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More than just Penetration: Perforation Design for Naturally Completed and Stimulated Wells

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More than Just Penetration: Perforating for Better Wells
Discussion Topics

- Introduction – A little bit about GEODynamics
- Perforation Performance Evaluation – Tools for Development
- Perforation Design for Natural Completion
  - New Wells
  - Re-perforation
  - Injection
- Perforation Design for Sand Control
  - Area Open to Flow: Gravel Pack Application
  - Overbalanced Sand Control: Systems for Stable Tunnels
- Perforation Design for Fracture
  - Tunnels that take Acid
  - Improvements in Well Decline
API RP19B Section I Test: Unstressed Concrete

- The API Section I Test is conducted by firing a representative gun section from the center of a poured cement target.
- This test can be registered with the API.
- The targets and charges are aged 28 days prior to performing the test for registered data.

Figure 1—Example Concrete Target
API Section I Test

- The target must meet minimum specifications of construction, composition, and compressive strength.
- After the shot, the targets are split, and data collected on:
  - Hole Size
  - Penetration Depth
  - Debris
  - Burr Height of Casing
New Industry Tools for New Products

- **API RP 19B Section 1: Evaluated**
  - Does not correlate to downhole performance
  - QC may not correlate for every charge either!

- **API RP 19B Section 4: Released**
  - Highlights sources of Experimental Error
  - Adds new ways to analyze results
  - Enables more uniform testing between companies

- **API RP 19B Section 2: Under Revision**
  - Wide Involvement by Service and Product Providers
  - Draft Standard: New Performance Metric
  - New Registered and Witnessed Test
  - Still Concentrating on Penetration Only – No Analysis
  - Currently Evaluating Equipment and Processes
Perforation and Well Geometry

- Perforations Near WB
- Interaction of perforation geometry with near wellbore geometry
- Improved perforation may not improve some wells
  - (too much or too little damage)
- Critical for others
Perforation Geometry Design Variation
Permeability Map, Conventional Tunnel
Permeability Map, Improved Tunnel

[Image of a cross-sectional diagram of a tunnel with labeled sections and a scale.]
Perforation Design for Natural Completions

- New Design Considerations!
  - Dual String – Plugging in second string
  - Gun plugging which alters dynamic surge
  - Real World Formation: Plugging in the hard layers
  - Injection Wells: Design for injection damage

- Other Lithology
  - Weak sandstone: Can we reduce the need for sand control with shaped charge systems?
  - Shale: In some cases much shorter than expected. Open tunnel a primary function of charge design, and not of perforating balance.
Field Applications • Re-Perforation

- Generally a tough task for perforators
  - Effective stress increases as reservoir pressure drops
  - Hard to apply underbalance with open perforations etc.
  - Depleted reservoirs have no pressure for DUB techniques.

- Success = increased productivity

- Examples:
  - UK • 30x productivity after re-perforation (best in field)
  - USA • 10x productivity ... more than 2x the increase seen re-perforating offset wells with conventional systems
  - USA • 10x increase in gas well production after re-perforation ... already shot twice with premium DP system
Perforation Design for Sand Control

- API RP 19B Section 1 Test
- Maximize Area Open to Flow (Square Inches/Foot) in Standard Casing Only
- Standard Casing is L-80 Grade, and thinner than most modern applications
- Extrapolation is used by software to predict down hole performance.
- This translation is charge design dependent.

Figure 1—Example Concrete Target
API RP19B Section 1 Test
Perforation Geometry for “Big Hole” Sand Control Charges

- Affected area much larger in diameter than hole size
- Crushed sand can form an effective injection plug
- In lab, plug can be broken down, fluidized without fracture
Perforator Performance: Gravel Pack

- Translation to Heavy Wall Casing is Design Dependent
  - In one instance heavy wall performance exceeds that in thin wall casing

- Design For Heavy Wall Casing
  - Publish performance in both standard casing and heavy wall casing
  - Two data point design allows for better prediction
  - Superior charges translate across all applications
Next Generation SBH Performance:
Dominant in Standard Casing

<table>
<thead>
<tr>
<th>Gun Size</th>
<th>Casing Info</th>
<th>Entry Hole</th>
<th>Penetration</th>
<th>Area Open To Flow</th>
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<tbody>
<tr>
<td>4-5/8&quot; 16 SPF</td>
<td>7&quot; 32# L-80</td>
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<td>5.5</td>
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<tr>
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Next Generation SBH Performance:

Unmatched in Heavy Casing

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<thead>
<tr>
<th>Gun Size</th>
<th>Casing Info</th>
<th>Entry Hole</th>
<th>Penetration</th>
<th>Area Open To Flow</th>
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</tbody>
</table>
Benefits

- Exceptional Area Open to Flow
- New Standard for Performance
- 2 Point Published Performance for Accurate Estimation of Hole Size in Casing
- Reliable, More Effective Stimulation
  - Reduced Pressure at Sand Face
  - Maximized Area Open to Flow for Gravel Pack
Opportunities

- GOM Platforms
- Drop-in Substitute for Conventional Charge
  - Deploys in identical hardware
  - No change in handling or running procedures
  - No change in HSE risk
Stable Clean Tunnels at 2000 psi OB

Charge design produces deep, clean, stable tunnels in low strength, high permeability, high-porosity sandstones at overbalanced conditions.

40% BETTER FLOW AT OVERBALANCED CONDITIONS

![Graph showing productivity ratio vs. underbalance and overbalance](image-url)
500 PSI Underbalance Condition

CONVENTIONAL @ 500 psi Underbalance

Overbalance Optimized Charge @ 500 psi Underbalance
1000 PSI Overbalance Condition

CONVENTIONAL @ 1000 psi Overbalance

OVERBALANCE Optimized Charge @ 1000 psi Overbalance
2000 PSI Overbalance Condition

CONVENTIONAL @ 2000 psi Overbalance

OVERBALANCE Optimized Charge @ 2000 psi Overbalance
Clear Tunnel at Overbalance: Flow
Performance

- Innovative Systems deliver good AOF
- Stable Tunnels at Overbalance Condition
- Flow Performance is 6% to 59% superior to the conventional charge at every balance condition.
- Optimized Overbalance Charge provided a PR of 0.92 at overbalance condition.
- Conventional charge produced deeper tunnels, however reactive design produces cleaner perforations, with better side wall condition.
Shaped Charge Systems for Fracture

- Many complex considerations!
- Acidizing plays a crucial role in many completions
- Improved Hole Size Distribution
- Interaction of the fracture with the near wellbore region – In some wells fractured tips and open tunnels improve near wellbore region

- Current Systems may not demonstrate a repeatable downhole performance
  - Therefore completion, stimulation, and fracture treatment design evolves to compensate
Matrix Acidizing:
Conventional Good Hole Geometry

Before Acidizing

After Acidizing
Tunnels Designed to Take Acid: Needs 1/6 of Acid to break through

Conventional

Fracture Charge
Field Result: Acid Elimination

Design Performance in Eagleford Shale

- Reactive XEH (No Acid Used)
- Conventional Charge (Treated with Acid)
- Conventional Charge (No Acid Used)
CT Scans, Mancos Shale, Frac Charges
CT Scans, Mancos Shale, Frac Charges
Field Results – Breakdown Pressure Red
Field Results – Treating Pressure Reduction
Field Results – Productivity Improvements
Field Results: 10 Well Pairs

- 10 Well Pairs – Frac Charge vs. Conventional
- Treating Pressures show no correlation
- 7 of 10 pairs showed higher MCFD/Stage with Frac optimized charges
- 7 of 10 pairs show higher total MCFD with Frac optimized charges
Field Result: Decline Curve Improvement
Thank you!

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