A Unique Multifunctional Foamer for Deliquification of Loaded Wells in Canada

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&
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Greater Sierra: Field Overview

- 800 Horizontal wells, 140 MMscfd
- Water gas ratio = 11-18 liters/1000m³ gas
- Condensate gas ratio = 5-15 liters/1000m³ gas
- Condensate water ratio = 0 to 2:1
- Salinity = 0 to 300,000 ppm
- Wet muskeg terrain, -40°C during the winter
Nature of Liquid Loading

Combination of factors:

- Reservoir depletion
- Water of condensation and formation water
- Liquid slugging
- Potential for static column of water in the wellbore
Deliquification Strategy

- Intermittent flow: Some wells may be shut in 75% of the time in order to build pressure to lift liquids.
- Plunger: Used in over 300 wells. Require additional operator time and maintenance.
- Velocity strings: Used in over 200 wells. Difficulty handling large hydrostatic caused by liquid slugs and are prone to corrosion.
- Unsuccessful field trial of previous incumbent’s foamer in 2007 on 10 wells with capillary strings. The foamer could not handle condensates.
- The use of foamers was revisited by Encana and Nalco in 2008 as Nalco had successfully used condensate foamers with other gas producing companies.
Advantages of Foamers

• Can be injected down the casing-tubing annulus – much deeper than the plunger. However, to be effective, the foamer has to reach and generate foam at the end of the tubing, preventing accumulation of liquids above the tubing.

• Low cost of the failure if the program proves to be unsuccessful. The cost of failure for a foamer is about $5,000 vs. $30,000 for a plunger lift install or $75,000 for a velocity string install.
Foamer Development: Criteria for Success

- Effective in the presence of 50% condensate with fresh water or brine
- Quick foam collapse at the well head
- A combination foamer product that contains corrosion inhibitor and scale inhibitor
- Foamer is stable and pumpable at -43°C
- Foamer is compatible with HDPE, stainless steel, and various elastomers
Typical Surfactants

• Nonionic:
  – More soluble at lower temperature
  – Increase temperature &/or salt concentration reduces solubility – lowers cloud point
  – Good for wells with unknown water chemistry

• Anionic
  – Excellent aqueous foamers
  – Highly polar
  – Can be affected by high brine solutions
  – At elevated temperatures can degrade

• Cationic
  – Good for foaming water/oil mixtures
  – Efficacy dependant on molecular weight
  – Can be prone to emulsion issues

• Amphotheric
  – Very versatile: Higher condensate tolerance
  – Good high temperature performance and stability
  – Effective in high salt content brines
Laboratory Testing

Impact of Salinity on Foaming Performance
50% condensate with 10000 ppm Foamer
5 scfh Nitrogen Flow Rate

Result: Foamer was effective in 50wt% condensate with chlorides > 4500 ppm
Foam Stabilizing: Area per molecule

Packing at the air-liquid interface

- Low salt
  - Unstable foam
    - Loosely packed film
      - High area per molecule
- High salt
  - Stable foam
    - Tightly packed film
      - Small area per molecule

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Foam Destabilizing – Reduced Electrostatic Repulsion

Low salt

Stable foam

High salt

Liquid flows

Unstable foam

Liquid flows

Drainage

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Laboratory Testing - Results

• Unloading efficiency results vary with brine/condensate composition

• For all samples the amphoteric surfactant showed greater potential for lifting fluids of various concentrations when compared with nonionic (alkyl poly glucoside) and anionic (sulfossucinate, alkyl diphenyloxide disulphonate) foamers

• Quick foam collapse was observed for the amphoteric foamer

• Good separation for water and condensate (i.e., unstable emulsion) was observed
Corrosion Inhibition: Linear Polarization Resistance Data

**Graphs:**
- **Left Graph:**
  - Decreased due to formation of a protective film
  - Final 63 mpy
- **Right Graph:**
  - Steep slope is an indication of a quick filmer
  - Final 0.06 mpy

**Table:**

<table>
<thead>
<tr>
<th>Cell</th>
<th>Weight Loss (mg)</th>
<th>Weight Loss Corrosion Rate (mpy)</th>
<th>Final Pit Depth (mils)</th>
<th>Final Fitting Rate (mpy)</th>
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</thead>
<tbody>
<tr>
<td>Blank</td>
<td>45.9</td>
<td>26.8</td>
<td>0.5</td>
<td>46.1</td>
</tr>
<tr>
<td>EC7029A (2500 ppm)</td>
<td>1.5</td>
<td>0.8</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>EC7029A (15,000 ppm)</td>
<td>1.3</td>
<td>0.7</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Gravimetric Results Sweet Conditions**

Feb. 27 · Mar. 2, 2011

2011 Gas Well Deliquification Workshop Denver, Colorado
Corrosion Inhibition: Electrode Photographs

Blank

Treated
In 2009, eight (8) wells were identified for foamer applications based on the following criteria:

- A large database of LGR data.
- Multiple condensate and water analyses.
- Many years of production information and well pressure profiles.
- Operator experience with wells.
- Comparatively easy access to the well sites – a key requirement.
- Suitable well trajectory profile with no liquid trap before the end of the tubing

Injection down casing on all wells
### Initial results very encouraging

<table>
<thead>
<tr>
<th>Status</th>
<th>Well</th>
<th>Production Uplift (e3m3/d)</th>
<th>Comment</th>
<th>Forward Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Working</strong></td>
<td>#1</td>
<td>4.6</td>
<td>2nd Lowest WGR (15 l/e3m3), some condensate (2%)</td>
<td>Optimize soap injection rate downward</td>
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<tr>
<td></td>
<td>#2</td>
<td>2.0</td>
<td><strong>Highest WGR (96 l/e3m3), no condensate</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Positive Response</strong></td>
<td>#3</td>
<td>1.5</td>
<td>2nd Highest WGR (68 l/e3m3), no condensate</td>
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</tr>
<tr>
<td>(long flow periods)</td>
<td>#4</td>
<td>0.9</td>
<td>4th Highest WGR (48 l/e3m3), <strong>highest CLR (15%)</strong></td>
<td>Optimize soap injection rate upward</td>
</tr>
<tr>
<td></td>
<td>#5</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>#6</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Not Working</strong></td>
<td>#7</td>
<td>2.1</td>
<td>3rd Highest WGR (51 l/e3m3), no condensate</td>
<td>Optimize soap injection rate upward. Capillary string candidates</td>
</tr>
<tr>
<td>(no response to soap)</td>
<td>#8</td>
<td>-1.2</td>
<td><strong>Lowest WGR (8 l/e3m3), no condensate, large water trap</strong></td>
<td></td>
</tr>
</tbody>
</table>

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### Soap Injection Summary

<table>
<thead>
<tr>
<th>Status</th>
<th>Well</th>
<th>On-Time Increase (%)</th>
<th>Production Uplift (e3m³/d)</th>
<th>Injection Rate (litres/d)</th>
<th>Net Incremental Income ($/d)</th>
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</thead>
<tbody>
<tr>
<td><strong>Working</strong></td>
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<tr>
<td>1</td>
<td></td>
<td>50 to 100</td>
<td>1.9</td>
<td>4</td>
<td>162</td>
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<td>2</td>
<td></td>
<td>33 to 100</td>
<td>1.6</td>
<td>4</td>
<td>130</td>
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<td>26 to 99</td>
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<td>88</td>
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<td>4</td>
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<td>38 to 100</td>
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<td>75</td>
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<td>39 to 79</td>
<td>1.2</td>
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<td>78</td>
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<td><strong>Marginal</strong></td>
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<td>6</td>
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<td>31 to 60</td>
<td>0</td>
<td>4</td>
<td>-99</td>
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<td>7</td>
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<td>22 to 59</td>
<td>0.3</td>
<td>10</td>
<td>-66</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dropped</strong></td>
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<td>8</td>
<td></td>
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</tbody>
</table>

AFE Amount: $345k  
Estimated Spend: $268K

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Results: Process Benefits

• No foam carryover in the vessels
• No emulsion issues noted
• Field trialled 8 wells in 2009; 38 wells in 2010; and began 37 more wells in 2011 with a success rate of 70%
• Batch treat many other wells as needed
Challenges

- High condensate to water ratio
- Salinity varies from well to well (e.g., fresh water to nearly saturated brine)
- Difficult to deliver foamer into the horizontal section due to liquid traps that occur a short distance from the horizontal section. There is not enough energy to cause foaming in that section and the liquids cause a flow restriction in the tubing or open hole area.
Way Forward

• Implement monitoring program to evaluate performance of foamer’s corrosion inhibition properties. If successful, significant cost savings could be realized.

• Ongoing expansion of foamer injection program.

• Possible continuous injection through capillary string installation to ensure the delivery of foamer through the liquid traps.

• Continued observation at the gas plant for potential foaming issue as more wells will be on foamer (today only about 7% of the wells are on foamer).
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