Dynamic Underbalance
A Case Study in the Lower Burgan Formation

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Why Perforate Underbalance?

- Improve flow efficiency
- Increase effective perforation length
- Increase perforation tunnel diameter
- Reduce/remove the thickness of the crushed zone
Underbalanced Perforating

Formation Penetration vs Effective Formation Penetration

Balanced vs 3,000 psi Underbalanced
Why Perforate Dynamic Underbalance?

- Saving intervention costs
- Saving additional rig time
- Easily integrated into any perforating system
- Ability to manage underbalance in each zone
- Can be conveyed on tubing, wireline, slickline, or modular
Dynamic Underbalance

1000 psi

~0 psi

5000 psi
Dynamic Underbalance

- The amount of dynamic underbalance is effected by
  - Gun volume
  - Surge chamber volume
  - Amount of energy being released
  - Type and amount of fluid in wellbore
  - Casing, gun, and tubular dimensions
  - Reservoir characteristics
How Much Dynamic Underbalance?
SPE 159413 “Evaluation of Established Perforation Cleanup Models on Dynamic Underbalanced Perforating”
Dennis Haggerty, G.G. Craddock, and Clinton C. Quattlebaum, SPE, Halliburton.

Fig. 4—Perforated cores using different free gun volume (FGV) resulting in different amounts of open perforation tunnel. Lower melting point temperature subject fills the ‘open’ portion of the perforation tunnel.

Fig. 5—Wellbore pressure during and immediately after perforating event, capturing the dynamic underbalance.

Eqn. 1A through 3A are solved for the required underbalance to achieve clean perforations tunnels, using core parameters from Table 1:

\[ P_{\text{max}} = \frac{7200}{144} = 502 \text{ psi} \]  
(1A) (King et al. 1986, Crawford 1988)

\[ \Delta P = \text{Max Pressure at perforation point} \]

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Assuming worst case, the alternative formula was used:

\[ \Delta P_{\text{max,alt}} = 667 \times 20 \times 0.345^3 / 144^\frac{3}{2} = 1.896 \text{ psi} \]  
(3A) (Bakman 1995)
Dynamic Underbalance Hardware

- A special charge used to create additional holes in the carrier and blank guns to allow flow path from the wellbore to the carrier.
- A vent valve between the guns to allow sufficient flow path from the wellbore into a specified chamber.
- Can the current hardware achieve the maximum possible Dynamic Underbalance safely?
Advantage of Having Vent Valve Between Guns

- Increase flow area into chambers
- Maximize the magnitude of dynamic underbalance
- Manage gun movement at the time of firing
Vent Valve Between Guns Manage Gun Movement when the Gun is Firing.
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Vents/Chambers Manage Gun Movement when the Gun is Firing and Significantly Increase the Amount of Dynamic Underbalance

<table>
<thead>
<tr>
<th>SurgeProSM Vent position</th>
<th>Extra Dynamic UB (PSI)</th>
<th>Guns Move Up (Ft)</th>
<th>Guns Move Down (Ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Vent</td>
<td></td>
<td>1.54</td>
<td>1.17</td>
</tr>
<tr>
<td>Vent at the bottom</td>
<td>544</td>
<td>0.13</td>
<td>5.17</td>
</tr>
<tr>
<td>Vent at the Top</td>
<td>569</td>
<td>5.11</td>
<td>2.98</td>
</tr>
<tr>
<td>Vent at top and bottom</td>
<td>1052</td>
<td>3.93</td>
<td>3.18</td>
</tr>
</tbody>
</table>
Case Study#1
Actual Fast Gauge Data
Well – (xx-xx09)
Case Study#1
Well – (xx-xx09)

- Perforate selected Lower Burgan intervals using dynamic underbalance perforation
- The estimated Productivity Index is 0.7 bbls/day/psi based on adjacent wells
- Well perforated using dynamic underbalance perforation “3600 psi”
- Well completed with Electric Submersible Pump per the program
- Once well connected to flow line, well start flow naturally
- Oil gain naturally after well connection is ~1500 bbls
- The actual Productivity Index is ~ 5.5 bbls/day/psi
Case# 2
Actual Fast Gauge Data
Well –(xx-xx33)

Perforating event

Area of Dynamic Underbalance
Case Study #2
Well – (xx-xx33)

- Perforate selected Lower Burgan intervals using dynamic underbalance perforation.
- The estimated Productivity Index is 1 bbls/day/psi based on adjacent wells.
- Well perforated using dynamic underbalance perforation “3650 psi”
- The actual Productivity Index is ~ 4 bbls/day/psi.
Summary

- Current hardware can achieve the maximum possible dynamic underbalance safely
- Vent between guns manage the gun movement during the firing process
- Additional work is required to verify the simulated gun movement at the time of fire with actual fast gauge data
Thank You