Development and Application of Foamers to Enhance Oil and Gas Production

Scott Lehrer, Saet Byul Debord
Scott Lehrer (presenter)
Baker Hughes Incorporated
Outline

• Introduction
  – Life cycle of a well
  – Foamer theory

• Current foamer technology
  – Benefits and gaps
  – On-land application of aqueous foamers
  – Offshore application of condensate foamers

• Development of crude oil foamers
  – Potential benefits
  – Experimental methods
  – Successful field application results

• Conclusions
Challenges with Mature Wells

- Decrease in reservoir pressure over time
  - Fluids accumulate, creating hydrostatic pressure
  - Rapid production decline
  - Wells become difficult to restart

- Sometimes alleviated by mechanical unloading
  - Not always best option, depending on specific well
  - Requires investment in capital equipment
  - Requires available space and power
Foamers Lower Critical Velocity

- Foam – bubbles of gas surrounded by thin liquid layer
- Foamers lower surface tension

\[ V_c = 1.593\left[\frac{\sigma^{1/4}(\rho_l - \rho_g)^{1/4}}{(\rho_g)^{1/2}}\right] \]
Existing Foamer Technology

- Aqueous foamers effective for brine-rich fluids
- Condensate foamers effective with high API fluids
- Current technology ineffective for crude oil
Foamers Became an Emerging Solution for Gas Wells

- Used a broad range of aqueous surfactants
- Economic and flexible solution for on-land gas wells
- Condensate foamers also used
  - Applied successfully both on-land and offshore
- Little or no capital equipment requirements
Benefits of Foamer Application

Aqueous Foamer Increased Production

\[(100 \text{ Mcf/D} \times \$3.50 / \text{ Mcf}) - \$22.50 \text{ foamer cost/D})\]
* 365 * 100 wells = $12MM/y incremental revenue

- Foamers can increase production significantly by unloading well fluids
Offshore Condensate Foamer Application

• Synopsis from previous presentations (Mark Embrey, BHI)
  – Gas Well Deliquification Workshop (Denver, 2010 & 2011)
• Offshore Thailand gas wells experience fluid loading issues
  – Reaches critical rate after 2 – 3 years
  – Current solution – wells flow intermittently
  – No artificial lift currently in place
  – Wells shut in due to fluid loading
Challenges in Offshore Applications

Subsurface Safety Valve Requirement and Surface Safety Valve Interference

- Offshore wells and onshore wells in Europe have a surface safety valve and subsurface safety valve.
- Capillary cannot be hung from the top of a standard wellhead like typical land wells installations.
• Modified WRSCSSV
  – Wireline retrievable surface controlled sub-surface safety valve
  – Provides chemical flow path around flapper valve
  – SCSSV still fully functional
  – No workover required

• Wellhead Adapter
  – Capillary hung below all tree valves
  – Still have access to BPT
  – Maintain full functionality of wellhead
Offshore Capillary Trials

- Performed trials on 3 wells in Gulf of Thailand in January 2009
- Ran capillary to set depth and pumped foamer while flowing the well for several days
- Results were promising and led eventually to a permanent installation
- Example presented is from Funan Field, Well #9
  - Fluids produced > 80% condensate
• Adding condensate foamer increased gas production by unloading well fluids

Drastic production decrease before foamer
Potential Foamer Benefits in Oil Wells

• Increase production of flowing wells
  – Alleviate liquid loading by reducing fluid density
  – Increase oil and gas flow, reduce downtime
  – Alleviate slugging

• Supplement gas lift when inadequate
  – Insufficient gas supply to optimize gas lift
  – Gas lift mandrels located well above end of tubing

• Restart wells shut in for maintenance
Oil Foamer Lab Test

- Fluids added to foam column, sparged with gas and preheated
- Fluid volume measured

- Fluids treated with foamer
- Foam volume measured during test
Lab Test (cont’d)

- Foam can reach the top of test column
- Foam overflow is captured and weighed
New Oil Foamer Requirements

- Identify appropriate chemistry to foam crude oil
- Perform in a wide range of oils
- Have flexible application methods
  - Capillary, batch, gas lift
- Stable in the well bore environment
- Resulting foam responsive to typical defoamers
- Has no impact on asset integrity
Two Oil Foamers Developed

<table>
<thead>
<tr>
<th></th>
<th>Oil foamer A</th>
<th>Oil foamer B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas lift application?</td>
<td>Yes *</td>
<td>No</td>
</tr>
<tr>
<td>Capillary approved</td>
<td>300°F</td>
<td>200°F</td>
</tr>
</tbody>
</table>

* Oil foamer A passed “gunking” qualification test
Oil Foamers Evaluated in Multiple Fluids

<table>
<thead>
<tr>
<th>Well #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOPD</td>
<td>1630</td>
<td>600</td>
<td>850</td>
<td>50</td>
<td>340</td>
<td>315</td>
</tr>
<tr>
<td>BWPD</td>
<td>20</td>
<td>30</td>
<td>90</td>
<td>50</td>
<td>185</td>
<td>270</td>
</tr>
<tr>
<td>API gravity</td>
<td>30</td>
<td>33.5</td>
<td>32</td>
<td>40</td>
<td>34.5</td>
<td>36.3</td>
</tr>
<tr>
<td>Bottom hole °F</td>
<td>137</td>
<td>192</td>
<td>133</td>
<td>300</td>
<td>183</td>
<td>168</td>
</tr>
<tr>
<td>Via Gas lift?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Oil foamer tested</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>ppm</td>
<td>5,000</td>
<td>2,000</td>
<td>1,000</td>
<td>1,500</td>
<td>2,500</td>
<td>500</td>
</tr>
<tr>
<td>Oil foamer effective?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Foamer Technology Extended to Treat Crude Oil

- Enhance production without water quality issues
- Effective in lab testing with crudes 25 to 40 API
- Water cuts 0% to 60%

![Graph showing API gravity vs. brine cut percentage with categories for Condensate foamer, Novel Oil Foamer, and Traditional water-based foamers.]
Background

- Well depth: 10,000 ft (3048 m)
- Bottom hole temperature: 300°F (149°C)
- ~50% brine / 50% oil; API 40°
- Aqueous foamer capillary applied to near bottom hole
- Retention time only 5 minutes due to small gas/liquid separator
Production History

- Cycling production – 7 days on, 7 days off

- Historical production
  - 250 Mcf/D gas, 40 BOPD, 40 BWPD

- 60 days before trial
  - 122 Mcf/D gas, 13 BOPD, 9 BWPD

- Aqueous foamer unable to maintain production
• Baseline fluid contained 1500 ppm aqueous foamer
• Baseline fluid did not reach unloading threshold
• Unloading occurred with 1500 ppm crude oil foamer
Field Trial Procedure

- Discontinued aqueous foamer and flushed capillary
- Applied 750 ppm oil foamer downhole via capillary
- Defoamer added upstream of separator
- Measured gas, oil, and water production
- Monitored foam carryover potential by “rag test”
- Collected water samples to evaluate emulsification
Field Trial Results – Incumbent vs. Oil Foamer

- Production time extended to 11 days from 7 days
- Gas and oil production rates more than doubled
Field Trial Results – Revenue Impact

Average Net Revenue /Day

Based on $75/barrel crude, $4/Mcf
Field Trial Results – Water Quality

Produced Water Quality w/ Aqueous Foamer

Produced Water Quality w/ New Oil Foamer
Conclusions

• Foamer injection is a viable method to enable wells with liquid loading issues to be returned to continuous flowing status
• Capillary injection systems are emerging as a viable option for offshore applications
• Oil foamers developed effective in lab testing over a wide range of crude oils
• Potential benefits of oil foamers identified include enhancing flowing well production and restarting wells
• Oil foamers were formulated for multiple application methods
• Field trial confirmed oil foamers’ effectiveness
  – Increased run length, oil & gas production
  – No negative impact on water quality, oil/water separation
  – Foam controlled with conventional defoamers
Acknowledgments

The authors would like to acknowledge Baker Hughes, Inc. for allowing us to publish this paper

The authors thank Carlene Means for her contributions in development of the crude oil foamer and Simon Crosby, Gus Fuentes, Jeff Long, in Baker Hughes production operations for supporting the field trial in south Texas

The authors thank Mark Embrey for his contributions to this presentation

The authors also thank EOG Resources for providing a location to field trial the new foamer technology and for their assistance during the trial