Charge testing for well concept selection

April 2012

Eelco Bakker, Al Zanimonsky, NAM
Mark Brinsden, Shell

IPS12-33

Presented at International Perforating Symposium, Houston 26 – 27 April 2012
content

- Well concept evolution
- Case for charge testing
- Test set-up / test conditions
- Charge test results
- Findings charge testing
- Impact concepts
- Conclusions
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 %

Typical features:
- 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 next step?
Well concept evolution – the next step?

**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: 1 9/16” or 1 11/16”

**Proposed “slim” case, high permeability**

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”
Slim well concept – impact gun size (base modelling)

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)

Charge testing conditions in lab

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

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)
Charge test results small charge

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)

- Futher analysis of results
  - Impact cement thickness clearly seen in majority of tests (6” vs 4 7/8” OH, 4 7/8” vs 3 15/16” OH)
Findings charge testing (2)

- Further analysis of results
  - 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%

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

Cumulative Gas Production

Small charge
Major Impact

2” charge
Minor Impact
Conclusions

- Charge testing results
  - Reducing tubing size to 2 7/8” requiring use of smaller charges not attractive given loss of inflow / recovery
    - Impact perf tunnel efficiency significant
  - Impact cement thickness for smaller charges potentially underestimated
    - Potential impact on selected drilling practices (OH drilling diameter)
  - 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.