)

Typical design margins for FLNG
- Increase amine circulation
- Increase absorber diameter and height
- Increase number of beds
Cryogenic LNG heat exchanger
Sensitivity to tilt and motions

How will the heat exchanger performance be affected by tilt and motions?

Test program performed in co-operation with Linde Engineering 2003-2007

CFD model developed

Single bundle heat exchanger*

Multiple bundle heat exchanger**

* Courtesy of Linde Engineering
** Courtesy of Air Products
Video - Test heat exchanger in oscillation
Deep sea-water intake systems
Beneficial with low temperature cooling water

- Increased process efficiency
  - ~1% increased production/°C

Typical SW temperature profile

- Increased gas turbine power
  - Cooling of intake air
  - ~1.5% increased power/°C
Deep sea-water intake systems
Principle system configurations

SW risers through turret

Free hanging SW risers
LNG tandem offloading
Based on Statoil patents, licensed to OneSubsea

OCT system

Cryodyn flexible pipe
LNG side-by-side offloading
Based on Statoil idea – Development by MacGregor Pusnes & Statoil
Conclusions

• The realization of FLNG requires fit for purpose technologies

• Important focused technologies;
  – Cryogenic heat exchangers
  – Acid gas removal
  – LNG offloading
  – Deep sea water intake
  – Layout, process selection and safety

• FLNG concept development has been matured and a basic concept is selected
Technical Innovation for Floating LNG

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