OIL & GAS

Risk-based abandonment of offshore wells
Examples and applications

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Content

- Re-introduction to DNV GL RP-E103
  “Risk based Abandonment of offshore wells”
- Case examples of alternative P&A designs
- Reflections on current use
Background of Knowledge

- DNV GL developed DNV GL RP-E103 “Risk based Abandonment of offshore wells
- Based on industry feedback through a first revision Guideline
- 2 OTC papers and presentations
- A large number of industry presentations
- Both high-level and detail dialogs ongoing with operators in the North Sea and worldwide
- Ongoing discussions with regulators
Rules and Regulations perspective

Norway’s regulations for petroleum operations offshore and on land are risk-based (ref. ptil.no)

UK Verification Scheme
- Performance standards
- ALARP principles

Netherlands
- “Goal setting” intention
- NOGEPA initiatives

- Industry standards, throughout the world, prescribe the number, type and size of the permanent well barriers.
- The standards differ throughout the North Sea alone.

ISO 16530 Well integrity series
- risk based P&A
Parallels to highway design code

- US highways are designed based prescriptive methods, such as xx" of cement.
- German highways are designed to withstand a certain number of years of service.
Are all P&A wells the same?
Environmental perspective reflections

- Oil from produced water released to the Norwegian Sector of the North Sea – 1800 tons in 2015 as a benchmark
  - Leak rates from case studies are significantly lower

- Natural seepage of gas in the North is a known phenomena, comparison with case studies
  - Methane release - 33,000 ton for NCS (2014)
  - Natural Methane Release
    - Scanner pockmark 50 Sm3/yr
    - Danish Kattegat 200 Sm3/yr

![Gas Rates compared with natural gas seepage](image)
Elements in well abandonment risk assessment

Well Abandonment Design

- Well barrier failure modes
- Flow potential
- Valued Ecosystem Components
- Dispersion modelling
- Impact analysis
- Risk analysis
- Risk evaluation
- Risk assessment
- Qualified well abandonment design

Identify failure modes for pathways

Potential rate with probabilistic modelling
Probabilities in the order of 10^{-4}
### Risk Evaluation Tool – Risk Matrix

<table>
<thead>
<tr>
<th>Reputation</th>
<th>Platform Safety Risk</th>
<th>Time &amp; Cost</th>
<th>Long-term Environment</th>
<th>Operational Risk</th>
<th>Increasing probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>I5</td>
<td>&gt; 1 kg/s hydrocarbons on platform</td>
<td></td>
<td></td>
<td>Loss of both barriers</td>
<td>1x10^{-4}</td>
</tr>
<tr>
<td>I4 Operator specific</td>
<td>&gt; 0.1 kg/s hydrocarbons on platform</td>
<td></td>
<td></td>
<td>Loss of one barrier</td>
<td>1x10^{-3}</td>
</tr>
<tr>
<td>I3 Operator specific</td>
<td>&gt; 0.01 kg/s hydrocarbons on platform</td>
<td>Operator &amp; Region specific</td>
<td></td>
<td>Uncertain well barrier condition</td>
<td>1x10^{-2}</td>
</tr>
<tr>
<td>I2</td>
<td>Undetectable hydrocarbons on platform</td>
<td></td>
<td></td>
<td>Negligible well integrity situation</td>
<td>5x10^{-2}</td>
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<tr>
<td>I1</td>
<td>No hydrocarbons on platform</td>
<td></td>
<td>No flow</td>
<td>No impact</td>
<td>1x10^{1}</td>
</tr>
</tbody>
</table>

- The proposed risk matrix is aligned with industry codes and operator best practice.

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1. Ref. NORSOK Z-013
2. Ref. NORSOK D-010
Case A

- Subsea Template, 360m water depth
- Oil production with two reservoir zones, where the lower completion is exposed
- 180 – 200 bar pressures for P&A
- Two overburden zones (gas, oil)
- Overburden pressure profiles were normal, but volume uncertain
- No significant annulus leakages were observed and recorded
- No migration of overburden fluids and no hydrocarbons observed in environment
Case A

- Analyses was run to identify and optimize the required minimum permanent well barrier length

Results

- Lowermost permanent barriers towards the reservoir should remain the same as regulations prescribed, minimum of 30m interval with acceptable bonding and casing cement verified by logging and a 50m interval of formation integrity, ref NORSOK D-010, rev 4.

- Lower overburden zone was analyzed to give a minimum of 15m interval with acceptable bonding and casing cement verified by logging (including safety factors and uncertainty in the analysis).

- Upper overburden zone the result was a minimum of 18m interval with acceptable bonding and casing cement verified by logging.
Case A

Surface barrier
Secondary barrier
Primary barrier

Primary barrier
Secondary barrier
Surface barrier
### Case A

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputation</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Platform Safety</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Time &amp; Cost</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Long Term Environment</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Operational</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

- The alternative P&A design was selected as the required permanent barrier lengths, which could be used operationally to simplify decision making and to potentially lower operational costs and well P&A time.
Case B

- Fixed platform (160m water depth), dry XT
- Injection well in oil reservoir, the well slot will be re-used and sidetracked
- Two potential reservoirs with high production indexes
- Annulus pressure buildup observed, signs of leakage in the lower scab pack liners
- Setting permanent barriers in the base is a challenge, straightforward for the alternative case
Case B

Surface barrier
Secondary barrier
Primary barrier
### Case B

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputation</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Platform Safety</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Time &amp; Cost</td>
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<td>Low</td>
</tr>
<tr>
<td>Long Term Environment</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Operational</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

- In this table, ALARP principles have been included to show the time & cost perspective.
- The most advantageous solution can then be selected, implemented and approved according to DNV GL-RP-E103.
Summary

- The methodology is in-use in the industry.
- Examples show that considerable savings can be achieved.
- DNV GL can assist in evaluating well abandonment design for optimization.
- “Fit-for-purpose ” designs can be used rather than “one size fits all.”
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