Extreme Overbalance Perforation

[ EOP ]

AIMING FOR IMPROVING WATER INJECTION WELL INJECTIVITY AND MINIMIZING NON COMFORMANCE ISSUE

Presented by:
Rashid Araimi

Team,

PDO:
Rafliansyah Andika Putra
Rashid Araimi

SLB:
Mohammed Taiwani
Ozgur Karacali
Agenda

- What is EOP
  - How it works
  - Main benefits
- Reservoir / Formation Background
- Field Trails: (Issue, execution, results)
  - Field Case Well-1
  - Field Case Well-2
  - Field Case Well-3 (Comparison HF vs. EOP)
- Conclusion & Away forward
**Definition:**
- Perforating above formation fracture gradient pressure.

**Main benefits:**
- Create better conductive path between the reservoir and Well bore.
- Go beyond expected damaged zone.
- Cheaper and more effective than HF.

**How it works**
- Run perforation guns to the depth of interest
- Spot to the top of the gun a small amount of liquid selected (brine, solvent, acid, frac fluid) – partial cushions
- Then the string will be filled with compressible gas - Nitrogen
- The gas column is then pressured up typically at about 4000 PSI (28000 kPa)
- With detonation of the guns, the liquid is driven at very high flow rates by the rapidly expanding gas N2 and rushes into the perforation
- Because the liquid is nearly incompressible, it acts as a wedge that initiates fractures, extending the effective wellbore radius
- The EOP pressure gradient usually needs 1.4 psi/ft or 31.6 kPa/m.
Reservoir / Formation Background

- Injection and Production from Upper, Middle and Lower Gharif
  - Stacked channel sands of alluvial plain deposits intercalated w/ silts and clays
- Surrounding oil producing wells (5 Spot pattern)
  - High permeability sands up to 4 D and 25% porosity
  - 30 API (0.876 g/cc), Oil viscosity 13 cp
- Low reservoir pressure and temperature
  - 10,000 kPa (1,450 psia)
  - 65 deg C (149 deg F)
- Wells depict positive skin damage in general.
- Very weak aquifer support.
- Secondary drive is required immediately once production commenced
Field Trails: (Issue, execution, results)

Well-1:

- **Main Issue:** non conformance
  - MPLT indicate water only goes lower layer

- **Execution:**
  - Re-perforate the upper zones layer with EOB Perforation
  - 4.5” HSD gun loaded w/ 5 SPF PJO 4505 HMX charges was run on 3-1/2” DP
  - The execution went well and no safety and environment issue.

- **Results:**
  - Injection profile improved resulted to better sweep efficiency and increase Gross of nearby OP-1 to +24% and net oil by +34%
Well-2:

- **Issue: Zero injection.**
  - New well, completed initially with common perforation system PJ 4505,5 spf.
  - Perforation ceased after a month period.

- **Execution:**
  - Acid was first spotted across the perforation
  - Re-perforate all layers together with EOB Perforation+ solvent compensation.
  - 4.5” HSD gun loaded w/ 5 SPF PJ 4505 HMX charges was run on 3-1/2” DP

- **Results:**
  - Injection profile improved and injection reestablished for all layer
Well-2: **Solvent Spot & Extreme Overbalance Perforation Result**

**Spot solvent**
Aromatic and Mutual Solvent with Surfactant

**Perf selection EOP**

**Injectivity test**
(Based on 5000 kPa injection pressure)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Rate (m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 1</td>
<td>40</td>
</tr>
<tr>
<td>Layer 2</td>
<td>120</td>
</tr>
<tr>
<td>Layer 3</td>
<td>526</td>
</tr>
</tbody>
</table>

5 times + injection target

**Well-2 injection profile**

*Job Completed: 6th March 2012*

**Flow rate**

<table>
<thead>
<tr>
<th>Pressures</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2000</td>
<td></td>
</tr>
<tr>
<td>2000-4000</td>
<td></td>
</tr>
<tr>
<td>4000-6000</td>
<td></td>
</tr>
<tr>
<td>6000-8000</td>
<td></td>
</tr>
<tr>
<td>8000-10000</td>
<td></td>
</tr>
<tr>
<td>10000-12000</td>
<td></td>
</tr>
</tbody>
</table>

**Injectivity Ratio vs Effective Shot Density**

<table>
<thead>
<tr>
<th>Phasing</th>
<th>Effect</th>
<th>kc/k</th>
<th>Form Per/</th>
<th>Comp Len/</th>
<th>Comp %</th>
</tr>
</thead>
<tbody>
<tr>
<td>135/48</td>
<td>12.00</td>
<td>0.07</td>
<td>19.96/1.42</td>
<td>24.0</td>
<td>32</td>
</tr>
<tr>
<td>45 pndim</td>
<td>6.00</td>
<td>0.10</td>
<td>22.75/1.05</td>
<td>24.0</td>
<td>32</td>
</tr>
<tr>
<td>45 pndim</td>
<td>5.00</td>
<td>0.05</td>
<td>30.95/1.33</td>
<td>24.0</td>
<td>32</td>
</tr>
<tr>
<td>72</td>
<td>5.00</td>
<td>0.03</td>
<td>27.75/1.65</td>
<td>24.0</td>
<td>32</td>
</tr>
<tr>
<td>72</td>
<td>5.00</td>
<td>0.03</td>
<td>32.69/1.78</td>
<td>24.0</td>
<td>32</td>
</tr>
</tbody>
</table>

*Rock-based Model*

4.50" HSD, 5 SPF PowerJet 4505 HMX

**Layer**

- **4.50" HSD, 5 SPF PowerJet 4505 HMX**
- **Job Completed: 6th March 2012**
- **Injectivity test (Based on 5000 kPa injection pressure)**
- **Reservoir Rate (m³/day)**
  - Layer 1: 40
  - Layer 2: 120
  - Layer 3: 526
- **Perforating System(s)**
  - 4-1/2" HSD, 34/4 UltraJet, HMX
  - 2-1/8" Power Spiral Enerjet, HMX
  - 2-1/4" Power Spiral Enerjet, HMX
  - 4-1/2" HSD, UltraJet 4505, HMX
  - 4-1/2" HSD, PowerJet 4505, HMX
  - Open Hole without Damage
  - Open Hole with Damage

**Well-2 injection profile**

- **Job Completed: 6th March 2012**
- **FLP**
- **Flow**

**Reservoir Rate (m³/day)**

Layer 1: 40
Layer 2: 120
Layer 3: 526

5 times + injection target
Comparison HF vs. EOP (Field Case Well-3)

Well-3 (WI)

- Prop Hydraulic Fracturing was performed.
- Injectivity has been improved and dropped to pervious level few weeks after Fracturing due to flowback proppant.

<table>
<thead>
<tr>
<th>Hydraulic Fracturing</th>
<th>EOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expensive</td>
<td>cheaper</td>
</tr>
<tr>
<td>Flowback proppant risk.</td>
<td>No risk, except controlling N2 high pressure.</td>
</tr>
<tr>
<td>Risk of getting breakthrough water shortcut</td>
<td>Minimum risk of water breakthrough.</td>
</tr>
</tbody>
</table>
Conclusion & Away forward

- EOP work effectively to reduce the non conformance injection.
- The injection after extreme overbalance was decent from zero injection to ~400 m3/d at low surface inj. pressure of 5,000 kPa.
- Extreme over balance perforating technique has been proven successfully and it could replace HF on some wells conditions.
- Methodology/technique can be applied to the other wells in different fields.
- Heading to complete 3 more trials at the same areas.
- Continue evaluate the results by PLT and calculate the oil gain.
- Continue using solvent spot combine with EOP in Water Injectors.
- Evaluate this method to apply it in our producer wells.
- Evaluate to combine this method with acid stimulation.
Thank you

Rashid Al Araimi
PDO
Rashid.Araimi@pdo.co.om
Back up
Fracture Orientations EOP vs. Underbalanced Perforations

A

Extreme Overbalance

B

Statically Underbalanced Perforations

$\sigma_{\text{max}}$
Details Operational Procedure (Well-2)

- A liquid head/solvent was first spotted in the zone of interest.
- Tubing conveyed guns were then run in hole with brine of 3500 kPa (~340 met.).
- Depths were correlated with WL GR/CCL and TCP guns were spaced out.
- Packer was set mechanically and pressure tested through annulus to 5000 Kpa for 15 mins. and correlation has been double checked.
- Bleed annulus to 1000 Kpa and held this pressure for gun firing.
- Surface pump was rigged up and all surface lines were pressure tested.
- Nitrogen was pumped down the tubing to generate sufficient pressure.
- 4000 psia was set as the shear pressure for HDF (hydraulic firing head).
- 800 gallons of N₂ was injected and surface pressure has been built up to 4000 psia.
- The guns were fired at 27600 Kpa (4000 psia) surface pressure.
- A bottom hole gradient about 23 Kpa/meter has been achieved.
- HDF Delay time was set to be around 5 mins with 4000 psia N₂ pres.
- Waited 15 mins while observing THP for stability.
- Opened packer bypass and reverse circulated and checked the flow.
- Unset the packer once well is stable and checked the flow to confirm.
- Pulled out of the hole.
- Run in hole again for selective injection test for individual zones.
- Performed selective injectivity tests by isolating individual zones.