Successful Use of API Section-IV Testing to Select Between Zinc and Steel Case Shaped-Charges in a Dual-Zone Cased-Hole Gravel Pack Tubing-Conveyed-Perforating Operation for a Gas Well: Case Study
AGENDA

- Design Drivers
- Charge Selection
- Shot Testing—Parameters
- Shot Testing Results—Charge Performance
- Shot Testing Results—Flow Performance
- Outcomes and Field Application
Design Drivers

- Well type: dual-zone cased-hole gravel pack
  - Large distance between zones: ~200 m—2 ea. runs
  - Large casing diameter: 10 3/4 in.—larger clearance
  - Intermediate completions valves between zones—debris risk
  - Vertical
  - Entry hole diameter (EHD) criteria from operator: 1.0 in.
  - Gas well—overbalance, shoot, and retrieve perforation with retrievable packer

- Lower zone
  - Open sump—no additional risk
  - Largest EHD big hole charge—more effective gravel pack, better production

- Upper zone
  - Sump packer with plug set—to stop debris going farther downhole
  - Risk of debris sitting on plug—unable to pull plug
  - Perforating close to sump, 3 m—high shock (pressure) loading on sump packer
Charge Selection

- Initial screening for best charge performed using perforation simulation software
- Best zinc and steel charge used in testing
- Bottom zone selection
  - No debris risk—steel charge
  - Conduct testing to validate charge performance with expected dynamic underbalance
- Top zone selection
  - Debris—major concern
  - Steel vs. zinc—shot testing
    - Shot performance
    - Perforation cleanup for zinc
    - Sump packer shock loading
    - Debris consideration
  - Evaluate sump packer shock loading for zinc

Successful Use of API Section-IV Testing to Select Between Zinc and Steel Case Shaped-Charges in a Dual-Zone Cased-Hole Gravel Pack Tubing-Conveyed-Perforating Operation for a Gas Well: Case Study
Shot Testing—Parameters

- Actual rock parameters (sandstone)
  - Top zone
    - Permeability: up to 4000 md; average 600 md
    - Porosity: 17 to 18%
    - Unconfined compressive strength (UCS): average ~6,000 psi
  - Bottom zone
    - Permeability: up to 1000 md
    - Porosity: 22%
    - UCS: average ~4,000 psi

Analog rock selected: outcrop
Bentheimer sandstone selected for both zones

- Test gun details to match actual
- Wellbore details based on ideal centralization
Shot Testing Results—Charge Performance

- **Testing plan**
  - Temperature
    - Shoot 1 ea. at ambient
    - Shoot 1 ea. at 257°F
  - Inject odorless mineral spirits (OMS) — simulate gravel packing
  - Flow with N₂ — simulate gas flow

- **Results**
  - Both charge performances met operator requirements
  - Identified dynamic underbalance could potentially clean up zinc perforations
  - Smallest EHD through cement
  - Zinc performance qualified for operator requirements

---

### Actual Dynamic Underbalance During Testing

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Wellbore Pressure Reached, psi</td>
<td>3,592</td>
<td>3,757</td>
<td>4,163</td>
<td>3,656</td>
</tr>
<tr>
<td>Observed Peak DOB(+)/DUB(−), psi</td>
<td>-708</td>
<td>-543</td>
<td>-337</td>
<td>-844</td>
</tr>
</tbody>
</table>

Successful Use of API Section-IV Testing to Select Between Zinc and Steel Case Shaped-Charges in a Dual-Zone Cased-Hole Gravel Pack Tubing-Conveyed-Perforating Operation for a Gas Well: Case Study
Shot Testing Results—Charge Performance

Successful Use of API Section-IV Testing to Select Between Zinc and Steel Case Shaped-Charges in a Dual-Zone Cased-Hole Gravel Pack Tubing-Conveyed-Perforating Operation for a Gas Well: Case Study
Shot Testing—Flow Performance

- Outcomes
  - Zinc performance met operator requirement—enabled option to use zinc charge
  - Zinc vs. steel performance in terms of injection/production was highly similar: zinc has a lower debris advantage
  - Zinc perforation clean-up—Dynamic Underbalance shown to be able to clean up perforation
  - Implemented a delayed Dynamic Underbalance surge event

<table>
<thead>
<tr>
<th>Post-shot Flow</th>
<th>1) Injectivity Index, ((\text{R.cm}^3\text{-cp})/\text{atm-s})) (start to end)</th>
<th>13.96</th>
<th>17.95</th>
<th>10.98</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1) Injection Ratio (to Restr.-Face RI)</td>
<td>1.88</td>
<td>1.78</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>2) Productivity Index, ((\text{R.cm}^3\text{-cp})/\text{atm-s}))</td>
<td>17.03</td>
<td>36.12</td>
<td>47.10</td>
</tr>
<tr>
<td></td>
<td>2) Production Ratio (to Restr.-Face RI)</td>
<td>1.53</td>
<td>4.86</td>
<td>4.67</td>
</tr>
</tbody>
</table>
Outcomes and Field Application

- Outcomes
  - Zinc performance met operator requirements
  - Similar zinc vs. steel flow performance
  - Zinc charge provided lower debris advantage
  - Zinc perforations clean-up — Dynamic underbalance shown to be able to fluidize the debris created during the Zinc perforation event

- Field application
  - Zinc charge used for top zone and steel charge for bottom zone
  - Implemented a delayed Dynamic Underbalance surge event — fast gauges verified
  - Well successfully gravel packed — injection rates achieved
  - Loss rates and production rates met operator expectations
  - Debris was cleaned using wellbore cleanup tools
  - Well successfully perforated, gravel packed, and completed
QUESTIONS?
THANK YOU!