Use of Foamer to Deliquify Natural Gas Wells with Dry-gas-lift System

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Nalco Company, Energy Services
Outline

• Background
• Developed foamer chemistry using DOE: synergism of mixed surfactants
• Test methods utilized to develop dry-gas-lift (DGL) foamer in the lab
  — Sci-Foam EC7018A
• Field performance data of EC7018A
  — On DGL well
  — On well without DGL
• Conclusions
Background

- Customer used very dry gas in the gas lift mandrel to mechanically unload liquid from natural gas wells
- A large amount of incumbent foamer was used to solve the loading problem
- The solvent in the conventional chemical foamers flashed off easily when injected through the gas-lift mandrel
- Conventional foamer “gunked” in the system and plugged the mandrel, resulting operational cost
Mixture Design Techniques
(Four components)

% Unloading = 36.8 X_A + 45.4 X_B + 8.4 X_C - 83.6 X_D
+ 152.7 X_A X_B + 22.0 X_A X_C - 38.1 X_A X_D
+ 182 X_B X_C + 274.4 X_B X_D + 62.1 X_C X_D
- 637.2 X_A X_B X_D - 810.3 X_A X_C X_D

Where:
X: weight percentage of component;
A = betaine ; B = anionic surfactant;
C = EGMBE ; D = cationic corrosion inhibitor

TYPICAL MOLECULAR INTERACTION PARAMETERS (β)

<table>
<thead>
<tr>
<th></th>
<th>ANIONIC</th>
<th>NONIONIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANIONIC</td>
<td>0 TO -1</td>
<td>-1 TO -5</td>
</tr>
<tr>
<td>NONIONIC</td>
<td>-1 TO -5</td>
<td>&lt; -1</td>
</tr>
<tr>
<td>AMPHOTERIC</td>
<td>-5 TO -15</td>
<td>&lt; -1</td>
</tr>
<tr>
<td>CATIONIC</td>
<td>-15 TO -25</td>
<td>-1 TO -5</td>
</tr>
</tbody>
</table>
Anionic Surfactant in Mixed Micelle

Mole fraction of anionic surfactant in mixed solutions

Non-Ideal $\beta = 0$

Ideal

Actual data $\beta = -3.0$

Mole fraction of anionic surfactant in mixed micelle

Mole fraction of anionic surfactant in mixed solutions
CMC of Mixed Solutions

- Non-Ideal
- Ideal

β = 0
β = -3.0

Actual data

Mole fraction of anionic surfactant in mixed solutions

CMC (mole/l)

0 0.2 0.4 0.6 0.8 1

Mole fraction of anionic surfactant in mixed solutions

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Test Methods Used to Develop & Validate DGL Foamer /CI/SI EC7018A

- “Gunking” test
- Dynamic foaming test
- Cold temperature stability
- Field trial
- Continuous injection
“Gunking” Test

• The bench top Rotary-Evaporator test

• Test temperature 115ºC / 240 ºF

• Weight loss calculated

• Sample residue visually inspected for solid, precipitation after test (both hot and cooled)

Reference: Cole-Parmer Rotary Evaporator Systems
Gunking Test Residuals (Cooled)

DGL foamer 1

DGL foamer 2

DGL EC7018A

Clear liquid
Dynamic Foaming Performance Test (DFP) - Nalco Deliquification Unloading Rig
DFP Test Results in Water and Brine

- Brine: 3.85% NaCl, 0.55% CaCl2·2H2O
- Tap water
  - DGL Foamer 2
  - 400ppm active foamer

![Bar chart](chart.png)

- In tap water: 73.81%, 62.69%, 61.43%, 30.40%, 70.02%
- In synthetic brine: 77.00%, 78.92%, 71.32%, 80.21%, 69.26%

- 400ppm active foamer
- Brine: 3.85% NaCl, 0.55% CaCl2·2H2O
DFP Test Results in Brine and Field Condensate

Liquid Unloading Efficiency in Brine + 20% Condensate

% Unloading by W.T.

0.00% 20.00% 40.00% 60.00% 80.00% 100.00%

DGL Foamer 1 DGL Foamer 2 EC7018A

2.89% 26.78% 45.92%
## Cold Temperature Stability Test

<table>
<thead>
<tr>
<th>Foamer</th>
<th>Winterization test @ -30 °C</th>
<th>Winterization test @ -45 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional foamer 1</td>
<td>Failed</td>
<td>Failed</td>
</tr>
<tr>
<td>Conventional foamer 2</td>
<td>Failed</td>
<td>Failed</td>
</tr>
<tr>
<td>DGL foamer 1</td>
<td>Failed: cloudy liquid with a small amount of solid</td>
<td>Failed: ice cube</td>
</tr>
<tr>
<td>DGL foamer 2</td>
<td>Passed: clear liquid</td>
<td>Passed: clear liquid</td>
</tr>
<tr>
<td>EC7018A</td>
<td>Passed: clear liquid</td>
<td>Passed: clear liquid</td>
</tr>
</tbody>
</table>
## Test Summary of DGL Foamers

<table>
<thead>
<tr>
<th>Foamer</th>
<th>Gunking test 115°C/240°F</th>
<th>Winterization - 30°C</th>
<th>DFT % unloading by w.t *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tap water</td>
</tr>
<tr>
<td>EC7018A</td>
<td>Pass</td>
<td>Pass</td>
<td>70.0</td>
</tr>
<tr>
<td>DGL foamer 1</td>
<td>Fail</td>
<td>Fail</td>
<td>73.8</td>
</tr>
<tr>
<td>DGL foamer 2</td>
<td>Fail</td>
<td>Pass</td>
<td>62.9</td>
</tr>
</tbody>
</table>

* 400ppm foamer active
** Brine 3.85% NaCl, 0.55% CaCl2.2H2O
¶ Condensate sample from the well
Taking the Technology to the Field
Dry-gas-lift Well Diagram

<table>
<thead>
<tr>
<th>Gas:</th>
<th>Mole Percent</th>
<th>GAL per 1000 Cu Ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARBON DIOXIDE</td>
<td>0.125%</td>
<td></td>
</tr>
<tr>
<td>NITROGEN</td>
<td>6.978%</td>
<td></td>
</tr>
<tr>
<td>OXYGEN</td>
<td>0.025%</td>
<td></td>
</tr>
<tr>
<td>METHANE</td>
<td>85.351%</td>
<td></td>
</tr>
<tr>
<td>ETHANE</td>
<td>4.299%</td>
<td>1.149</td>
</tr>
<tr>
<td>PROPANE</td>
<td>1.644%</td>
<td>0.453</td>
</tr>
<tr>
<td>ISOBUTANE</td>
<td>0.338%</td>
<td>0.111</td>
</tr>
<tr>
<td>BUTANE</td>
<td>0.456%</td>
<td>0.144</td>
</tr>
<tr>
<td>ISOPENTANE</td>
<td>0.162%</td>
<td>0.059</td>
</tr>
<tr>
<td>PENTANE</td>
<td>0.143%</td>
<td>0.052</td>
</tr>
<tr>
<td>HEXANES</td>
<td>0.252%</td>
<td>0.104</td>
</tr>
<tr>
<td>HEPTANES</td>
<td>0.169%</td>
<td>0.078</td>
</tr>
<tr>
<td>OCTANES</td>
<td>0.045%</td>
<td>0.023</td>
</tr>
<tr>
<td>NONANES</td>
<td>0.010%</td>
<td>0.006</td>
</tr>
<tr>
<td>DECANES PLUS</td>
<td>0.003%</td>
<td>0.002</td>
</tr>
<tr>
<td>Total</td>
<td>100.000%</td>
<td>2.181 C2+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.032 C3+</td>
</tr>
<tr>
<td>HEXANES PLUS</td>
<td>0.479%</td>
<td>0.213 C6+</td>
</tr>
</tbody>
</table>
Field Performance

- Used conventional foamers
- Started EC7018A injection
- Trialed conventional foamer
- Switched back to EC7018A
- Water slugs
- Stabilized water production
How about Topside?
Field Performance — Fluid Separation on the Surface
Field Performance — Water Quality

Right after pulling off flow line

2 minutes after sampling
Field Performance — Water Quality

• Foam collapsed quickly and left good quality water behind

• Clear water to be re-injected via disposal well

• No top side upset due to the use of Sci-Foam EC7018A
Conventional Well: Three-Month Trend

Start Soap Injection
Rate $14.1 \times 10^3 \text{ m}^3/\text{d}$

Declining Casing Pressure

With Soap Performance
Continuous production for 7 weeks at high rate.
Estimated up-lift: $5 \times 10^3 \text{ m}^3/\text{d}$
On-time increased from 50 to 100%

Forward Plan
Reduce soap injection rate
Conclusions

• Utilized DOE* and studied the synergy of surfactant mixtures

• Designed test methods to develop DGL foamer EC7018A in the lab

• Validated the efficiency of EC7018A by successful field trial and continuous injection

• Use of EC7018A boosted gas production without upsetting the gas mandrel and the topside separation

• Sci-Foam, when used in a conventional gas well, maximized the gas production as well

Acknowledgements

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