CONSISTENT ENTRY HOLE PERFORATORS KNOW THE DIFFERENCE

NAPS-11-18
AUTHORS: James Kinsey, Cory Day, Justin Coker, Owen Oil Tools
Consistent Entry Hole Perforators vs. Gun Differences

- As consistent entry hole (CH) perforators are becoming the norm in the North American Pump Down market, the need for gun system flexibility is higher than ever.

- As with many mechanical technologies in our industry, not any two perforating carriers were designed the same.

- A detailed test series was conducted in an effort to understand the performance differences seen from changing gun designs.

- This testing featured multiple CH perforators and multiple gun systems.
Test Parameters

Test Specifics

- Two different CH perforators were selected from two different charge manufacturers
- These charges were tested in five different gun manufacturers, including each charge’s home gun system
- All tests were done in 3.125” perforating guns with a minimum 12 shots in each gun
- The guns were welded eccentric in the casing with the bottom shot directly on the 0° phasing
- The casing used for this testing was 5.5” 23# P-110 casing, all from the same heat lot to reduce potential lot-to-lot variability
Multi-Charge Test Results Comparison

Hole Size Avg vs Gun (Charges 1-2)

<table>
<thead>
<tr>
<th>Gun MFG</th>
<th>Charge 1</th>
<th>Charge 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home Gun</td>
<td>0.36</td>
<td>0.42</td>
</tr>
<tr>
<td>B</td>
<td>0.36</td>
<td>0.41</td>
</tr>
<tr>
<td>C</td>
<td>0.35</td>
<td>0.42</td>
</tr>
<tr>
<td>E</td>
<td>0.35</td>
<td>0.43</td>
</tr>
<tr>
<td>F</td>
<td>0.36</td>
<td>0.42</td>
</tr>
<tr>
<td>Avg.</td>
<td>0.36</td>
<td>0.42</td>
</tr>
</tbody>
</table>
Multi-Charge Test Results Comparison

Hole Size Avg. vs Gun (Charges 3-4)

- Home Gun: 0.35
- B: 0.40
- C: 0.45
- D: 0.41
- E: 0.47
- F: 0.47
- Avg.: 0.40

Charge 3 ■ Charge 4
Multi-Charge Test Results Comparison

STDEV vs. Gun (Charges 1-2)

<table>
<thead>
<tr>
<th>Gun MFG</th>
<th>Charge 1</th>
<th>Charge 2</th>
<th>STDEV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home Gun</td>
<td>3.2</td>
<td>3.6</td>
<td>4.5</td>
</tr>
<tr>
<td>B</td>
<td>5.8</td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td>C</td>
<td>5.9</td>
<td></td>
<td>5.9</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>4.6</td>
<td>6.9</td>
</tr>
<tr>
<td>F</td>
<td>3.8</td>
<td>3.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Avg.</td>
<td>6.1</td>
<td>4.7</td>
<td></td>
</tr>
</tbody>
</table>

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Multi-Charge Test Results Comparison

STDEV vs. Gun (Charges 3-4)

<table>
<thead>
<tr>
<th>Gun MFG</th>
<th>Charge 3</th>
<th>Charge 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home Gun</td>
<td>3.0</td>
<td>3.8</td>
</tr>
<tr>
<td>B</td>
<td>9.5</td>
<td>14.5</td>
</tr>
<tr>
<td>C</td>
<td>8.7</td>
<td>15.5</td>
</tr>
<tr>
<td>E</td>
<td>7.6</td>
<td>7.5</td>
</tr>
<tr>
<td>F</td>
<td>7.3</td>
<td>12.3</td>
</tr>
<tr>
<td>Avg.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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What Affects Performance?

Mechanical Differences

- There are several mechanical differences within the perforating gun that can affect charge performance:
  - Tube Strip Design
  - Internal Standoff
  - Scallop Thickness
  - Scallop Design
  - Gun Grade/Yield
  - Machined Tolerances
Perf Friction

- When using the Bernoulli equation to determine perforating friction through an orifice, changes in expected hole size avg. (home gun system) to hole size avg. in alternative gun systems can produce drastic fluctuations.

- Charge “3” Data Comparison
  - Hole Size Avg. in Home Gun = 0.35”
  - Overall Perf Friction = ~1,074 psi
  - Hole Size Avg. in Alternate Gun = 0.43”
  - Overall Perf Friction = ~471 psi

- Difference in expected Perf Friction vs. Alternate Gun = 56.15%
Recommendations

- This data indicates that alterations in gun design can produce significant performance changes, specifically in hole size average
  - This effect can be more noticeable as casing sizes/weights/grade changes away from designed conditions

- To protect the integrity of CH perforator design and to ensure the customer optimizes the frac design appropriately, we recommend the following steps when selecting a perforating gun:
  - Consult the charge manufacturer to see if they have actual test data in the gun selection and specific casing scenario
  - If not, recommend a test be conducted so you ensure you and your customer know what to expect from a performance standpoint
QUESTIONS? THANK YOU

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