New Technologies to Expand Foamer Applications

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Agenda

1. Introduction
   - Foamer basic
   - Challenges in conventional foamers

2. New technologies to expand foamer applications
   - High temperature foamers
   - Condensate foamers
   - Crude oil foamers

3. Summary
Flow Regime Change of a Well

Reservoir pressure decreases & fluids increases, causing loading.
Why Apply Foamers?

• Without removing liquid, the production decreases rapidly and ceases prematurely.

• Deliquification technologies enhance gas production and $$$.

• Foamers are simple and economic technologies for low produce wells.

• No down hole equipment is required.
What Are Foamers?

Foamers are surfactant-based products

- Chemical technology for gas well deliquification
- Became emerging gas well deliquification technology
- Come in two forms: liquid and solid (“sticks”)

How Do Foamers Work?

Foamer reduces critical velocity \( (V_t) \) that is needed to lift the fluid up the production tubing by reducing the density and surface tension of liquid. i.e. foamers lighten up liquid.

\[
V_t = 1.593\left[\frac{1}{4}(\rho_l - \rho_g)^{1/4}\right] / (\rho_g)^{1/2}
\]

Without foamer

\[V_t > V\]
Well loaded up

With foamer

\[V_t < V\]
Well flows
Foamers Application Flow Chart

1. Gather Information
2. Good candidate for foamer application?
3. Select Candidates
4. Evaluate Candidate Foamers
5. Determine Foamer & Dosage
Information Needed

1. Know the well conditions
   - Well diagram
     • Completion, is there a packer, what is depth and diameter of tubing
     • Sub-Surface Safety Valves (SSSV)
   - Bottom Hole Temp (BHT) of a well
   - Production data: brine rich or oil rich?

2. Treating Objective
   - Deliquification only?
   - Deliquification and Scale /Corrosion control?
What Are Good Candidate Wells?

- The gas production is erratic. And the well produces intermittently.
- The production decreases rapidly.
- Coleman curve determines liquid loading.
- Modeling can predict whether/where liquid loading occurs.
- Typically, foamers are economic solution for wells with small amount of liquid production.
Candidate Foamer Selection

Example: Well conditions of well A

- Continuous treatment is required
- 15,000 feet deep with packer
- 94% brine and 5% condensate
- BHT of 275 °F
- Deliquification only
- Located in Rockies

Liquid product only
Capillary injection only
Select water based foamers
Foamers product matrix
## Select Candidates from Product Matrix

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>Pour Point °F (°C)</th>
<th>Capillary Approved/Temp Tolerance °F (°C)</th>
<th>Combination Type (CI or SI)</th>
<th>Flash Point °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foamer A</td>
<td>-40 (-40)</td>
<td>180 (82)</td>
<td>No</td>
<td>95 (35)</td>
</tr>
<tr>
<td>Foamer B</td>
<td>10 (-12)</td>
<td>300 (148)</td>
<td>No</td>
<td>&gt;200 (&gt;93)</td>
</tr>
<tr>
<td>Foamer C</td>
<td>0 (-18)</td>
<td>200 (149)</td>
<td>SI/CI</td>
<td>172 (78)</td>
</tr>
<tr>
<td>Foamer D</td>
<td>-20 (-7)</td>
<td>300 (148)</td>
<td>CI</td>
<td>76 (24)</td>
</tr>
<tr>
<td>Foamer E</td>
<td>-40 (-40)</td>
<td>300 (148)</td>
<td>No</td>
<td>70 (21)</td>
</tr>
</tbody>
</table>
Evaluate Foamers via Column Test

- So far, possible foamer candidates were selected based on well information.
- This is the step to select a cost effective foamer among candidates and determine recommended dosage.
- Foamer performance varies depending on fluids, both brine and condensate.
Evaluate Foamer via Column Test

No gas flow

Foamer test column

Gas flow
Performance Evaluation Results

- Compare the performance of products.
- Determine the recommended dosage.

Foamer performance comparison

<table>
<thead>
<tr>
<th>Foamer concentration, ppm</th>
<th>% unloaded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>28%</td>
</tr>
<tr>
<td>2,000</td>
<td>40%</td>
</tr>
<tr>
<td>3,000</td>
<td>45%</td>
</tr>
</tbody>
</table>

Foamer A (purple) vs Foamer B (yellow)
Challenges in Current Foamers

- Water based foamers are cost effective deliquification technology.
- However, treating high temperature wells is a still challenge.
- Traditional water based foamers do not foam hydrocarbons. At best, it is not cost effective.
New Foamer Technologies

1. High Temperature Foamer
2. Condensate Foamer
3. Crude oil Foamer
1. High Temperature Foamer

- Goal: develop condensate tolerant high temperature foamers
- Results: developed foamers that are stable up to 300F and have better condensate tolerance
High Temperature Foamer

• **Field Information**
  - Cotton Valley, Texas
  - Bottom hole temperature ~300°F
  - 10 BWD, 2BOD
  - Incumbent foamer was treated

• **Foamer Application**
  - Continuous injection via capillary tubing
  - Injection rate 0.2% based on total fluids
High Temp Foamer- Case History

- The foamer was applied via continuous treatment, dosage of ~ 0.2%.
- Average gas production increased from 187 to 247 mscf/d.
2. Condensate Foamer

- Goal: develop foamers for condensate rich fluids
- Results: developed condensate foamers that are stable up to 400°F and unload condensate rich fluids
Condensate Foamer

• **Field Information**
  o McAllen, Texas
  o Bottom hole temperature 350 F
  o 10 BWD, 20 BOD
  o Intermittent production

• **Foamer Application**
  o Continuous injection via capillary tubing
  o Injection rate 1% based on total fluids
Average gas production increased from 338 mscf/d to 589 mscf/d, for three days of foamer and intermitter to 939 mscf/d of foamers only for the remaining 11 days.
New Foamer Technologies

3. Crude Oil Foamer

- **Goal**: develop foamers to unload crude oil wells
- **Results**: developed crude oil foamers that unload oil with API 25~40 with some brine tolerance
Crude Oil Foamer

<table>
<thead>
<tr>
<th>Days of production(^{(1)})</th>
<th>7 days on/7 days off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Depth, feet(^{(2)})</td>
<td>13,000</td>
</tr>
<tr>
<td>Gas production, Mcf/D</td>
<td>250</td>
</tr>
<tr>
<td>Oil production, BOPD</td>
<td>40</td>
</tr>
<tr>
<td>Water production, BWPD</td>
<td>40</td>
</tr>
<tr>
<td>API gravity, °C</td>
<td>40</td>
</tr>
<tr>
<td>Bottom hole temperature, °F</td>
<td>300</td>
</tr>
</tbody>
</table>

\(^{(1)}\) The capillary is installed closed to perforation and good mixing of produced fluids and foamer is expected.
Prior to oil foamer injection, water based foamer was injected continuously.

Oil foamer was injected via capillary continuously at a rate of 750 ppm, 3 gallon/day.
Summary of Foamer Technology

1. Foamer is economic and flexible deliquification technology for low producing wells.

2. Conventional water based foamers were not cost effective treating
   ✓ High temperature wells
   ✓ Condensate rich wells
   ✓ Crude oil wells

3. Foamers technologies expanded beyond treating brine rich wells to enhance both oil and gas production
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Benefits of Foamer Applications

- Increase gas/oil production i.e. increase revenue
- Protect assets for example, corrosion inhibition and/or scale inhibition
- Reduce wear and tear in plunger for plunger lift application
- Reduce the injection gas rate for gas lift application