The BP Valhall Field – 2/8 G7 Zonal Isolation

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Valhall Field

- Located in the North Sea
- 290 km offshore southern Norway
- 69m of water
- Discovered in 1975
- Started producing in October 1982
The Tor Formation

- Upper Cretaceous chalk reservoir
- NNW-SSE trending anticline
- Tor thickness varies from 0 to 80m
- Reservoir quality varies considerably
- up to 50% porosity
- 1 to 10 mD permeability
Waterflood Challenges 2/8 G-7

- Possible flow anisotropy and direction
  - Risk of premature water breakthrough along faults/fractures
- Water injectivity
  - Effect of pressure/temperature induced fracturing
- Effect of Water weakening of the Chalk
- Scaling
- Proactive Water management of unwanted water production
- Chalk influxes

This led to a requirement for a smart-type lower completion
• Reservoir management relies on multi-zone water injection

• Produced water isolation is achieved with an arrangement of heavy duty sliding sleeves

• Annular OH Zonal Isolation

• Sustainable Frac Pressure Differential
Valhall IP – Statement of Requirements

Producer Wells:
- Max DP for propped fracturing – 10,000 psi (Tip screen out 12,000 - 13,000 psi at liner with reservoir pressure of 3,000psi.)
- Max long term DP = 4,000 psi (6,000 psi injection finger with 2,000 psi BHFP)

Injection Wells:
- Max DP for hydraulic un-propped fractures 3 - 4,000psi
- Long term DP similar with intra-zonal pressure of 3 – 4,000 psi

General:
- Reservoir Pressure = 2,700 psi – 4,000 psi
- Reservoir Temp = 95degC, Bubble point 3350 psi, GOR = 914 scf/stb
- Fracture Temp = 20degC
- Initially for 8.5” hole but need to cope with hole sizes 8.5 – 9.5”
Valhall Specific Issues

- Pressure / Temp and Differential requirements
- Frac tip screen out pressure
- Strength of chalk formation
- Open hole / RIH constraints
- Acceptable Leak Rates
Development

- ZIB Material - Sanicro 28
- Seal material and design (reduced OD of end caps)
- In-house FEA for ZIB design
Expansion of ZIB with 10,400 psi internal applied pressure. The ZIB expanded as predicted by FE and demonstrated no leaks.
Valhall Closure Stress vs ZIB Forces

\[ y = 0.915x + 1534. \]
\[ R^2 = 0.931 \]

ZIB Final Inflation pressure can be set below the closure stress
### Results of ZIB Full Scale Testing

#### Zonal Isolation Barrier
ISO 14 310

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<th>5&quot;</th>
<th>5-1/2&quot;</th>
<th>6-5/8&quot;</th>
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</thead>
<tbody>
<tr>
<td>Base Pipe Size</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Running OD</td>
<td>6,200&quot;</td>
<td>8,190&quot;</td>
<td>8,190&quot;</td>
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<tr>
<td>Maximum OD after inflation</td>
<td>7,910&quot;</td>
<td>10,40&quot;</td>
<td>10,40&quot;</td>
</tr>
<tr>
<td>% Expansion of running OD</td>
<td>27,60 %</td>
<td>27,0 %</td>
<td>27,0 %</td>
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<tr>
<td>Delta P - hydrostatic / production (psi)</td>
<td>4 000</td>
<td>4 000</td>
<td>4 000</td>
</tr>
<tr>
<td>Delta P injection or frac (psi)</td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
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</table>
ZIB Advantages

- 10,000 psi rating during stimulation / injection & hydrostatic / production
- Pressure balance during frac process
- Not affected by temperature change
- Large expansion ratio (up to 40%)
- Minimal O/D for deployment
- Not affected by fluid type
- Provides metal barrier to flow (V0-classified)
- Anchoring force higher than thermally generated loads
Value for the Valhall field

• Able to drill longer reservoir sections without the worry of exceeding the reservoir formation breakdown pressure resulting from the high ECD’s while cementing

• Zonal selection improves PI and water-flood management capability to maximise recovery

• 10,000 psi differential pressure packer technology can be applied in both 8-1/2” and 6-1/2” OH sizes

• Robust and non complex zonal isolation solutions

• Design suits high frac pressures

• Scale able to differential completion sizes
Conclusion and Future Potential

- Robust and non complex zonal isolation solutions
- Design suits high frac pressures
- Scale able to different completion sizes
- Cement less completion
- Sand control applications
- Extension of ERD envelope
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