Using Foam Technology as an Artificial Lift Method

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multi-chem®
FAL: Foam assisted Lift

- Liquid Loading will occur on all gas wells which produce formation or condensed fluids. The question to ask is:
  - When will the loading cycle begin?
  - How effective and efficient will the program be in controlling the liquid loading?
FAL Program

- Liquid Loading Over Time:

- ANNULAR MIST
- SLUG-ANNULAR TRANSITION
- SLUG
- BREAK THROUGH

Decreasing Gas Rate
FAL Program

• A properly designed Foam Assisted Lift (FAL) Program can be an integral part of the production plan to keep a well flowing at its true potential

• FAL is a process, not an application

• The process is measured by the percentage of success and efficiency achieved in the FAL program
FAL Program

• An example would be to create a FAL program that generates 90% to 100% efficiency VS. a simple application that generates a lower percentage of efficiency.

• Remember – The measure of a truly successful FAL program is not that you foamed a well, but rather the efficiency at which you unloaded the well and maintained incremental gas flow.
FAL Program

• Three steps for a successful FAL program:
  – Proper well diagnostics
  – Proper product selection
  – Proper application assessment
When selecting candidate wells for a FAL program, it is critical to gather as much data as possible including production history, wellbore schematics, downhole and surface pressures, temperatures, etc.
Modeling programs can be a very efficient tool when selecting candidate wells for a FAL program. However, it is critical to understand that the output data from any modeling program is only as good as the input data.
Multi-Chem currently uses two intrinsically safe Echometer systems for the candidate selection and treatment design phase of the FAL process.
Product Selection

• **Multi-Chem’s Foam Assisted Lift Product Line:**
  - Liquid Foaming Agents – 104 products
    - Low temperature products – 37 (200 F)
    - High temperature products – 60 (200 F)
    - Hydrocarbon products – 7
  - Liquid Foaming Agents with multi-treatment packages – 58
    - i.e. corrosion, scale, salt dispersion, etc.
  - All liquid foaming agents are formulated in the field, utilizing fresh produced brine and hydrocarbon fluids
Product Selection

- How does a Foaming Agent affect the critical rate?

<table>
<thead>
<tr>
<th></th>
<th>Liquid Density (lb/cu-ft)</th>
<th>Surface Tension (dynes/cm)</th>
<th>Critical Rate (mcfd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without foaming agent</td>
<td>67</td>
<td>72</td>
<td>220</td>
</tr>
<tr>
<td>With foaming agent</td>
<td>34</td>
<td>30</td>
<td>150</td>
</tr>
</tbody>
</table>
Product Selection

- **Test Methods**
  - **Field VS. Lab**
  - **Blender / malt mixer for water based foaming agent selection**
  - **Sparge method for hydrocarbon or combination hydrocarbon / water foaming agent selection**
  - **Produced fluids VS. synthetic brine / hydrocarbon**
Product Selection

• Application Considerations
  – Fluid composition (water analysis essential)
    • Scale / Corrosion
    • Solubility / dispersion / emulsion tendencies
  – Presence of solids
  – Temperature
  – Residence time
  – Addition of optional components (i.e. corrosion inhibitors, scale inhibitors, salt dispersants, etc.)
• It is extremely important to utilize the proper test methods when selecting liquid foaming agents in order to achieve the highest level of product performance
• Blender / high shear testing should be utilized when selecting liquid foaming agents for downhole applications in high to 100% water ratio wells
• It is critical to duplicate as closely as possible the amount of shear being generated downhole
Product Selection: Blender VS. Sparge

• Ignoring the reaction of downhole shear during product selection can result in:
  – Foam locking
  – Emulsion
  – Improper product selection (productivity variation)

• When to use blender / high shear testing:
  – Any time you are testing water based foaming agents
  – Wells producing 100% water
  – Wells producing higher water to condensate ratio
  – Wells with high bottom hole pressure / turbulent flow
Product Selection: Blender VS. Sparge

- Sparge / low shear testing is primarily performed using either nitrogen or methane gas at a 50 LPH rate as the agitation source.

- Fluid volumes required are the same as with the blender / high shear testing. However, due to the test method, a much lower shear rate is observed.
Product Selection: Blender VS. Sparge

- When to use sparge / low shear testing:
  - When illustrating slug flow in a liquid loaded well to an audience
  - When selecting 100% hydrocarbon foaming agents
  - When selecting combination hydrocarbon / water foaming agents for wells producing a higher percentage of condensate to water ratio
  - In wells which yield a very low bottom hole pressure / less turbulent flow (where over-treatment is commonly observed, test in conjunction with high shear blender testing)
Product Selection

• Avoid Stiff Foam
  – Shaving cream quality foam produces a tight dry foam which produces friction. A well cannot unload stiff foam any easier than it can unload heavy water

“If a little works well, a lot does not necessarily work better”
Product Selection: Hydrocarbon Foaming

- Best utilized when attempting to provide foam assisted lift to wells producing 65% and above condensate to water ratio VS. water-based foaming agents
- Primary chemistries currently being studied:
  - Fluorocarbon
  - Silicon
  - Amine
- Testing must be performed via sparge method VS. blender method due to short “half-life” of foam
Product Selection: Hydrocarbon Foaming

- Continuous application VS. batch application method is recommended with hydrocarbon foaming agents.
- Cost of hydrocarbon foaming agents are much higher than conventional water-based foaming agents.
- Injection rates for hydrocarbon foaming agents in high hydrocarbon to water ratio wells are typically 500 to 2500 ppm VS. 2500 to 25,000 ppm of conventional water-based foaming agents.
- Currently utilizing both 100% hydrocarbon foaming agents and combination hydrocarbon / water foaming agents for high hydrocarbon percentage wells.
Product Selection: Hydrocarbon Foaming

- Combination hydrocarbon / water foaming agent
- Sparged combination hydrocarbon / water foaming at 80% hydrocarbon and 20% produced water
- Pictures indicate individual foam columns for both water and hydrocarbon indicating complete foaming of fluids is occurring
- Picture to far right indicates no emulsion occurred during foaming or after foam break
Application Assessment

• Application Method
  – Batch: manual / cyclic / automated
  – Continuous: annular / capillary / plunger lift / gas lift / coil tubing / tubing punch / in conjunction with compression

• Diagnostic Treatment
  – Batch application is an excellent tool to determine well’s response to the addition of a foaming agent
  – Apply product to the loaded area
  – Analyze the reaction
  – Determine most efficient treatment design for long term application (batch VS. continuous)
Application Assessment

• Best Practices
  – Communicate process to facilitate understanding
    • It is critical to train all personnel involved on the overall FAL process
  – Flow conditions will change with time
    • Continuously trend gas production
    • Ongoing review of foaming agent performance
    • Evaluation of changing condensate and water ratios
    • Adjust foaming agent selection, application rates and dilution rates as required
  – Review program frequently with the production team
    • Quarterly reviews of the program is recommended
    • Base decisions on production improvement VS. cost

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Case History #1

• Approximately 700 Wells
  – Approximately 8000 foot packerless completions
  – Gas wells with varying water and condensate rates

• 154 wells with foaming agent in MeOH from supplier “B”
  – Average production increase of 22 MCFD per well was achieved
  – Emulsion problems
  – High cost of product application
Case History #1

• Re-evaluation of wells
  – FAL process developed and implemented
  – Average production increase of 114 MCFD per well was achieved
  – 418% increase VS. previous program
  – Increase in revenue of $25,856,600 per year
Case History #2

- Well producing 600 MCFD, 0 BCPD, 400 BWPD
- 3.5 inch tubing, horizontal completion, approximately 14,000’
- Well loaded up daily, shut-in time of 1-2 weeks for pressure build up
- Previous attempts to use foaming agent were unable to keep the well on line
- Well evaluated and proper product selected
  - Foaming agent applied continuously via capillary
  - Constant production of 1.6 MMCFD, 0 BCPD, 650 BWPD
  - Steady revenue of $2,920,000 annually
Case History #3

- Mature offshore field with 5 candidate wells
  - 2 wells flowing; 3 wells shut-in

- Diagnostic Review
  - Echometer analyses were utilized in conjunction with a modeling program to determine the loaded state of each well
  - 4 wells were found to be at varying levels of liquid loading
  - 1 well was found not to be loading / loaded based upon Echometer analysis and well flow history
Case History #3

• Application
  – Multiple batch applications of liquid foaming agent was performed on each candidate well

• Result
  – Production gain of 9.5 MMCFD @ $5/MCF
  – Revenue increase of $17,337,500 annually
Summary

• Foam Assisted Lift is an important tool
  – When performed properly, it can be the difference between success VS. failure
  – The process is measured by the percentage of success and efficiency achieved in the FAL program
  – Onsite evaluation of produced fluids and products is essential
  – Modeling programs are useful tools; however, to find the “unlikely candidates” you must look beyond modeling programs
  – The use of Echometer analysis can be a very useful tool when production data is not available
  – Ongoing program reviews are essential
Continued Education

- Two books which discuss both mechanical and chemical means of gas well deliquification are recommended:
  - *Gas Well Deliquification* “Solutions to Gas Well Liquid Loading Problems” by Dr. James Lea
  - *Gas Well Deliquification* “Second Edition” by Dr. James Lea
  - Multi-Chem was a contributor to the “Second Edition”
    - Chapter 8 “Use of Foam to Deliquify Gas Wells”
  - Both books can be purchased online at www.amazon.com or www.barnesandnoble.com
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