Technology Status and Challenges for Floating LNG

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• What is Floating LNG? (FLNG)

• Technical challenges concerning FLNG
  – Offloading
  – Motion and tilt effects on process equipment

• Liquefaction process selection for FLNG
  – Boiling hydrocarbon refrigerants
  – Nitrogen expander

• Status of FLNG projects
What is a Floating LNG unit?

No FLNG unit built so far!
Advantage of FLNG

- Numerous stranded and remote gas fields
- Cheaper and faster in-yard construction than greenfield onshore
- No pipeline to shore, only riser required
- Also for fields where onshore development is undesired

- Why no FLNG at this point?
  - Easy fields developed with other solutions
  - First mover risk
Main technical challenges

• Effect of movement and tilt on critical equipment
  – Absorption/fractionation columns
  – Main cryogenic heat exchangers
  – LNG sloshing in storage tanks

• LNG transfer/offloading

• Safety/Safety distances

• Deep water sea-water intake and riser systems
Columns

• CO₂ absorber
  – Only very small gas bypass will give off-spec CO₂ level (50 ppm)
  – Offshore CO₂ absorber at Åsgard B performs satisfactorily – not relevant for LNG
  – Onshore CO₂ absorber experience from Hammerfest LNG
    -> No experience in “moving CO₂ absorber” for 50 ppm spec.
  – Special design will be needed for FLNG
  – Final CO₂ removal could be done in subsequent water adsorption system

• Fractionation/condensate stabilisation
  – StatoilHydro have experience with Condensate Stabilization column at Åsgard B

• A more systematic review on columns is needed
Main cryogenic heat exchanger

• StatoilHydro has pre-qualified the Spiral Wound Heat Exchanger (SWHE) for floating applications.

• Unique knowledge of SWHE and Plate-Fin Heat Exchanger from Hammerfest LNG

• Effect of tilt in liquid distributors need to be addressed
LNG offloading

• Tandem offloading by aerial pipe
  – Flexible pipes, Offshore Cryogenic Transfer (OCT)
  – Currently being developed in a JIP together with ExxonMobil, Shell, Chevron, Petrobras and StatoilHydro
  – Vacuum insulation
  – 16” inner pipe

• Other offloading concepts include
  – Traditional Chiksan (smooth sea only)
  – Floating hoses
  – Aerial composite hose
# Liquefaction process selection

<table>
<thead>
<tr>
<th>Type</th>
<th>Principle</th>
<th>Pros and cons</th>
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<tbody>
<tr>
<td>Gas expander cycles</td>
<td>Gas heating at linear gliding temperature and constant pressure</td>
<td>• Simple and compact&lt;br&gt; • Nitrogen not flammable and easy to produce&lt;br&gt; • Low sensitivity towards movement regarding two-phase flow refrigerant&lt;br&gt; • Lower efficiency, equipment in parallel</td>
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<tr>
<td>Cascade cycle</td>
<td>Pure refrigerants boiling at constant temperature at different pressure</td>
<td>• No issues with refrigerant distribution&lt;br&gt; • Extensive equipment count&lt;br&gt; • Flammable refrigerant + ethylene import</td>
</tr>
<tr>
<td>Mixed refrigerant cycle</td>
<td>Mixed refrigerant boiling at gliding temperature at constant pressure</td>
<td>• High efficiency&lt;br&gt; • Lower volume flow of refrigerant&lt;br&gt; • Requires refrigerant make-up of many components&lt;br&gt; • Refrigerant distribution in SWHE</td>
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Processes can also be combined
Advantages with expander processes

• Equipment
  – Simple and compact
  – Few parts and low CAPEX

• Distribution of refrigerant
  – No maldistribution issues as for two phase flow
  – Small or no sensitivity towards orientation or movement

• Refrigerant
  – Nitrogen not flammable and easy to produce

• Regularity
  – Simple design and automated operation
  – Fast start-up

Good alternative for smaller sized units
StatoilHydro FLNG concept history

1985: 3 MTPA
1998: 5 MTPA
2001: 6-8 MTPA
2003: 6 MTPA
2004: 6-8 MTPA
2006: 1 MTPA
2007: 1.5 MTPA

MTPA = million tons per annum
Other published FLNG concepts

Source: Internet
Project status

• Many concepts have been suggested, but no steel has so far been cut

• Most promoted concepts (all in FEED-status):
  – Shell/Technip/Samsung (has money and fields, recently announced FLNG off shore Australia, barge is 470 x 70 m)
  – Flex/Samsung (ship hull, generic + field specific modules)
  – Linde/SBM (strong player with Linde’s process and SBM’s FPSO experience)

• Technical challenges remain, but none considered show stoppers

Depletion of close-to-shore fields will force the development of more remote fields using FLNG