Charge testing for well concept selection

impact of gun selection on development concept

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Well concept evolution

- Netherlands / Southern UK sector scene setting
  - Mature area, remaining gas/oil accumulations small size (0.2 – 1 BCM)
  - Early 2000’s: “step change” in costs required

- Significant changes (down sizing) required in well design, rig selection, well functionality and surface lay-out in order to meet challenge
Well concept evolution – 1st step

Typical well data
- Reservoir depths: 2800-4600 mAH (1800 – 3500 m TVD)
- Reservoir pressure 250 – 360 bar (undepleted)
- Reservoir temperature 100 - 125 deg C
- Permeability: <1 - 50 mD, porosity 8 - 20 %, streaks with higher %

Typical features for new standard:
- Reduced csg sizes
- Simple wellhead
- 3½” cemented completion
- 2” perf guns, static balanced / slight underbalance for trigger interval

Concept worked for no. of years BUT further steps required to reduce costs/increase value.
Well concept evolution – step 1

Current base case

Proposed “slim” case, low permeability

Proposed “slim” case, high permeability

3 ½” tbg, cemented in 6” – or 4 7/8” OH

2” guns

2 7/8” tbg, cemented in 4 7/8”- or 3 15/16” OH

small guns: 1 9/16” or 1 11/16”

3 ½” * 2 7/8” tbg, cemented in 4 7/8”- or 3 15/16” OH

small guns: 1 9/16” or 1 11/16”
Case for charge testing:

Based on initial modeling, impact (Q/NPV) of changing to slim completion could be significant → needs further clarification

→ test DoP assumptions!!
Test set-up / test conditions

Field conditions

Overburden = approx 9200 psi (634 bar)

reservoir
UCS = 1000 – 2000 psi (70 – 140 bar)

Res Pressure = 4350 – 5000 psi (180 – 350 bar)

In order to mimic field conditions as good as possible selected the following parameters:

- Carbon Tan material (sandstone)
- Internal / confining stress
- Section 2 only, no flow conditions
- Various combinations OH size / tbg – and charge size
- Varying cement thickness

Charge testing conditions in lab

UCS of test sample
Internal Pressure

Confining stress on outside of the sample
Carried out some 33 tests (3 labs, test data randomly plotted !!)
Tests in 7” and 4” Carbon Tan cores, both centralised / excentralised.
In some tests free gun volume (FGV) reduced to minimise effect DUB (dyn underbalance)
Carried out some 17 tests (3 labs, test data randomly plotted !!)

Tests in 7” and 4” Carbon Tan cores, both centralised / excentralised.

In some tests FGV reduced to minimise effect DUB
Findings charge testing (1)

Further analysis of results

- For 3 ½” tbg geometry, impact cement thickness clearly seen in majority of tests (6” vs 4 7/8” OH, 4 7/8” vs 3 15/16” OH)

![Graph showing DoP impact cement thickness]
Well concept evolution – step 2 (ongoing)

Current base case

- 3 ½” tbg, cemented in 6” – or 4 7/8” OH
- 2” guns

Proposed “slim” case, low permeability

- 2 7/8” tbg, cemented in 4 7/8”- or 3 15/16” OH
- small guns not attractive.
- Alternative: use 2” guns*

Proposed “slim” case, high permeability

- 3 ½” * 2 7/8” tbg, cemented in 4 7/8”- or 3 15/16” OH
- Alternative: use 2” guns*

*: providing swell tests successful
Follow-up 1st test phase – 2” gun in “slim” configuration

Proposed “slim” base case

Data used in original modelling

NB: testing 2” charges in 2 7/8” tbg still in progress, includes swell tests under ambient conditions
Follow-up 1st test phase – 2” gun in “slim” configuration

Proposed “slim” base case

DoP 2” charge

Data used in original modelling

NB: testing 2” charges in 2 7/8” tbg still in progress, includes swell tests under ambient conditions
# Findings charge testing (2)

- Further analysis of results
  - 3 1/2” tbg configurations:
    - Centralisation / stand-off impact: significant and hence to be included, not directly included in original modeling
    - Overall “perforation efficiency” (OH tunnel length/TCP tunnel length) from tests some 80%, hence efficiency for actual field conditions lower → tentatively set @ 50%
  - 2 7/8” tbg configuration
    - Small charges disappointing, 2” prelim DoP data: as expected (still work in progress)

<table>
<thead>
<tr>
<th></th>
<th>DoP 2” charge</th>
<th>Small charge</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>vertical</td>
<td>Deviated</td>
</tr>
<tr>
<td><strong>6” OH</strong></td>
<td>9”</td>
<td>7.7”</td>
</tr>
<tr>
<td><strong>4 7/8” OH</strong></td>
<td>11”</td>
<td>9.6”</td>
</tr>
<tr>
<td><strong>EH</strong></td>
<td>0.19”</td>
<td>0.17”</td>
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<tr>
<td><strong>Eff, %</strong></td>
<td>50</td>
<td>50</td>
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</tbody>
</table>
Impact charge testing on well concept selection

Impact 2” charge:
- test results impact rel. minor
- Higher DoP offset by lower assumed perforation eff.

Impact small charge:
- impact clear
- Lower DoP + lower assumed perforation eff.
- Small charge will result in loss in IPR (value)
Impact charge testing on well concept selection

Test results 2” charge in 2 7/8” tbg:

- No / minor impact on inflow, likely artefact due to testing.
Impact charge testing on well concept selection

Cumulative Gas Production

- BASE
- Small charge
  - Major Impact

- 2" charge
  - Minor Impact
Conclusions

- Charge testing results
  - DoP impact cement thickness for smaller charges potentially under-estimated
    - potential impact on selected drilling practices (OH drilling diameter), well productivity impact small.
  - Perforation tunnel efficiency possibly overestimated in original modelling
    - “ideal” lab tests gave results of approx 80%, field conditions (small clearance, low static UB) far from ideal.

- Concept selection
  - Reducing tubing size to 2 7/8” and using smaller charges not attractive given loss of inflow / recovery ➔ tests of 2” guns inside 2 7/8” tbg very promising ➔ very likely way forward driving development costs down by slimming down wells. Some penalty on initial productivity.