Dynamic Underbalance (DUB) Perforating

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Perforating Product Champion
Agenda

- Overview
  - DUB Software
  - Tools
- Case histories
Dynamic Underbalance Software

- Dynamic pressure and fluid flow predictions
  - Accurately modeling the effects of pressure transients during the perforating event
    - Packer differentials, reservoir reaction
  - Service provide precise management of dynamic perforating pressures
    - Enhancement, mediation
  - Main purpose is to provide optimal cleanup
Applications

- Assess the natural surge potential of conventional gun systems
- Evaluate the effectiveness of underbalance perforating and back-surring techniques
- Customization of BHA to generate the desired DUB
  - Vents, chambers, partial loading
- Evaluate tools that are use to mediate DUB
  - Charge Selection, PID, Propellants
- Monitor the effects of operational procedures on the perforating process
  - Applied pressures, opening/shutting of valve, pumping, etc.
Surge Vent

Loaded Gun

Blank Gun
Pressure Isolation Device (PID)

- Provides the capability to isolate wellbore pressure when deploying and/or retrieving perforating guns under pressure.

- Providing a means for isolating gun spacer chambers, the PID helps manage DUB surges during perforating.
Pressure Isolation Device (PID) Effects

Loaded Gun

Blank Gun
Case History - DUB Orientated Perforating in Horizontal
DUB Orientated Perforating in Horizontal

- Norwegian North Sea
- Sandstone
- Oil
- 5570mMD / 2602mTVD
- Automated gun handling subs
- 4 5/8” ultra low debris internal oriented perforating system, 10-350, 4spf
Automated Gun Handling Subs-The Automated Solution

- Fully Automated Gun Handling
- Safety - No personnel required on rig floor
- Rig Time/Cost Savings up to 40% reduction in deployment and recovery
Sand Control Theory
Internal Oriented Perforating System

- The assembly is made up of five separate sub-assemblies allowing each charge tube to rotate independent of the gun carrier.
- These sub-assemblies are comprised of a section of charge tube and weighted tube connected to a bearing assembly.
Orientation Verification
4 5/8” 39gm Ultra Low Debris Charge
4 5/8” 4 SPF Ultra Low Debris Charge Tube

- Expended gun sectioned to show charge holder with charge cases in tact
- Test conducted at JRC, Alvarado on 10-12-04
Section 5
Debris Test of 4ft 4 5/8” Ultra Low Debris Gun

<table>
<thead>
<tr>
<th>Debris Rolled From Gun, % By Weight Retained on US Sieve Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen .500 In. 12.7mm</td>
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<tr>
<td>Wt. In gms</td>
</tr>
<tr>
<td>% by Wt.</td>
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</tbody>
</table>

- 29.89gm / 4ft = 7.47gm/ft
Perforating String

- Pressure Gauge
- 13.75m SurgePro Chambers
- Average Pressure Working Region #1
- 21.22m Perforating Guns
- 6.41m SurgePro Chambers
- Average Pressure Working Region #2
- 31.83m Perforating Guns
- 21.99m SurgePro Chambers
- Average Pressure Working Region #3
- 21.22m Perforating Guns
- 21.99m SurgePro Chambers
- 25.36m Spacer Guns
- 13.75m SurgePro Chambers
- Average Pressure Working Region #4
- 31.83m Perforating Guns
- 8.24m SurgePro Chambers
- Average Pressure Working Region #5
- 5.64m Perforating Guns (0.5m Loaded)
- 12.68 Spacer Guns
- 13.75m SurgePro Chambers
- Average Pressure Working Region #6
- 21.22m Perforating Guns
- 13.75m SurgePro Chambers
- Average Pressure Working Region #7
- 53.05m Perforating Guns
Pre-job Results

<table>
<thead>
<tr>
<th>Working Zones</th>
<th>Perf Interval Depth (mMD)</th>
<th>Perf Interval (m)</th>
<th>Avg Well Pressure (psi)</th>
<th>Avg Reservoir Pressure (psi)</th>
<th>Avg Peak Drawdown Pressure (psi)</th>
<th>Avg Dynamic Surge (psi)</th>
<th>Perf Clean Up (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>5185.5-5205.6</td>
<td>20.1</td>
<td>5308</td>
<td>4731</td>
<td>2320</td>
<td>2411</td>
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<td>2618</td>
<td>2113</td>
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<tr>
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<td>0.5</td>
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<td>1063</td>
<td>99</td>
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</tbody>
</table>

- Porosity 21-29%
- Perm 30-3306mD
High Speed Gauge Data

Pressure up to fire

Bleed off pressure

Dynamic underbalance

Slow Speed mode - Orange
Intermediate Speed mode - Green
Fast Speed mode - Blue
Model Validation to 0.2 second

![Graph showing model validation to 0.2 second with a well pressure of 5070 psi and gauge data comparison. The graph includes a model line and a gauge data line over time.]
Model Validation to 1 second
Model Validation to 9 second

![Graph showing model validation to 9 seconds with model and gauge data compared. The graph plots pressure against time with a model line and a gauge data line. A note indicates well pressure at 5070 psi.](image)
Eliminating the Back Surge
- RIH
- Make sure FAS-FIL has closed
- Set Packer
- Apply 1500psi down drill pipe
- Apply 1500psi to annulus to open bottom Multi Service Valve
- Bleed annulus pressure then tubing pressure and wait 2 hours
- Apply 1500psi to annulus to open top Multi Service Valve
- Cycle OMNI to circulate position
- Circulate 2 tubing volumes or until clean fluid at surface
- Cycle OMNI to well test position
- RIH to tag for fill
- Reverse circulate and pull packer plug if necessary
- POOH
Why Perform a Back Surge?

- **Pros**
  - To clean out perforations
  - To minimize risk of sanding up the guns
  - Can be more aggressive with UB condition

- **Cons**
  - Extra Trip
  - Additional tools
Surge Model: Effect UB across the sandface

Below surge assembly ~120 psi

Annulus below ports ~700 psi

Inside tubing above ports ~1,000 psi
Surge Model: Effect UB across the sandface

Avg. pressure in wellbore across the sandface ~100 psi

MENAPS-11-21
Outcome of Study

- 1,500 psi UB backsurge did not result in much differential across the sandface
- Eliminated the back surge
- Wells are to be perforated with 1,500 psi UB
- Wells left in completion plan were perforate successfully with the change in perforating procedure
- Average cost savings of 1MM per well