Wellbore Implosion: Case Study of Perforation Enhancement

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AGENDA

• Field Background
• Perforation Damage
• Dynamic underbalance technique
• Wells candidates
• Pre-job simulation
• Operation
• Wells performance
INTRODUCTION

- Field on land in Oman with more than 250 producers and injectors
- Sandstone 1500m deep at 50mD and 20% porosity.
- 4.5” or 7” cemented casing.
- Water injection started in January-2013 but some wells with low injectivity.
- Perforating system including reactive liner charges and propellant tried but result was not satisfactory.
- This case study is about dynamic underbalance post perforating (DUB-PP)
Perforation Damage

- Perforation damage:
  - Plugged tunnels
  - Low permeability crushed zone around the tunnel
Why Dynamic Underbalance?

- Dynamic underbalance aka Wellbore Implosion
- Magnitude and sharp pressure drop is key to break (fail) the crushed zone, leading to cleaner perforations.
- Design guns to achieve dynamic wellbore implosion pressure event.

![Conventional Underbalance vs Dynamic Underbalance](image)
Dynamic Underbalance (DUB) and Dynamic Underbalance Post Perforating (DUB-PP)

- DUB-PP evolved from conventional DUB.
- Both create “implosion” in wellbore.
- DUB-PP used anytime after the actual perforations established.
- DUB-PP required for lower pressure environment.
Well Candidates

- Start operation with Well-B and C, followed by Well-A later.
- Reperforation not planned for Well-B and Well-C.
Well-B and Well-C
Operations
Pre-Job Simulation

- DUB-PP gun designed based on simulation.
- Reservoir pressure expected to be about 900-psi
Operations

• Stop well injection 2-days before the actual operation.
• Run pressure survey to confirm wellbore pressure stability.

• Re-run the pre-job simulation based on new pressures.
• Run DUB-PP guns together with fast-recording-pressure-gauge to record DUB event.
Pre-Job Simulation – Based on Actual Well Pressure
Operations – Post Job

• DUB achieved.
• Gauge data compares well to simulation
# Post Job Well Performance

<table>
<thead>
<tr>
<th>Date</th>
<th>Events on Well-B</th>
<th>Reservoir Pressure (psi)</th>
<th>Injection Pressure (psi)</th>
<th>Injection Rate (litres/minute)</th>
<th>Injectivity (Litres per day/psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-13</td>
<td>Perforating using Reactive Liner followed with propellant</td>
<td>900</td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>Feb-13</td>
<td>Welltesting using dedicated well test unit</td>
<td>900</td>
<td>1150</td>
<td>2.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Nov-13</td>
<td>Wellbore Implosion using DUB-PP system</td>
<td>2112</td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>Jan-14</td>
<td>Welltesting using dedicated well test unit</td>
<td>2112</td>
<td>1250</td>
<td>53</td>
<td>64.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Events on Well-C</th>
<th>Reservoir Pressure (psi)</th>
<th>Injection Pressure (psi)</th>
<th>Injection Rate (litres/minute)</th>
<th>Injectivity (Litres per day/psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec-12</td>
<td>Perforating using Reactive Liner followed with propellant</td>
<td>900</td>
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<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>Jan-13</td>
<td>Welltesting using dedicated well test unit</td>
<td>900</td>
<td>1250</td>
<td>1.9</td>
<td>1.1</td>
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<tr>
<td>Nov-13</td>
<td>Wellbore Implosion using DUB-PP system</td>
<td>2075</td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>Jan-14</td>
<td>Welltesting using dedicated well test unit</td>
<td>2075</td>
<td>1250</td>
<td>53</td>
<td>62.5</td>
</tr>
</tbody>
</table>
## Well-A Operations

<table>
<thead>
<tr>
<th>Well</th>
<th>Casing Size</th>
<th>Perforation History</th>
<th>Perforating Plan</th>
<th>DUB-PP Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well A</td>
<td>7-in.</td>
<td>Previously perforated with 4.5-in, 5-spf guns</td>
<td>Reperforate existing interval with 4.5-in, 5-spf guns</td>
<td>4.5-in. DUB-PP guns</td>
</tr>
<tr>
<td>Well B</td>
<td>7-in.</td>
<td>Previously perforated with 4.5-in, 5-spf reactive liner charges followed by 3.375-in. propellant system</td>
<td>Not applied</td>
<td>4.5-in. DUB-PP guns</td>
</tr>
<tr>
<td>Well C</td>
<td>4.5-in.</td>
<td>Previously perforated with 2.875-in, 5-spf reactive liner charges followed by 3.375-in. propellant system</td>
<td>Not applied</td>
<td>2.875-in. DUB-PP guns</td>
</tr>
</tbody>
</table>
Well-A Plan

• To reperforate followed by DUB-PP
• Job sequence similar to previous two wells

Well A historical injection performance prior to the reperforation and DUB-PP job.
Well-A Post Job Analysis

- DUB achieved but well injectivity did not improve.
- Neither reperforation nor DUB-PP effective.
Conclusion

• Wellbore implosion using the DUB-PP technique successfully improved injectivity of two water injector wells in the low to medium reservoir pressure range.

• Standard perforating or DUB-PP could not overcome well with suspected water-rock compatibility problem.
QUESTIONS?
THANK YOU!