Chemical Foamers For Gas Well Deliquification Training Workshop

European Gas Well Deliquification Conference

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Workshop Contents

• Theory of Foam
• Foamer Chemicals
• Laboratory Testing
• Application in the Field
• Summary
Basic Foam Theory

Physics of foam
  - in "close-up"
  - at a molecular level

How foam is stabilised
Role of surfactants

Foam

Why is High Foam Desirable?
  - Seen as evidence product is working
    - ie. Shampoo, dishwashing liquid
  - Indicates where product has been applied
    - ie. Shaving foams, abattoir cleaners
  - High expansion ratio
    - Fire fighting foams
  - Reduced liquid density and reduced surface tension
    - i.e, gas well deliquification
Soap – We Use It Everyday!

- Daily used surfactant

- **Definition:**
  - Foam is a dispersion of gas in liquid and is caused by agitation and surfactant

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Foamer Chemicals

- **Surfactants typically applied to aqueous systems**
  - Reduce surface tension
  - Decrease relative density
  - Increases elasticity

- **Allows gas/liquid dispersion at a lower gas pressure.**
  - In the lamellar condensate is trapped

- **The benefits**
  - Reduces the critical velocity of the well
  - Enables liquid unloading with low set-up cost
  - Customised for local environment
  - Facilitates continuous production
  - Reduces well decline curve
Dynamic Surface Tension Apparatus

\[ P = \frac{P_0 - P_{\text{app}}}{r} \]

Dynamic Surface Tension Data

10.2% NaCl and 3.7% CaCl₂·2H₂O

- Betaine at 400 ppm
- Alkyl Ether Sulfate at 400 ppm
- Olefin sulfonate at 400 ppm
**Correlation Between Max DST Reduction Rate & % Liquid Unloading**

Conditions: 400 ppm active surfactant in 10.2% NaCl and 3.7% CaCl$_2$·2H$_2$O, 0% condensate

- **Betaine**
- **Alkyl ether sulfate**
- **Olefin sulfonate**

$R^2 = 0.95$

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**Surfactant Properties - Foam**

**Foam Life Cycle**

- Liquid drains into junctions leaving thin lamellae between cells.
- Honeycomb with thick lamellae between cells.
- Gas forms spheres in liquid.
Pure Liquids Don’t Foam

When the Bubbles Collide .....
Two Types of Foam

- Low Gas Volume
- High Gas Volume

Foam Drainage

Foam Drainage Leads to Collapse

Caused by
- Gravitational force
- Capillary pressure
- Diffusion of gas
- Bursting of bubbles
- Rearrangement of lamellae

Kugelschaum

Polyhederschaum
Gas Permeability & Bubble Growth

. . . Also leads to foam collapse

Film Elasticity .......

...... makes them stretchy!
**Marangoni Effect**

The dynamics of rapid diffusion needed to restore and maintain film elasticity . . .
Foam Stability: Area per molecule

Packing at the air-liquid interface

- **Unstable foam**
  - Loosely packed film
    - High area per molecule
    - Low degree of packing

- **Stable foam**
  - Tightly packed film
    - Small area per molecule
    - High degree of packing

**FOAM**

- **Elasticity**
- **Degree of packing**
Foam

- Foam stabilisation is thought to occur via the following mechanisms:
  - Increasing elasticity of the foam film
  - Slowing drainage of liquid in the lamellae
  - Decreasing the diffusion of gas across the lamellae
  - Increasing the thickness of the electrical double layer
  - Increasing the surface and bulk viscosity of the foam film

Foam Inhibition

- Disruption of interfacial film structure
  - Displacement of stabilising surfactant
  - Poor interfacial orientation

- Spontaneous spreading of oils
  - Low surface tension liquids
  - Positive spreading coefficient

- Physical rupture of lamellae
  - Waxy or hydrophobic particles
  - Oil droplets and inverse micelles
**Configuration of Oil at the Air-liquid Interface**

- Air
- Water
- Oil
- Pseudoemulsion Film

- Oil drop inside the solution
- Oil drop at the surface separated by a pseudoemulsion film from the air
- Oil spreads at the solution surface and ruptures the bubble
- Oil drop enters the gas phase and forms lens

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**Mechanisms of Foam Break Degradation**

- **Coalescence**
  - The flocculated foam cells form larger bubbles due to thinning and rupture of the lamellae separating the bubbles. Usually occurs as a result of thinning due to prolonged drainage

- **Gravitational separation**
  - Rise of bubbles through foam mass, while liquid is draining due to gravity through lamellae and plateau borders between bubbles

- **Disproportionation**
  - The gas inside the bubbles diffuses across the foam lamellae, from areas of high pressure - small bubbles to areas of lower pressure - large bubbles
What does a foam modifier/booster do?
- Product that acts synergistically with another product to increase volume of foam
- Product that stabilises the foam to prevent breakdown of the foam structure
- Improves appearance of a foam
  - i.e. creamier appearance

Additives for foam stabilisation
- Organic compounds
  - Polymers
  - Surface active materials
  - Biopolymers
- Electrolytes
- Finely divided particles
Foam

- **Effect of addition of foam stabiliser**
  - Increases packing density at air/water interface
  - Cause charge shielding of charged surfactant
  - May interact with charged surfactant
  - May reduce the CMC

Foam

- **Commonly used foam stabilisers**
  - Fatty alcohols
  - Amine oxides
  - Betaines
  - Alkanolamides
### Typical Chemicals

- **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

- **Amphoteric**
  - Very versatile
  - Good high temperature performance and stability
  - Effective in high salt content brines

#### Chemical Structures

- **Alkyl ether sulfate**
- **Alkyl sulfonate**
- **α-olefin sulfonate**
- **Cocoamidopropyl betaine**

### Combination Products

- **Formulating additional actives into foamers**
  - Corrosion inhibitors
  - Scale inhibitors
  - Biocides
  - Paraffin inhibitors
  - *etc*

- **Facilitates easier chemical programs**
  - Less inventory
  - Reduce exposure risks
  - Saves on pumps, storage and freight
Foam

- **Selection of surface active foam stabiliser**
  - Type of foam to be stabilised
    - Charged
    - Nonionic
  - Structure of surfactant hydrophobe
    - Alkyl chain length
    - Branching on alkyl chain
  - Presence of polar entities capable of forming multiple hydrogen bonds
  - Ability to lower the CMC

Foamer Chemical Requirements for Gas Well Deliquification

- Provide foam stability to carry liquids to surface
- Thermal stability
- Fluid compatibility (chloride, solids,..)
- Ability to unload hydrocarbon
- Break at surface before entering surface equipment
- Delivery (batch, continuous)
- Winterized
Chemical Solutions

- **Solid state**
  - Dropped downhole to find aqueous environment
  - Dissolve in the liquid
  - Foam when liquid and gas mix

- **Liquid Foamers**
  - Delivered by various means at targeted locations
  - Already in liquid state, so require less soak time
  - Foam when liquid and gas mix

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Foaming Technology

**Yesterday**

Yesterday, foamer selection was a lot like fishing. It was an art.

**Today**

Modeling and prediction of foamer performance: a proactive approach

**Tomorrow**

Investigation of key factors that govern the foaming performance and foaming mechanisms.

*To be published in “Petroleum Science and Technology” Journal*
Factors That Influence Foaming

A $2^5$ Factorial Design (a 2 level with 5 factors) 
with two replicates (64 experiments)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Levels</th>
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<tbody>
<tr>
<td>Temperature</td>
<td>25°C</td>
</tr>
<tr>
<td></td>
<td>70°C</td>
</tr>
<tr>
<td>Oil</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>Chloride</td>
<td>2.4%</td>
</tr>
<tr>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Foamer dosage</td>
<td>400 ppm</td>
</tr>
<tr>
<td></td>
<td>1000 ppm</td>
</tr>
<tr>
<td>Oil type</td>
<td>cycloalkane</td>
</tr>
<tr>
<td></td>
<td>aliphatic</td>
</tr>
</tbody>
</table>

Performance Response: % Unloading

Design Of Experiment

Temperature  Chloride  % Oil
Design Of Experiment

Foamer Dosage

Oil Type

Prediction of Foamer Performance

Predicted vs. Actual % Unloading

R² = 0.917
Conclusions

- Prediction and modeling of foamer performance with confidence
  - A proactive approach to manage program

- “No touch” foaming testing

- Quick response when process variables change

- Foamer mapping

Laboratory Testing
Laboratory Testing

- **Standard Laboratory Testing**

- **Standard performance tests**
  - ASTM D-3601 - Foam in Aqueous media (Bottle Test)
  - ASTM D-3519 - Foam in Aqueous media (Blender Test)
  - ASTM D-892 - Column/Cylinder Test Method (Dynamic Test)

- **Specialised performance test**
  - Unloading rig
  - Injection systems
  - Well simulators

- **Customer tests**
  - Example Protocol

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Standard Chemical Testing

- **Density**
- **Ecotox Environmental Profile**
- **Flash Point**
- **Viscosity Profiles**
- **Thermal Stability**
- **Emulsification Tendency**
- **Defoamer Compatibility**
- **Chemical Compatibility**
- **Materials Compatibility**
ASTM D-3601
(Foam in Aqueous media - Bottle Test)

- Quick and cheap test
- Established for aqueous, low viscosity system
- Using low shear to generate foam
  - Some foamers are prone to perform better under shear rather than gas flow
  - If high shear required use the blender test
- Result is a comparison of foam height and nature versus a control

ASTM D-3519
(Foam in Aqueous Media - Blender Test)

- Data Collected
  - Foam Height
  - Foam Life
  - Drainage Half Life
- Foam characterization under high shear conditions
  - Hydrocarbon influences difficult to assess due to affect on foam height and emulsification issues
- Some surfactants prone to generate more foam in high shear conditions
ASTM D-892 & Modifications
(Column/Cylinder Test Method – Dynamic Test)

- Data Collected
  - Foam height versus Time
  - Fluid carry over with given gas rate (0.01–10 ft/sec)
  - Foam life
  - Drainage half life

- Modifications
  - Heating the liquid to provide more representative conditions
  - Changes the size of the cylinder – gives different ID
  - Still assess the same properties

Dynamic Unloading Rig

- Carry over arm
- Jacketed cylinder
- Gas In

Foam Stability
- α-olefin sulfonate
- Betaine
- High condensate foamer

% Unloading vs Time
400 ppm active foamer and 75% Condensate

\[ \text{% Unloading} = \frac{W_{\text{final}}}{W_{\text{initial}}} \times 100 \]
Capstring Injection Performance

- Capstring simulation
- Fitted with atomising nozzle at base of column
- Same principal and output as the unloading rig

Atomiser Performance

Effect of Foamer Concentration on Unloading Efficiency
Conditions: Tap Water, No Condensate

- Nalco’s Patented Nozzle: 30% more effective
- Conventional Method
Automated High Pressure & Temperature Foam Column Testing Apparatus

- Lab simulator to make closer comparison to the field
  - Temperature
  - Pressure

Operator Test Protocol

Procedure for testing foamer performance

200 milliliters tap water (or produced water from a well, or artificial brine based on well water analyses) is transferred into a 1000ml measuring cylinder ($h = +/- 450mm, \phi = 60mm$). 40ml white spirit, and foamer is added (1000-5000ppm). A nitrogen sparge (50l/hr) is applied to the cylinder via a P2 sintered gas dispersion tube. The height reached in the column after 2 minutes bubbling is noted, or the time taken to fill the column up to the 1000ml mark (1). The gas sparge is removed and for those samples that reached the 1000ml mark and the time taken to collapse to half of the foam column level ($= 600ml$) is noted together with the time taken for the foam to collapse completely. At this stage, any observations regarding the mixture quality are noted (emulsions, solids, water quality, condensate quality). The nature of the foam is noted.

The following observations are noted:
- Foam build up time (s)
- Half-life of foam column (or >240 s)
- Foam type
- Other observations

<table>
<thead>
<tr>
<th>Foam build up time</th>
<th>Foam build up time</th>
</tr>
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<tbody>
<tr>
<td>$&lt;$ 90 s</td>
<td>good</td>
</tr>
<tr>
<td>90 s $\leq x &lt; 120$</td>
<td>moderate</td>
</tr>
<tr>
<td>$&gt;$ 120</td>
<td>poor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foam half-life time</th>
<th>Foam half-life time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt;$ 240</td>
<td>good</td>
</tr>
<tr>
<td>240 s $\leq x &lt; 240$</td>
<td>moderate</td>
</tr>
<tr>
<td>$&lt;$ 65 s</td>
<td>poor</td>
</tr>
</tbody>
</table>
Taking Technology To The Field

Chemical Methods of Artificial Lift

- Soapsticks
- Batch treatments
- Squeeze treatments
- Continuous applications
  - Chemical drip
  - Capillary injection
- Combination products
Pros & Cons of Chemical Methods

**Pros**
- Set-up and operating cost
- Potential to use to abandonment
- Versatility for different completions and environments
- Can be used in addition to mechanical methods
- Tolerance of particulates
- Rapid response
- Automated continuous programs
- Can controls down hole corrosion, scale and paraffin problems

**Cons**
- Placement can be difficult
  - Soapsticks
  - Capstrings
- Need to monitor stock
- Personnel intervention
- Well conditions change could render specific product ineffective
- Temperature stability on surface and down hole
- Environmental concerns

Well Suitability & Modelling - From The Lab To The Field
Production Patterns

- Sharp decline in production rate
- Changes in water production
  - Slugs of liquid coming through
  - Decline in produced water &/or condensate
- Changes in pressure deltas
  - Casing minus tubing versus time

Critical Velocity Model

**INPUT DATA:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubing I.D., inches</td>
<td>2.441</td>
</tr>
<tr>
<td>Wellhead Temperature, °F</td>
<td>85</td>
</tr>
<tr>
<td>Wellhead Pressure, psig</td>
<td>500</td>
</tr>
<tr>
<td>Gas Specific Gravity</td>
<td>0.68</td>
</tr>
<tr>
<td>Mole Fraction N₂</td>
<td>0.002</td>
</tr>
<tr>
<td>Mole Fraction CO₂</td>
<td>0.023</td>
</tr>
<tr>
<td>Mole Fraction H₂S</td>
<td>0</td>
</tr>
<tr>
<td>Condensate Rate, bbls/d</td>
<td>57.4867</td>
</tr>
<tr>
<td>Condensate API Gravity</td>
<td>55</td>
</tr>
<tr>
<td>Water Rate, bbls/d</td>
<td>56.2397</td>
</tr>
<tr>
<td>Sodium - Na</td>
<td>17,000</td>
</tr>
<tr>
<td>Calcium - Ca</td>
<td>250</td>
</tr>
<tr>
<td>Potassium, - K</td>
<td>150</td>
</tr>
<tr>
<td>Magnesium - Mg</td>
<td>10</td>
</tr>
<tr>
<td>Strontium - Sr</td>
<td>5</td>
</tr>
<tr>
<td>Barium - Ba</td>
<td>3</td>
</tr>
<tr>
<td>Iron - Fe</td>
<td>12</td>
</tr>
<tr>
<td>Chloride - Cl</td>
<td>55,000</td>
</tr>
<tr>
<td>Sulfate - SO₄</td>
<td>75</td>
</tr>
<tr>
<td>Bicarbonate - HCO₃</td>
<td>25</td>
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</table>

**PREDICTION OF LIQUID LOADING:**

**Desensitized Model - WATER ONLY**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>vₚ, ft/sec</td>
<td>9.46</td>
</tr>
<tr>
<td>Qₓ, Mscf/d</td>
<td>967</td>
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<tr>
<td>v, ft/sec (w/ Turner Adj. Factor of 20%)</td>
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**Desensitized Model - CONDENSATE ONLY**

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<tr>
<td>v, ft/sec</td>
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<tr>
<td>Qₓ, Mscf/d</td>
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<td>v, ft/sec (w/ Turner Adj. Factor of 20%)</td>
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**Desensitized Model - WATER & CONDENSATE**

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<td>Qₓ, Mscf/d</td>
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<td>Qₓ, Mscf/d (w/ Turner Adj. Factor of 20%)</td>
<td>982</td>
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**Desensitized Model - WATER & FOAM**

<table>
<thead>
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<th>Value</th>
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<tbody>
<tr>
<td>v, ft/sec</td>
<td>6.426</td>
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<tr>
<td>Qₓ, Mscf/d</td>
<td>657</td>
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</table>
### Modeling Process, Output & Ranking

**INPUT DATA:**

<table>
<thead>
<tr>
<th>Well</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tubing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water only</td>
<td>4.396</td>
<td>2.927</td>
<td>3.905</td>
<td>4.294</td>
<td>2.679</td>
</tr>
<tr>
<td>Condensate only</td>
<td>2.180</td>
<td>1.797</td>
<td>2.530</td>
<td>2.530</td>
<td>2.530</td>
</tr>
<tr>
<td>Water/Condensate</td>
<td>3.009</td>
<td>2.582</td>
<td>2.464</td>
<td>3.801</td>
<td>3.801</td>
</tr>
<tr>
<td>Water/foam</td>
<td>2.009</td>
<td>1.920</td>
<td>2.611</td>
<td>2.611</td>
<td>2.611</td>
</tr>
<tr>
<td><strong>Casing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water only</td>
<td>4.396</td>
<td>2.927</td>
<td>3.905</td>
<td>4.294</td>
<td>2.679</td>
</tr>
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<td>3.801</td>
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<td>Water/foam</td>
<td>2.009</td>
<td>1.920</td>
<td>2.611</td>
<td>2.611</td>
<td>2.611</td>
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<tr>
<td><strong>Ranking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Model shows leading edge in both tubing and casing. Liquid production is low, so this could indicate DH liquid accumulation.</td>
<td>Hard decline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Evidence to infer leading in both the well’s tubing and casing. Liquid production is low, so this could indicate liquid build up DH. Supported by production rate decline.</td>
<td>Decline from start of year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Model shows well is producing above tubing critical rate, but below critical in the larger ID casing. Flow regime and liquid production would indicate this as a candidate for treatment.</td>
<td>Steady decline, intermittent rates above critical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Model shows both the well tubing and casing are not far from critical conditions. Application of foamer now could delay the onset of liquid loading and maintain continuous production.</td>
<td>Rise at year start, but now decline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Production for this well is intermittent, but would appear to be already critical for water and foam combined. Possible batch candidate, although it may be beyond help from foamer.</td>
<td>Rise to manufacture then decline</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Echometer

- A tool for finding the liquid level
- Can assist in treatment planning and suitability assessment
- Widely used in the industry

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**ACOUSTIC LIQUID LEVEL TEST**

The Echometer is a gas gun assembly and pressure transducer. The pressure transducer provides a reliable and accurate determination of the casing pressure buildup rate which is essential to determine the casing annulus gas flow rate. The component utilizes the acoustic data and casing pressure buildup data in conjunction with the well’s data base to calculate the well’s analysis shown below.
Lab Testing & Product Selection

- Performance
- Density
- Ecotoxicity
- Environmental profile
- Flash point
- Thermal stability
- Materials compatibility
- Viscosity profiles
- Emulsification tendency
- Chemical compatibility
- Defoamer compatibility

Field Application

- **Treatment options**
  - Topside trial
  - Batch
    - Liquid batch
    - Solid state
    - Squeeze
  - Continuous
    - Drip
    - Capillary string

- **Well & process considerations**
  - Climate
  - Supply / logistics
  - Well completion
  - Hardware limitations

- **Easy to control treatment and optimise rate**
  - Rapid response to dosing
Monitoring Performance

› Foamers will respond quickly in a system
  › Beneficial for trials and optimisation

› KPIs
  › Production rates
    • Gas, Liquids (water / condensate)
  › Flowing time
  › Shut-in period
  › Wellhead temperature
  › Other important parameters
    • Separation efficiency
    • Oil in Water levels

› These are often dictated by the well and process set-up
  › E.g. if there is no test separator then accurate monitoring of production rates can be difficult

Batch Treatment

› This can be applied in a various ways
  › Solid state soapsticks
    • Manual or automated drop via production tubing
  › Batching down the backside
    • Only on packerless completions
  › Batch and Fall
    • Good if the well can be rocked
    • If there is a very high level of loading
  › Bull heading or tubing displacement
    • Use a volume of flush to drive the chemical into location
  › Squeeze
    • Can be achieved with liquid or gas and the post-treatment flush
**Offshore Application**

- **Condensate loaded well (>95%)**
  - 30,000 ppm foamer batched via production tubing

- **Well shut-in for 24 hours**

- **Initial flow back, well failed to kick**

- **Shut-in for additional hour**

- **Production kicked with significant benefits**

<table>
<thead>
<tr>
<th>Down hole Batch Treatment</th>
<th>Previous Flow back</th>
<th>Trial results</th>
<th>% gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensate within 30 mins/bbls</td>
<td>5</td>
<td>40</td>
<td>700</td>
</tr>
<tr>
<td>Gas Rate after 30 mins/mmscfd</td>
<td>5</td>
<td>6.5</td>
<td>30</td>
</tr>
<tr>
<td>Condensate after 12 hours</td>
<td>50</td>
<td>81</td>
<td>62</td>
</tr>
<tr>
<td>Well uptime (days)</td>
<td>6</td>
<td>60</td>
<td>900</td>
</tr>
</tbody>
</table>

**Trial Conclusions**

- Batch treatments completed on a condensate dominant well
  - Levels at >90% condensate

- Key differentiators observed by Operator
  - Superior modelling of candidate wells
  - Unrivaled performance in lab tests
  - Knowledge and contribution of foamer expertise
  - Minimal effect on PW quality
  - Environmentally "green", non-sub product, gold HQ

- Production benefits observed in many ways
  - Key advantage being well shut in cycling went from every 6-8 days to 63 day interval
  - No impact on BS&W or OIW
Continuous Treatment

- Continuous injection is preferred
- Capillary strings are most efficient means
- Can occur via the gas lift system
- Depending on completion strings can be run down the producer (concentric) or banded on the tubing (eccentric)
- Various types of atomisers and nozzles available
- Placement is key to performance
  - Need to ensure that the chemical is delivered to the correct location
  - Typically aim for top perforations
- Can be used in addition to other artificial lift methods
Continuous Application Using Atomiser

Well #3, 35% Condensate
Well #2, 24% Condensate

Onshore Application Batch & Continuous

- Batch and Continuous trials completed versus incumbent product
  - Performance comparable or better

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Product</th>
<th>Treat Rate</th>
<th>Ave. Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 / hr</td>
<td>Mm³ / day</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>215</td>
</tr>
<tr>
<td>+1 hr</td>
<td>Product A</td>
<td>5</td>
<td>185</td>
</tr>
</tbody>
</table>

System flush and change out of product

First trial well neither product improved production
Second application Product A gave excellent performance improvement over Incumbent
Application of Chemical with Plunger

Application Above Critical Velocity
**Application of Combination Products**

### Well A
- **Production**
  - Gas Mscf/d: 450
  - Water / BOPD: 12
  - Condensate / BOPD: 0
  - Tubing Pressure / Psi: 400
  - Casing Pressure / Psi: 400

<table>
<thead>
<tr>
<th>Date</th>
<th>Treatment</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>13/09/2007</td>
<td>Chemical Backside Treatment</td>
<td>Batch CI</td>
</tr>
<tr>
<td>26/09/2007</td>
<td>Installed continuous</td>
<td></td>
</tr>
</tbody>
</table>

### Corrosion Data
- **Pitting Rate / MPY**: 1.4 - 5.3
- **General Rate / MPY**: 2.4 - 7.3

### Caliper Surveys
- 03/12/2007
- 06/06/2008

### Well B
- **Production**
  - Gas Mscf/d: 330
  - Water / BOPD: 14
  - Condensate / BOPD: 0
  - Tubing Pressure / Psi: 400
  - Casing Pressure / Psi: 800

<table>
<thead>
<tr>
<th>Date</th>
<th>Treatment</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>26/09/2007</td>
<td>Chemical Backside Treatment</td>
<td>Batch CI</td>
</tr>
<tr>
<td>21/11/2007</td>
<td>Installed continuous</td>
<td></td>
</tr>
</tbody>
</table>

### Corrosion Data
- **Pitting Rate / MPY**: 4.5 - 12.2
- **General Rate / MPY**: 0.6 - 2.9

### Caliper Surveys
- 29/11/2007
- 02/06/2008

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**Application Trouble Shooting**

- **Emulsion formation**
  - Surfactants can potentially increase emulsion tendencies
  - Foamer treatments are often managed with antifoam and emulsion breakers as required
  - Field evidence demonstrates no impact on process

- **Process upsets**
  - Proper topside foam control should prevent any disruptions
    - Correct defoamer application
  - No reported impact on water quality specification
Application Trouble Shooting

- **No well response**
  - Dead well
    - Insufficient gas or agitation
    - Can rock or swab the well
    - Apply gas sticks / pellets – introduce localised gas
  - Flowing well
    - Chemical not reaching the liquids
    - Well conditions are not conducive to loading
      - Modelling error

- **Capstring issues**
  - Plugging of the line
    - Use only capstring qualified products
    - Apply appropriate flushing procedures for shut down
  - Compatibility
    - Materials
    - Chemicals
    - Produced fluids
Foamer Performance Summary

- See great versatility of the foamer application
  - On- and Off-Shore
  - Continuous and Batch
    - Continuous is preferable in majority of instances
  - Optimisation is facile with rapid response

- Performance observed:
  - Above the critical velocity
  - When the casing is loaded
  - Instead of and with plungers

- Benefits:
  - Increased production
  - Improved decline curve
  - Extended flowing period
  - Well clear out
  - Extend well longevity
  - Can be used to support asset integrity and flow assurance programs
    - Reduce chemical inventory and injection hardware requirements
Workshop Summary

- Demonstrated the benefits chemical foamers can offer gas producers

- Applying a robust selection and testing process means best suited products are recommended

- Utilising surfactant chemistry expertise and the fundamentals of foam science facilitates the development of efficient deliquification chemicals

Questions
Referenced Material