2016 LATIN AMERICA PERFORATING SYMPOSIUM, BUENOS AIRES

ADVANCING CONSISTENT HOLE CHARGE TECHNOLOGY TO IMPROVE WELL PRODUCTION

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HUNTING DIVISION TITAN
AGENDA/INTRODUCTION

ADVANCING CONSISTENT HOLE CHARGE TECHNOLOGY

- Consistent Hole (CH) Technology
- Growth in a Down Market
- Opportunities for Advancement
- Review of Published Data
- Comparison of Charges in Common Well Configurations
- Guidelines for Selection, Evaluation, Comparison and Feedback
- Recommendations for Improvement to API RP19B
Conventional DP and GH Shaped Charges

- Non-uniform distribution of treating fluids
- Erosion and slotting of small perforations
- Under-utilization of all perforations
- Less efficient well stimulation
- Slow ramp-up to higher treating pressures
Advancing Consistent Hole Charge Technology to Improve Well Productivity

Shaped Charge Jet Profiles

Conventional Shaped Charge

- Wide Jet Profile
- Narrow Jet Profile

API Standard L-80

Common P-110

Consistent Hole Technology

- Uniform Jet Profile

API Standard L-80

Common P-110
Importance of CH Technology

- API 19B Section 1 Data
- Predictive models

\[ \Delta p_{perf} = \frac{0.2369 \rho}{d^4 C_d^2} \left( \frac{q}{N} \right)^2 \]
Importance of Consistent Hole Technology

Consistent Hole Technology enables opportunity for optimal well stimulation
Consistent Hole Shaped Charges

CH Technology

- New category of shaped charges
- Designed for decentralized perforating
- Improves efficiency of well stimulation
- Achieves consistent hole size regardless of fluid clearance
- Advertised with Average Hole Size AND Variation in Hole Size

<table>
<thead>
<tr>
<th>Angle</th>
<th>CH Technology</th>
<th>Conventional Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>0.2 in</td>
<td>0.2 in</td>
</tr>
<tr>
<td>60°</td>
<td>0.5 in</td>
<td>0.5 in</td>
</tr>
<tr>
<td>120°</td>
<td>1.1 in</td>
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</tr>
<tr>
<td>180°</td>
<td>1.5 in</td>
<td>1.5 in</td>
</tr>
<tr>
<td>240°</td>
<td>1.1 in</td>
<td>1.1 in</td>
</tr>
<tr>
<td>300°</td>
<td>0.5 in</td>
<td>0.5 in</td>
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</table>
Consistent Hole Market Trend

Growth in a Down Market

CH Technology has seen significant growth despite a 50% reduction in the overall charge market.
Consistent Hole System Growth

- Exponential growth in availability of CH perforating systems
- Growth driven by market demand for efficient technology
Why Growth in Consistent Hole Technology?

- ...operator *Increased Injectivity* by 20%
- ...evaluated 15 frac stages to show *Lower Treating Pressures* at the same pump rate or 8-10% higher pump rate
- ...two well studies show 10% *Reduction in Breakdown Pressure*, 2% *Reduction in Treating Pressure*, and 3% *Increase in Proppant Placement*
- ...*Reduced Injection Pressure* by 15%
- ...achieved and maintained *Faster Pump Rate* with *Reduced Stimulation Pump Pressure*
- ...*More Consistent Treating Rate* with *Increased Sand Concentration* at *Lower Pressure*
- ...*Decentralized* CH charge resulted in 10% *Higher Treating Rate* than a *Centralized* DP charge

*Case study information compiled from multiple CH technology providers*
Advancing Consistent Hole Technology

Existing case studies highlight benefits of CH Technology utilizing the same well simulation method

**Good News!!**

These studies have established a foundation for CH Technology

Are current well simulation methods and designs best?
Advancing Consistent Hole Technology

**Conventional Shaped Charges**
- Variation in hole size (a key design input) yields unpredictable stimulation result
- Accept that actual results differ from design – often without explanation

**Consistent Hole Technology**
- Consistent hole size increases control and predictability of stimulation →
- More strategic placement of perforations
- Removing hole size variability provides opportunity to investigate difference between design and actual results → Increased understand of effective stimulation
Advancing Consistent Hole Technology

CH Technology

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Conventional Charge

Unlikely that the same stimulation design is optimal for both perforation profiles
Advancing Consistent Hole Technology

1. Select the optimal CH Technology – use CH Technology with distinctly different performance from conventional charges

2. Evaluate down hole performance – comparable baseline, ideally different stages in the same well

3. Provide feedback – what worked? Where is the opportunity for improvement?
Selecting Advanced Consistent Hole Technology

<table>
<thead>
<tr>
<th>Company A</th>
<th>Number of Systems: 8</th>
<th>Size Range: 2-1/2” – 4-1/2”</th>
<th>Casing: Common size, grade, weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company C</td>
<td>Number of Systems: 3</td>
<td>Size Range: 3-1/8” – 3-3/8”</td>
<td>Casing: Low grade and small dia. or low weight</td>
</tr>
</tbody>
</table>

- Several perforating systems currently available
- Anticipate increase in options:
  - Broad range of systems optimized for different casing sizes, weights, and strength
  - Broad range of hole size options tailored for various well stimulation techniques
- **CAUTION!** Variation from tests in low grade, small diameter or low weight casing does not reflect performance in common casing.
## Selecting Advanced Consistent Hole Technology

<table>
<thead>
<tr>
<th>Gun Size</th>
<th>Casing</th>
<th>Hole Size</th>
<th>Variation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1/2&quot;</td>
<td>4-1/2&quot;</td>
<td>13.5# P-110</td>
<td>0.29</td>
<td>7.3%</td>
</tr>
<tr>
<td>2-3/4&quot;</td>
<td>4-1/2&quot;</td>
<td>13.5# P-110</td>
<td>0.38</td>
<td>6.8%</td>
</tr>
<tr>
<td>2-3/4&quot;</td>
<td>5-1/2&quot; 23# P-110</td>
<td>0.33</td>
<td>5.9%</td>
<td></td>
</tr>
<tr>
<td>3-1/8&quot;</td>
<td>4-1/2&quot;</td>
<td>13.5# P-110</td>
<td>0.40</td>
<td>2.5%</td>
</tr>
<tr>
<td>3-3/8&quot;</td>
<td>5-1/2&quot; 23# P-110</td>
<td>0.38</td>
<td>4.9%</td>
<td></td>
</tr>
<tr>
<td>3-3/8&quot;</td>
<td>5-1/2&quot; 23# P-110</td>
<td>0.44</td>
<td>5.9%</td>
<td></td>
</tr>
<tr>
<td>4&quot; 7&quot;</td>
<td>29# P-110</td>
<td>0.46</td>
<td>22.0%</td>
<td></td>
</tr>
<tr>
<td>4-1/2&quot;</td>
<td>7&quot; 29# P-110</td>
<td>0.47</td>
<td>13.4%</td>
<td></td>
</tr>
</tbody>
</table>

**Company A**
- Low variation in high strength casing
- Moderate to high variation in unknown casing strength
- Low to moderate variation in low strength casing

**Company B**
- 2-3/4" 4-1/2" 0.41 22.0% Unk.
- 3-1/8" 4-1/2" 0.46 10.9% Unk.
- 3-3/8" 5-1/2" 0.43 25.6% Unk.

**Company C**
- 3-1/8" 4-1/2" 11.6# L-80 0.48 7.1% 19B
- 3-3/8" 4-1/2" 11.6# L-80 0.50 6.6% 19B
- 3-3/8" 5-1/2" 17# L-80 0.45 13.4% 19B
Advancing Consistent Hole Charge Technology to Improve Well Productivity

### 3-3/8” 6 SPF 60 deg. Gun

**5-1/2” 23# P-110**

<table>
<thead>
<tr>
<th>Company A</th>
<th>Company C</th>
<th>Conventional GH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average: 0.43 in.</td>
<td>Average: 0.39 in.</td>
<td>Average: 0.36 in.</td>
</tr>
<tr>
<td>Min: 0.40 in.</td>
<td>Min: 0.26 in.</td>
<td>Min: 0.24 in.</td>
</tr>
<tr>
<td>Max: 0.46 in.</td>
<td>Max: 0.51 in.</td>
<td>Max: 0.52 in.</td>
</tr>
<tr>
<td>Variation: 5.9%</td>
<td>Variation: 32.6%</td>
<td>Variation: 35.7%</td>
</tr>
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</table>

**API Test: 5-1/2” 23# P-110**

**API Test: 5-1/2” 17# L-80**
### Calculation of Variation

**Range:** \( \frac{\text{Max} - \text{Min}}{\text{Avg}} \times 100 \)

**Coefficient of Variation:** \( \left( \frac{\text{St.Dev}}{\text{Avg}} \right) \times 100 \)

<table>
<thead>
<tr>
<th>System</th>
<th>Min</th>
<th>Max</th>
<th>Range</th>
<th>% Range</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp. A 3-3/8&quot; (5-1/2&quot; P-110)</td>
<td>0.39</td>
<td>0.47</td>
<td>0.08</td>
<td>18.3%</td>
<td>5.9%</td>
</tr>
<tr>
<td>Comp. C 3-3/8&quot; (5-1/2&quot; L-80)</td>
<td>0.35</td>
<td>0.53</td>
<td>0.18</td>
<td>40.1%</td>
<td>13.4%</td>
</tr>
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</table>

*Important Statistically Important*
Selection Principles

- Only compare performance data for charges tested:
  - Casing of equivalent or higher strength/weight
  - Fluid clearance of equivalent or greater distance
- Ensure the same calculation method is used when comparing variation
- Verify suitable Quality Control for CH Technology
  - CH Charges require more stringent QC methods
  - Review manufacturer’s QC procedure
Recommendations for API Standardized Testing

- Decentralize perforating gun
- Align perforating gun with one bank of shots at the minimum and maximum fluid clearances
- Common casing strength (i.e. P-110 casing)
- Common casing size (i.e. 5-1/2” casing for 3-3/8” gun)
- Minimum of two shots at each fluid clearance
**Recommendation for Data Publishing**

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OD, Weight, Grade  |  Specific Hole Size Range  | Comparison Values
Conclusion

- Consistent Hole Technology’s market presence is expected to increase
- Consistent Hole Technology has proven to reduce stimulation costs
- There is need for standardized testing and data publication

Next Phase:
Optimizing stimulation design with Consistent Hole Technology to increase well productivity
QUESTIONS?
THANK YOU!

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SLAP 2016

Improving Consistent Hole Charge Technology to Improve Well Production