Perforating for Squeeze Through Four Casing Strings to Remediate Annulus Gas Leak Problem

Mohamed El-Sayed Ibrahim, Ahmed Khalifa Al-Neaimi, Mohamed Abdelsalam Hassane, Abdul Salam Mohamed Al-Mansoori, Shanof Mohamed, Omar Al-Mutwali, ADMA OPCO

Alan Salsman, Schlumberger
Well Data

- **Background**
  - Well A was Drilled & completed in November 1994 to supply gas to complex/ auto gas inj. Into other well
  - Tower – three gas producers, one gas injector and two vacant slots

- **Well “A” Casing Details**
  - 30” conductor
  - 18 5/8” casing
  - 13 3/8” casing
  - 9 5/8” casing
  - 7” liner
  - 7” liner tied back to surface with 7 5/8” casing
**Problem & Consequences**

- **Well “A” HSE Problems**
  - Gas/Oil Bubbles at sea bed around the conductor pipe
  - High Annulus Pressure in 18 5/8” x 13 3/8” – 2600 psi (max recorded)
  - High Annulus Pressure in 13 3/8” x 9 5/8” – 900 psi (max recorded)
  - Risk rank No. 1 - Entire tower Unsafe.

- **Consequences**
  - All the wells on tower shut in since Jan 2001 due to the integrity problems with Well “A”
  - Huge Loss in gas Production and Injection
Objectives

- Identify Leaking Source.
- Restore Integrity – Cure Annuli pressures and eliminate gas/oil bubbles
- Abandonment of Gas Well in line with International Standards
Leak Source Identification

- Well Data & Operations Review
- Leak Rate Test
- Compositional Analysis
- Noise & Temperature Logs
- Multiple Bleed Downs
Conclusion: Source is Reservoir A behind 3 & 4 Casings
Options to Cure Leaking Source

- **Milling.**
- **Slicing.**
- **Perforations.**
Innovative Option - Perforation

- Gun Selection, Deeper Penetration (4 1/2” Premium Deep Penetration charge).

- Used Orienting Adaptors to ensure effective gun phasing.

- Selected Proper Type of squeeze cement.
Perforation Simulation & Real Test

Company: ADMA

Perforating System #2
4-1/2" KSD, PowerJet Omega 407, HMX, 22.9 g/CD 4.5 in
10% N2 Phasing, 130 psi

<table>
<thead>
<tr>
<th>Angle</th>
<th>Distance (in)</th>
<th>Total Pen *</th>
<th>Form Pen *</th>
<th>Form Dia (in)</th>
<th>Cig EH Dia</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.1</td>
<td>16.94</td>
<td>6.32</td>
<td>6.31</td>
<td>0.240/0.296/0.190.14</td>
</tr>
<tr>
<td>90</td>
<td>0.89</td>
<td>14.59</td>
<td>6.24</td>
<td>6.24</td>
<td>0.250/0.296/0.190.17</td>
</tr>
<tr>
<td>135</td>
<td>0.23</td>
<td>13.54</td>
<td>6.34</td>
<td>6.34</td>
<td>0.410/0.376/0.259.22</td>
</tr>
<tr>
<td>180</td>
<td>0.00</td>
<td>13.24</td>
<td>6.40</td>
<td>6.40</td>
<td>0.180/0.340/0.230.20</td>
</tr>
<tr>
<td>225</td>
<td>0.23</td>
<td>13.54</td>
<td>6.34</td>
<td>6.34</td>
<td>0.250/0.296/0.190.17</td>
</tr>
<tr>
<td>270</td>
<td>0.50</td>
<td>14.58</td>
<td>6.87</td>
<td>6.87</td>
<td>0.320/0.306/0.259.22</td>
</tr>
<tr>
<td>315</td>
<td>1.73</td>
<td>14.34</td>
<td>6.03</td>
<td>6.03</td>
<td>0.250/0.296/0.190.17</td>
</tr>
<tr>
<td>Average</td>
<td>1.59</td>
<td>14.09</td>
<td>6.31</td>
<td>6.31</td>
<td>0.250/0.296/0.190.17</td>
</tr>
</tbody>
</table>

API: Pen 34.00 in, EH Dia 0.26 in, 1501st Std
* Rock-based model

Remarks:
Casing Godes are different in the actual test
Pl. 12 spf, did not penetrate at the 180 degree phase in 18 5/8" casing
In actual tests, all casings were Eccentricized
Orienting Adaptors

Perforation against 4 Casings

Gun Offset by 90 degrees with Orienting Adaptors

Orienting Adaptors Provide Effective Phasing of 18 degree
Cement Types

Selected proper type of cement to plug the source behind & between four casings

<table>
<thead>
<tr>
<th>Property</th>
<th>Class-G</th>
<th>Fine Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Size microns</td>
<td>~50</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Temperature</td>
<td>No limitation with (35% Silica flour)</td>
<td>Up to 320F</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>~3000</td>
<td>~2300</td>
</tr>
<tr>
<td>Acid Solubility</td>
<td>&lt;3%</td>
<td>Yes</td>
</tr>
<tr>
<td>Use When Injectivity</td>
<td>High &gt; 5 bpm</td>
<td>Very Low &lt; 1 bpm</td>
</tr>
</tbody>
</table>
Remedial Against Source

- Perforated 3 ft below 18 5/8” shoe against A – 40 ft. (PJ, 12 spf)
- 2 runs to have 24 spf
- Injectivity after perf – 3.5 BPM
- Remedial:
  - Bottom Perfs – 31 bbls fine cement
  - Top Perfs – 53.2 bbls fine cement
  - Pressure tested to 0.8 psi/ft – Holding
- Perforated against 4 Casings top A – 20 ft (PJ, 5 spf, 2 runs)
- Orienting Adaptors for effective phasing
- Improved injectivity to 3 BPM
- Remedial
  - Squeezed 40 bbls fine cement
  - Pressure tested to 0.8 psi/ft – Holding
- Losses & Continuous return f/ 13 3/8” x 9 5/8”
Top Up Job

- Topped Up 18 5/8” x 13 5/8” annulus with 42 bbls Class G cement
- Topped Up 13 3/8” x 9 5/8” annulus with 5 bbls Class G cement
Perforation Verifications

- Injectivity tests
- Cement Squeezed
- Losses into formations
- Fluid to surface
Abandonment Operation

- Isolated Reservoir D
- Isolated potential leaking points
- Cured Leaking Source
- Isolated Aquifer
- 9 cement plugs
- No annulus pressure build up is observed.
- Each cement plug Pressure tested for integrity check.
- Squeezed off Perforations pressure tested.

Pumped 1000 bbls of Cement
Post Abandonment Evaluation

- Graph shows the Annuli pressure decreasing as operation progresses.
- The pressure shown after rig release is trapped pressure.

Objective Achieved & Tower Safe for Commissioning
Results & Benefits

ORIGINALITY: (FIRST TIME)

- Success of Perforation & Cementing behind Four Casings – First Time in OPCO’s
- Successful Abandonment in line with International Standards

VALUES:

- Avoided Costly & Complication Options : 5 – 10 MM $ Saving
- Tower is Safe for production and injection (100 MMSCFD)
- Tower Integral - Vacant slots can be utilized

COLLABORATION:

- Project handled by Multidisciplinary Team within ADMA and Schlumberger.

PEOPLE:

- Excellent reference for all OPCOs, shareholders and International companies
Acknowledgements

- Heart Felt Appreciation to the management of ADNOC and ADMA-OPCO for permission to publish the paper.
- Appreciation extended to Schlumberger personnel for their continuous support.
Thank You
Petroleum Engineering Division

Tower

- 3 Gas Producers
- 1 Gas Injector
- 2 Vacant Slots

Well XX
SGP Prod Data
Gas Rate: 20 MMscfd
Condensate: 37 stb/MMscf

Well XX
SGP Prod Data
Gas Rate: 20 MMscfd
Condensate: 75 stb/MMscf

Well XX
SGI Injection Rate
Gas Rate: 50 MM scfd