Configuring Dynamic Underbalance to Achieve Perforation Tunnel Cleanup in a Gas Well at High Static Overbalance
AGENDA

- Static preperforation wellbore balancing, comparison with dynamic underbalance (DUB) and how it is achieved
- How to create underbalance dynamically
- DUB design service and its application
- Findings
- Expansion-of-application opportunities
Defining Dynamic Underbalance (DUB)

Static vs. Dynamic

Pressure

P_{\text{wellbore}}

P_{\text{wellbore}}

Time

Max UB Surge

P_{\text{reservoir}}

Halliburton
Configuring Dynamic Underbalance

RIPS 2017
Defining Dynamic Underbalance (DUB)

Static OB(+)/UB(-):
- Overbalance (OB) \[= (+) \text{psi}\]
- On-balance (BAL) \[= 0 \text{ psi}\]
- Underbalance (UB) \[= (-) \text{psi}\]

Peak DUB
\[\equiv p_{\text{WB}}^{\text{min}} - p_{p}^{i} [= (-) \text{psi}\]

Minimum or Lowest, \(p_{\text{WB}}^{\text{min}}\)

Initial pore pressure, \(p_{p}^{i}\)

Initial wellbore pressure, \(p_{\text{WB}}^{i}\)

Time of detonation, \(t_{\text{perf}}\)

Elapped Time, seconds

\(t_{\text{DUB}} = \text{time to } p_{\text{WB}}^{\text{min}}\)

\(t_{\text{rec}} = \text{time to pressure recovery, } p_{\text{WB}} = p_{p}\)
Why Static Overbalance is Used
Keeping Adjacent Zones Under Control with Overbalance

Formation Pressure of the Zone Above: 11,500 psi

Formation to Perforate with Pressure 8,000 psi
Laboratory Setup. Section IV Diagram

Simulated Wellbore
Detonating Cord in Wellbore Chamber
Simulated Formation
Simulated Single Shot Perforating Gun
Flow Loop / Pressure Vessel

- Wellbore tubing
- Pore tubing
- Lab gun with single shaped charge
- Core
- Pressure vessel
- Fluid loss pill
- Wellbore pressure transducer
- Bypass valve
- Accumulator valve
- Wellbore isolation valve
- OMS
- N₂
- Pore accumulator valve
- N₂

Accumulator piston was pushed to bottom before nitrogen gas was used to pressurize from below.
How Changing Only Free Gun Volume Affects Dynamic Underbalance

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Free Gun Volume (cm³)</th>
<th>Dynamic Underbalance Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Red)</td>
<td>127</td>
<td>1,250</td>
</tr>
<tr>
<td>2 (Dark blue)</td>
<td>241</td>
<td>3,100</td>
</tr>
<tr>
<td>3 (Brown)</td>
<td>346</td>
<td>4,500</td>
</tr>
<tr>
<td>4 (Light blue)</td>
<td>401</td>
<td>4,750</td>
</tr>
</tbody>
</table>

**TABLE 2—SUMMARY OF FGV TEST RESULTS AND PARAMETERS.**

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Entrance Hole Diameter, in.</th>
<th>Total Core Penetration, in.</th>
<th>Open Hole, in.</th>
<th>Percent Open Hole</th>
<th>Void Space in Gun, cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.35</td>
<td>8.7</td>
<td>1.2</td>
<td>13.80%</td>
<td>127</td>
</tr>
<tr>
<td>13</td>
<td>0.35</td>
<td>8.2</td>
<td>3</td>
<td>36.60%</td>
<td>241</td>
</tr>
<tr>
<td>14</td>
<td>0.32</td>
<td>8.35</td>
<td>6.95</td>
<td>83.20%</td>
<td>346</td>
</tr>
<tr>
<td>15</td>
<td>0.31</td>
<td>6.72</td>
<td>5.98</td>
<td>89.00%</td>
<td>401</td>
</tr>
</tbody>
</table>
No Dynamic Underbalance - Computed Tomography (CT) Imaging

FGV/WB = 0.007
Wellbore pressure = 9,500 psi
Pore pressure = 7,500 psi
Static overbalance = 2,000 psi
Penetration depth = 7.84 in.
Open tunnel = 0 in.
Dynamic underbalance = 0 psi
Partial Dynamic Underbalance

FGV/WB = max
Wellbore pressure = 11,000 psi
Pore pressure = 7,500 psi
Static overbalance = 3,500 psi
Penetration depth = 6.673 in.
Open tunnel = 1.949 in., 6.50 in. loose material
Dynamic underbalance = 3,425 psi
Dynamic Underbalance

FGV/WB = max
Wellbore pressure = 11,000 psi
Pore pressure = 7,500 psi
Static overbalance = 3,500 psi
Penetration depth = 5.440 in.
Open tunnel = 4.578 in., 5.39 in. loose material
Dynamic underbalance = 5,438 psi
Flow Comparison Chart
Flow Comparison Chart
DUB Design. Modelling.
Conclusions

- DUB can be achieved, even at a high static overbalance, provided the formation pressure is adequate.

- DUB effectiveness at high static overbalance can be assessed both qualitatively with CT scan images and quantitatively with an API RP 19B Section 4 flow loop.

- Results show that increasing the free gun volume increases the magnitude of DUB, which in turn cleans debris from the perforation tunnels and leads to higher production rates.

- Laboratories have the option to set a wide range of over- or underbalance pressure scenarios along with testing the effects of varying wellbore or formation fluids.
Thank you!

Questions?

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