Perforating with Deep Penetrators Followed by Propellant Treatment Yields Results in Tight Reservoir

Gehad Mahmoud, Muhammad Nadeem Aftab, ADCO, Abu Dhabi and Alan Salsman, Sherif Abdel-Shakour, Schlumberger

MENAPS 13–21
Back Ground

- Well drilled to evaluate tight gas
  - Good gas shows were observed during drilling
  - Unconventional gas layer

- Rigless well test

- Lower zone
  - 4½” casing, 4½” tubing
  - Min ID 3.688”, PBTD to Packer ~2,300’

- Tight gas carbonate
  - 5% φ, 0.01 md perm
  - Hydrostatic pressure ~5200 psi
  - BHT ~305 degF

- Objective – test for gas production
  - Gross interval 660’
1st Attempt

- Coiled tubing run with abrasive perforator
  - Attempt to perforate with abrasive water mix
  - Attempt local fracture treatment with acid
  - Several intervals attempted
  - No connection made to reservoir
    - 2 days lost time

- Not appropriate for this application:
  - Completion constraints
  - High formation stress
  - Tight reservoir
  - CT depth shift
Gun Selection

- Deepest penetration
  - Bypass near well damage and access
- Modeled several systems
  - Rock model
- 2 7/8”, 6 spf, 60 deg
  - Wireline conveyed
    - 40’ per run
    - Balanced conditions
- Chose rock optimized premium deep penetrating charge
  - 25% deeper in this zone

**Standard Deep Penetrator**

- 2-7/8” HSD, PowerJet 2906, HMX, 15.0 g, OD 2.802 in
- 60º Phasing, 6.00 spf

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance Avg</td>
<td>0.54 in</td>
</tr>
<tr>
<td>Total Pen Avg *</td>
<td>6.83 in</td>
</tr>
<tr>
<td>Formation Pen Avg *</td>
<td>5.81 in</td>
</tr>
<tr>
<td>Formation Dia Avg</td>
<td>0.59 in</td>
</tr>
<tr>
<td>Casing EH Avg</td>
<td>0.36 in</td>
</tr>
<tr>
<td>AOF (at 6.00 spf)</td>
<td>0.61788</td>
</tr>
</tbody>
</table>

API: Pen 25.30 in, EH Dia 0.38 in, 19B 1st Ed
* Rock-based Model

**Premium Deep Penetrator**

- 2-7/8” HSD, PowerJet Omega 2906, HMX, 16.0 g, OD 2.802 in
- 60º Phasing, 6.00 spf

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance Avg</td>
<td>0.54 in</td>
</tr>
<tr>
<td>Total Pen Avg *</td>
<td>8.22 in</td>
</tr>
<tr>
<td>Formation Pen Avg *</td>
<td>7.19 in</td>
</tr>
<tr>
<td>Formation Dia Avg</td>
<td>0.63 in</td>
</tr>
<tr>
<td>Casing EH Avg</td>
<td>0.38 in</td>
</tr>
<tr>
<td>AOF (at 6.00 spf)</td>
<td>0.69664</td>
</tr>
</tbody>
</table>

API: Pen 36.00 in, EH Dia 0.34 in, 19B 1st Ed
* Rock-based Model

**Rock Optimized Premium Deep Penetrator**

- 2-7/8” HSD, PowerJet Nova 2906, HMX, 16.9 g, OD 2.802 in
- 60º Phasing, 6.00 spf

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance Avg</td>
<td>0.54 in</td>
</tr>
<tr>
<td>Total Pen Avg *</td>
<td>9.94 in</td>
</tr>
<tr>
<td>Formation Pen Avg *</td>
<td>8.92 in</td>
</tr>
<tr>
<td>Formation Dia Avg</td>
<td>0.62 in</td>
</tr>
<tr>
<td>Casing EH Avg</td>
<td>0.37 in</td>
</tr>
<tr>
<td>AOF (at 6.00 spf)</td>
<td>0.65766</td>
</tr>
</tbody>
</table>

API: Pen 30.70 in, EH Dia 0.38 in, 19B 1st Ed
* Rock-based Model
Propellant Stimulation

- Propellant conveyed on metal tube
  - Internal deto cord initiates propellant burn
  - Creates high pressure gas bubble
    - Burn time 50–100 ms

- Modeling
  - Critical for safe operation
    - Also determine effectiveness
  - PulseFrac model predicts
    - Pressure from burn
      - >5000 psi over well pressure
    - Frac half length
    - Tool movement and weakpoint strain
Propellant Model Output

Predicted Fracture width and Length

Predicted Well Pressure
Propellant Surface Test (from YouTube)
Propellant Impact

- Perforate at balance or OB
  - Tunnels damaged
  - Limited clean-up
- Propellant treatment
  - High pressure gas bubble
    - Pressure oscillations
  - Cleans tunnel and may create cracks in the rock
- Improves path to reservoir
Program

- Objective – Get gas indication at surface
- Perforate 5 x 40’ intervals spaced out over 660’
  - Rigless wireline
  - 2 7/8” spf, 60 deg DP guns
- Treat each interval with 12’ of 2” propellant sticks
  - Wireline conveyed
- Test for gas flow
Planning

- Increase weak point rating
  - Electrical release allows full cable strength
- Concern over packer pressure differential
  - Modeling showed 8500 psi differential (dynamic)
    - Packer rating 7500 psi
    - No flags from planning tool
  - Need to understand static versus dynamic ratings??
- Clear surface area before ignition
  - Violent cable movement at surface
Execution

- All rigless operation
- 5 perforating runs
  - Pressure seen at surface after 1st run
- 5 runs of propellant
  - Large shocks seen at surface
  - Large fluctuations in cable tension
    - Electrical release
  - Wellhead pressure increased
Results

- Wellhead pressure versus time plot
- Reservoir access evident on the 1st perforation run
- Increased surface pressure after 1st propellant run
- Gas flared at surface during bleed down periods
  - SUCCESS – discovery of unconventional HC gas
Deep penetration perforating plus propellant stimulation yields results in tight gas carbonate

Propellant treatment improved the connection with the reservoir

- Proper planning is critical for successful propellant treatment