Lesson learnt from Aasgard - Development of new generation cooler

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Agenda

- Introduction
- Aasgard Subsea Compression Project
- Next Generation – Subsea Cooler
**Advanced Subsea Production**

Typical Subsea Process Block Diagram - Building Blocks

1) Gas Processing
   - Gas Treatment
   - Gas Liquid Separation

2) Oil-Water Processing
   - Oil Water Separation
   - Oil Treatment
   - Water Treatment

3) Boosting
   - Compressor
   - Pump

Production → Host Facilities
Injection

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Subsea Technology Development Timeline

Concept

1985

1989-1993
Kværner Booster Station

1985
Conceptual development

Qualification

2001-2003
Demo 2000 GasBooster™ Qualification

2004-2013
Ormen Lange Subsea Compression Pilot
System Testing at Nyhamna

Project

2010-2015
Åsgard Subsea Compression system EPC

Next steps:
- Next Gen Compression System Development
- Next Gen Cooler
- Subsea Dehydration
- Gas Treatment – CO2 Removal

Operating since Sept 2015

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Åsgard Subsea Compression – Process System
Åsgard Subsea coolers

In Åsgard:
- Inlet/recycle coolers, multiphase, duty approx. 11 MW each
- Discharge coolers, single phase, duty approx. 8 MW each

Passive cooler module design is characterized by the following components:
- Inlet piping and header, ensuring even liquid/MEG distribution
- Cooler pipes, cooling the process fluid
- Structure, including sacrificial anodes
- Instrumentation, valves, connectors etc.

Based on experience from design, fabrication and operation there is potential for improvement to reduce size, weight and cost and at the same time improve the efficiency.
Cooler walls

Asgard cooler – no walls
- Natural convection
- Seawater can be drawn from the side – weakening the cooling
- Sea current may increase cooler performance – however lower predictability

With walls
- Enhanced natural convection (chimney effect)
- Better cooling performance
- Less susceptible to seawater current – leading to reliable cooling duty with increased predictability
Active vs Passive

Passive cooling
- Natural convection by seawater
- Chimney effect

Active Cooling
- Subsea pump (already qualified) is used to increase the seawater velocity hence the performance.
- Utilize baffles to channel the seawater through the cooler
- Incorporates louvers (open / close) in the lower section – to switch active / passive mode

Passive Cooler

Active Cooler

Louver operated by actuator
Aker Boxed Cooler

Key Features
• Reduced size, weight and cost
• Increase efficiency, especially for low process fluid temperatures
• Enable temperature regulation for more advanced cooling requirements i.e. hydrate control
• Standardized system solution both for active and passive cooler

Current Qualification Activities
• Qualify TSA coating system for cooler application
• Detail cooler design for constructability and fabrication (baffles, support, stacking, walls etc.)
• Develop solution for CP protection in a compact cooler
• Verify design tools to optimize cooler for efficient heat transfer with minimum pressure drop
• Cooler regulation (temperature control, response time, turndown)
Performance comparison

- The measured performance of the Åsgard Inlet Cooler is compared towards a CFD simulation of the new improved cooler (same operating case).

<table>
<thead>
<tr>
<th>Åsgard Inlet /Recycle Cooler</th>
<th>Åsgard 2.0 Inlet /Recycle Cooler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (L x W x H): 5.1m x 11.4m x 2.4m (140m³)</td>
<td>Dimensions (L x W x H): 4.5m x 4.9m x 2.3m (51m³) (-63%)</td>
</tr>
<tr>
<td># 3” pipes: 40</td>
<td># 3” pipes: 36</td>
</tr>
<tr>
<td>Pipe length: 85 m</td>
<td>Pipe length: 69 m</td>
</tr>
<tr>
<td>Outer surface: 950 m²</td>
<td>Outer surface: 784 m² (-17%)</td>
</tr>
<tr>
<td>Coating: Painted</td>
<td>Coating: TSA</td>
</tr>
<tr>
<td>OHTC: 260 W/m²K (Passive)</td>
<td>Minimum OHTC: 350 W/m²K (Passive) (+34%)</td>
</tr>
<tr>
<td>Pressure drop: 0.5 - 1 bar</td>
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</tr>
<tr>
<td>Design case: Compressor full recycle stream</td>
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</tr>
</tbody>
</table>
Summary

- Aker Boxed Cooler is technology development stemmed out of past project experiences
- A high efficiency cooler using proven cooler design
- Better temperature predictability / regulation
- Reduced size, weight and cost
Thank You!! Question?
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