Foam Assisted Gas Lift

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Executive summary

- Trial Time: 8 days
- Total spent: ~ USD $300,000
- Net Oil gain: 60-65 m³/d
- Optimum concentration of foam: 800 ppm
- Possible savings: *10,000 m³/d of gas lift
- Applicable base: gas lifted oil wells with high water cut (tested at 70%)
- No process upsets
Global projects R&D – Test Foaming in Oil Wells

- America – proposal stage
- Brunei – execution phase
- Rotterdam field was chosen to test the concept of foam lift in oil operated wells

- RTD-4 picked because:
  - high water cut (~70%)
  - outflow is constrained due to the gas lift arrangement
  - max deviation only 55 deg, allows for cap string installation
Success criteria

• Production Criteria
  • Noticeable increase in oil production and/or less sluggish flow behaviour
  • Production rate is the same at a 50% lower gas lift rate with foam application.

• Facilities Criteria
  • No process upsets to topsides, including the formation of emulsions.
  • Ensure export oil quality meets spec:
    • <1% water
    • <75 g/m3 salt content
  • Ensure water disposal and injection meets spec:
    • <25 ppm TSS
    • <250 ppm oil in water concentration
Well Diagram & Target depth

1/4" Capillary

3 1/2' Tubing

9 5/8" Casing

Upper KNGLG
Perforations:
1672-1697m

Lower KNGLG
Perforations:
1703-1765m

X
1711 m + DHG

Tubing Punch:
1695m
Year - 2002

Tubing Punch:
1723m
Year - 2015

7" Liner

Capillary string for foam injection

Orifice (GL Injection)
690m TVD

Perforations
1280-1318 mTVD

Foam injection, 1280m TVD

Plug
Capillary installation set-up
Production data

Pre-cap string installation

Post-cap string installation
- Water/glycol injection
- No foam injection
Baseline data

Cycle: 1 hour high production
- Average Gross: 215 m3/d
- Water: 175 m3/d
- Oil: 40 m3/d

Cycle: 2 hours low production
- Average Gross: 85 m3/d
- Water: 50 m3/d
- Oil: 35 m3/d

Feb. 4 – 8, 2013

2013 Gas-Lift Workshop
Start of foam injection

Observations:

- Longer stable production at higher rates compared to baseline data at the same gas lift injection rate.
- (Average gross rate increased from 155m³/day to 305m³/day)
- (Average oil rate increased from 40m³/day to 90m³/day)
- Observations for LAB: No breach in oil/water specs. No foam seen on samples on surface so far
Increasing foam concentration

<table>
<thead>
<tr>
<th>Step</th>
<th>No foam</th>
<th>1 (1.5 kg/hr)</th>
<th>2 (2 kg/hr)</th>
<th>3 (4 kg/hr)</th>
<th>4 (6 kg/hr)</th>
<th>5 (8 kg/hr)</th>
<th>6 (10 kg/hr)</th>
<th>7 (11 kg/hr)</th>
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<tbody>
<tr>
<td>Foam (ppm)</td>
<td>0</td>
<td>110</td>
<td>160</td>
<td>285</td>
<td>430</td>
<td>560</td>
<td>690</td>
<td>760</td>
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<tr>
<td>Gross (m3/d)</td>
<td>160</td>
<td>307</td>
<td>290</td>
<td>320</td>
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<td>325</td>
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<tr>
<td>Water (m3/d)</td>
<td>120</td>
<td>217</td>
<td>207</td>
<td>230</td>
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<td>235</td>
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<td>Oil (m3/d)</td>
<td>40</td>
<td>90</td>
<td>83</td>
<td>90</td>
<td>90</td>
<td>90</td>
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</table>
Foam Injection rate increased to 16kg/hr (1140 ppm)

Oil in Water above limit of 250 mg/L
Step 7: 11 kg/hr
Foam Concentration: 800 ppm
Phase 2: Decreasing gas lift injection rate
Phase 2: Decreasing gas lift injection rate

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<tr>
<th>Step</th>
<th>GL rate (m3/d)</th>
<th>Gross (m3/d)</th>
<th>Water (m3/d)</th>
<th>Oil (m3/d)</th>
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<td>315</td>
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<td>2</td>
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<td>10</td>
<td>3,000</td>
<td>75</td>
<td>55</td>
<td>20</td>
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</table>

By using foam rate of 4 kg/hr and only 4,000 m3/d, the same production rates can be achieved when the well was on production with 14,000 m3/d gas lift and no foam.
Overview of production

RTD-4 Foam Trial
(Sampled Data)
Re-test; production data

Significant change in production with the addition of foam

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