Cluster Perforating Systems: Technology tailored for modern completions
Cluster Perforating Systems

Technology tailored for modern completions

- Technology Acceptance: CH, Addressable Switch, P&P Guns
- Technology Acceptance: Ideal Perforating Systems
- Current Industry Trends
- Modern Perforating System Need and Requirements
- Cluster Perforating System
- Case Studies
- Observations and Next Steps
Technology Acceptance

- Consistent Hole Technology – preferred perforating charge required by most operators
- Addressable Switch – preferred initiating system for reliability and safety used on over 70% of work
- Plug and Play Perforating Systems – preferred for simplicity and reliability
Completion Trends

- **Well Design**
  - Longer wells
  - More stages

- **Stimulation Design**
  - Shorter spacing between clusters
  - More clusters per stage
  - Fewer charges per cluster
  - Strategic placement of charges for limited entry perforating
  - Focus on hole size and consistency over penetration depth

Source: https://seekingalpha.com/article/3970147-pioneer-natural-resources-giant-wells-new-routine
Perforating System Limitations

• Acceptance of consistent hole technology and advancements in stimulation design require more perforating guns per stage

• Perforating gun manufacturers recognized the length of existing perforating systems were the limiting factor on guns per stage and guns per trip

• A new perforating system was needed
Requirements

- Consistent hole charges
- Short gun system for increased guns per stage
- Reliability of addressable initiating systems
- Simplicity and efficiency of plug and play perforating systems
Perforating System Design Limits

- Charge spacing is critical in conventional perforating systems.
- Adjacent charges can interact resulting in decreased performance when spaced too closely together.
- Gun system length is driven by minimum spacing between charges.
Cluster Perforating System: Charge Design

- Charges aligned on a plane, reducing length
- Simultaneous charge initiation eliminates interference
- Charge size is reduced to fit the same gun size
- Critical design decisions on charge performance

Example for 3-1/8” System in 5.5” Casing

<table>
<thead>
<tr>
<th></th>
<th>Penetration</th>
<th>Entry Hole</th>
<th>Entry Hole CV</th>
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<tbody>
<tr>
<td>Focus On Penetration</td>
<td>22.5&quot;</td>
<td>0.21&quot;</td>
<td>30%+</td>
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<tr>
<td>Balanced</td>
<td>12.0&quot;</td>
<td>0.25&quot;</td>
<td>13%</td>
</tr>
<tr>
<td>Focus On EH, CV</td>
<td>4.0&quot;</td>
<td>0.27&quot;</td>
<td>5%</td>
</tr>
</tbody>
</table>
Cluster Perforating System

• Simplified arming using addressable technology without the need for wired connections
• Simplified loading process achieving less than 30s per gun
• Elimination of detonating cord; charges initiated directly by a detonator
• Additional planes of charges may be added
• Gun to gun length: 7.5”
• # of Guns on Toolstring Surface Tested: 50
• # of Guns on Toolstring Field Tested: 45

3-1/8” CPS for 5-1/2” Casing
Case Study #1

Synopsis:
• CPS was run on the final 2 stages for each well on a 4 pad well, consistent hole charges run on all stages.
• CPS increased cluster count from 12 to 20 to establish equivalent total area open to flow per stage.
• CPS increased entry points from 24 to 40 holes per stage.

<table>
<thead>
<tr>
<th>EH</th>
<th>AOF/shot</th>
<th>Shots/gun</th>
<th>Guns/stg</th>
<th>Holes</th>
<th>Stg AOF</th>
<th>Treating Pressure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS Stages</td>
<td>0.25</td>
<td>0.049</td>
<td>2</td>
<td>20</td>
<td>40</td>
<td>1.963</td>
<td>n/a</td>
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<tr>
<td>Prior Stages</td>
<td>0.32</td>
<td>0.080</td>
<td>2</td>
<td>12</td>
<td>24</td>
<td>1.930</td>
<td>n/a</td>
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</table>

Conclusions:
• CPS resulted in on average ~1500 psi lower treating pressure compared with prior stages on the same wells
• CPS increased cluster count from 12 to 20 while decreasing overall length from 45ft to 22ft
Case Study #1

Cluster count increased from 12 to 20 but overall length was cut by over half
Case Study #2

Synopsis:

- CPS was run on stage 16 for one well, consistent hole charges run on all stages
- CPS increased cluster count from 27 to 45 to achieve operator’s ideal gun number per stage. 27 was the maximum gun number due to length restrictions of the existing gun system.
- CPS increased entry points from 81 to 135 holes per stage.
- CPS decreased the stage area open to flow by approximately 38%

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<th>Guns / stg</th>
<th>Holes</th>
<th>Stg AOF</th>
<th>Treating Pressure</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS Stage 16</td>
<td>0.25</td>
<td>0.049</td>
<td>3</td>
<td>45</td>
<td>135</td>
<td>6.627</td>
<td>6600</td>
<td>10% reduction in treating pressure</td>
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<tr>
<td>Prior Stages</td>
<td>0.38</td>
<td>0.113</td>
<td>3</td>
<td>27</td>
<td>81</td>
<td>9.186</td>
<td>7300</td>
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Conclusions:

- CPS resulted in 10% psi lower treating pressure compared with prior stages on the same wells
- Reduced length of CPS allowed for customer’s ideal number of clusters per stage
Case Study #2

45 gun string ~36 ft long from Cable head to bottom of plug
Observations and Next Steps

• Treating pressures were reduced in both cases
• The reduction in treating pressure was not correlated to area open to flow
• Increased entry points/perforations is correlated to reduction in treating pressure and corresponds to industry trends towards more clusters per stage/more perforations per stage
• More perforations per stage is only beneficial when holes take fluids uniformly

Next Steps
• Continued field trials
• Transition from stage comparison to full wells and production
QUESTIONS?

THANK YOU

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NORTH AMERICA PERFORATING SYMPOSIUM

AND SAFETY FORUM

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