Gas Well Deliquification Using Foamers

A Practical Approach

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Steven Oude Heuvel, Development Chemist
Sen Ubbels, Account Manager
Gerrit van Dijk, Product Development Manager
An Introduction to Gas Well Liquid Loading

Steven Oude Heuvel
What is gas well liquid loading?
» An accumulation of fluids in the tubing

When does gas well liquid loading begin?
» Gas flow rate insufficient to overcome gravity
» Point where both forces are equal is the critical velocity
What are the consequences of gas well liquid loading?

» Once fluids build up to the point where the hydrostatic head is equal to reservoir pressure, no production will occur.
Flow Regimes

Qg > > Qc
Qg >= Qc
Qg < Qc
Qg << Qc
Qg = 0

Qg = Actual Velocity
Qc = Critical Velocity
Critical Velocity

(calculation based on work done by Turner et al. or Coleman et al.)

\[ V_c = C \frac{(\rho_{\text{Liquid}} - 0.0031p)^{\frac{1}{4}}}{(0.0031p)^{\frac{1}{2}}} \]

\( p \) = tubing pressure
\( \rho \) = liquid density
\( C \) = a constant, depending on pressure, fluids, and surface tension
Critical Velocity results: what do they mean?

When the actual flow rate is above critical velocity:

» All fluids should be moving out of the well in entrained droplets or along the annular film. Well not considered to be “loading”.

» Possible exceptions apply, e.g. very high liquid to gas ratio.
Critical Velocity results: what do they mean?

When the actual flow rate is below critical velocity:

» Some or all fluids are not being carried out of the well. Well can be considered “loading”. Liquids will build up in well bore and create some back pressure further reducing flow rate. Lower flow rates cause more fluid accumulation and this situation will continue to cascade.
Liquid Loading Prevention Techniques

» Downhole choke
» Velocity strings
» Gas lift
» Jet pump
» Downhole separation
» Foamer treatment

» Plunger
» Compression
» Cycling
» Thermolift
» ESP
» And more
Advantages of Foamers

» A batch trial is relatively low cost

» Easy to evaluate the response of well to deliquification

» Foamers can be synergistic with other unloading methods: 
  e.g. plunger, compression, jet pump and gas lift
The Theory Behind Foaming

Gerrit van Dijk
Foam is used extensively everyday
  » Fire-fighting foam
  » Shampoo lather
  » Washing up liquids/detergents

Foam in the oilfield is normally unwanted
  » Foaming in separators leads to inefficiency

Exception:
  » Use of foaming agents in gas well deliquification
  » Use of foaming agents in foam drilling
THEORY OF FOAM

- Thin Film Region (Liquid Phase)
- Plateau Border
- Lamella
- Gas Phase
- Interface (2D Surface Phase)

GAS

BULK LIQUID
» Lower relative density of fluids due to foam generation

» Reduced back pressure result

» Gas-liquid interface increases, increases effective gas lifting force
Not all foam is the same

» For unloading of gas wells, a wet foam is required
Mechanism for the stabilisation of foam

- Increasing surface and bulk viscosity
- Increasing thickness of electrical double layer
- Slowing film drainage
- Decreasing gas diffusion across the lamella
- Increasing the elasticity of the film
Foam can be broken by:

» Displacing the surfactant from the interface
» Lowering surface tension
Foam can be broken by:

» Physical rupture of the lamella (i.e. by sand or other particulates)
» Physical rupture is also possible by oil lens formation, so if condensate is present it will require additional foamer to stabilize the foam
What To Expect From Foaming Agents

Gerrit van Dijk
Increased gas production depends on:

» How far the actual flow in the well is below the critical velocity
» Dosage rate
» Product selection
» Application method
Foaming agent performance (1)

Salinity of water
» Specific gravity of brine
» Solubility of the surfactant
» Hydrophilic Lipophilic Balance (neutralisation of charges)

Operating conditions
» Surface equipment
» Thermal stability of the components must be considered
» Volatility of low boiling solvents can reduce foamer performance
Foaming agent performance (2)

Gas flow rate
» The closer to the critical rate, the less foamer will be needed
» Flow rate more important than composition

Presence of condensate
» Condensate acts as an antifoam
» Higher dosage of foamer is needed
Foaming agents: Actives

Standard foamers
» For fluids with low to medium condensate content
» Different surfactants: nonionic, anionic, cationic and amphoteric

Specialty foamers
» For fluids with high condensate content
» Specialty actives, e.g. fluoro-surfactants
Foaming agent requirements (1)

» The main requirement of a foamer is the ability to build a wet foam in the presence of condensate.
Foaming agent requirements (2)

Additional requirements might apply
» Flash point > 61°C
» Meeting environmental requirements
» No negative impact on produced water quality (OiW)
Foaming agent requirements (3)

Additional requirements might apply

» High temperature stability
» Low viscosity at low temperature
» Compatibility with other treatment chemicals, like Defoamer and Water Clarifier
Foaming agent requirements (4)

Customers might have additional requirements to take into account

» Specific test protocols to be met
» Material compatibility toward specific metals or elastomers
» No negative impact on condensate quality
Nonionic surfactant

» Low to medium foaming performance
» Solubility reduces at higher temperatures (cloud point)
» Solubility reduces at higher salt content
» May act as an emulsifier, thereby reducing water quality
» Often applied in foam sticks
» Applied as co-surfactant in formulations
» In general environmentally acceptable
Anionic surfactant

» High foaming performance
» Foaming performances reduces at higher salt content
» In general not stable at high temperature, except sulfonates
» May act as an emulsifier, thereby reducing water quality
» Often applied in high water cut / low temperature wells
» In general toxic to fish, especially the long hydrophobic chain versions
Cationic surfactant

» Moderate foaming performance
» High temperature stability
» Acts substantive (metal surfaces), losing active content to tubing wall
» Might act also as corrosion inhibitor
» Often applied in low condensate wells
» Toxic for organisms
Amphoteric surfactant

» High foaming performance
» Also good foaming performance at high salt content
» Also good foaming performance at medium condensate content
» Excellent temperature stability
» Often corrosive due to presence of chloride as by-product
Specialty foaming agents

» Foaming agents are formulated by blending at least 1 surfactant in a solvent.

» The optimal product is often a compromise between the requirements, i.e. foaming performance, temperature stability, environmental properties, compatibility with fluids, material compatibility, corrosivity, etc.
Testing Of Foamers
In The Laboratory

Steven Oude Heuvel
» Testing done according to ASTM method D-892

» Used to test compatibility of fluids beforehand
Procedure is modified to suit purpose better

» Higher gas flow rates
» Monitor foam build up and break times
» Can monitor water carryover on some set ups
» Jacketed cylinder / water bath for temperature control
» Taller cylinder to more closely model actual well conditions
Candidate selection

» Well selection is key to a successful foamer program
Candidate selection

Several criteria should be evaluated when selecting wells to implement a foamer program:
» Orifice pressure spikes indicate fluid slugging
» Decline curve analysis shows a departure from natural decline curve
Candidate selection

Several criteria should be evaluated when selecting wells to implement a foamer program:

» Increase in $\Delta P(\text{Casing-Tubing})$, limited to packerless wells
» Well shows a response to batch treatment with foamer or to a shut-in/build up cycle
» Use a well modeling program to predict loading
Candidate selection

Critical data for candidate selection:
» Information on gas composition and production
» Tubing dimensions
» Information on fluid composition, properties and flow rates
Candidate selection

Important data for candidate selection:
» Temperatures
» Pressures
» Depths (i.e., end of tubing and perfs)
Candidate selection

Calculates critical velocity of the fluids

Critical velocity for is different for water, condensate and Foam due to changes in specific gravity
Applying Foamers
In The Field

Sen Ubbels
Key points of a foamer program

» Foamer program (just a foamer or in combination with other oil field chemicals)

» Delivery method (liquids or sticks)

» Application method (batch or continuous treatment)
Foamer programs

Standard foamer package
» Just a foamer

Enhanced foamer package
» Combination products, e.g. formulated with Scale, Halite or Corrosion inhibitors in field specific applications

Full chemical programs might be required for treatment
» Water clarifier chemicals
» Defoamer applications
Combination products of Foamer + Halite Inhibitors

» Remove liquids from the gas wells and stops the formation of salt in the flow lines and separators.
Improved water quality after a batch of Foamer + special clarifier
Defoamer programs

*Treatment assists in foam collapse to prevent downstream system upsets*

Chemical functionality

» Silicone
» Non-silicone

Environmental functionality

» Sub or No-Sub (Off-shore substitution warning)

Defoamers versus Anti-foamers

» Defoamers break existing foam and an Anti-foamer prevent foam formation
Ideal wet, coarse foam - which does not require de-foamer
Foamer Delivery methods

Liquid foamers.
» Most foamers are supplied as low viscous liquids in drums or IBC’s, ready to be used.
  
  Good control of the dosage

Soap sticks.
» In small gas wells, with a simple completion, foamer sticks can be alternative.
  
  Less control over the dosage
Application methods

» Batch application

» Continuous application
Batch applications

Used extensively to prove response
» Enhance candidate selection before cap-string capital expense

Simple to use, without any high capital cost

In packer-less wells, the Foamer can be applied with gas production on going
Standard Batch Treatment or Kick-off Treatment:

» 10 - 100 liter of a concentrated foamer
» Flush the foamer to the bottom of the well with 300 to 1000 liters of water or gas with a higher pressure
» Shut the well in overnight
» Open the choke of the well as much as possible when returning to production
» Monitor production for about seven days after treatment. If elevated production rates continue for the final three to five days, the well is a candidate for regular foamer applications.
What does a Loaded Well look like, which is batch treated with foamers?

**EXAMPLE 1**

![Graph showing production, MSCFD over time from 1-Jun to 24-Aug. The graph displays a pattern of production peaks and troughs, indicating the behavior of a Loaded Well treated with foamers.](image-url)
Disadvantages of batch treatments

» In wells with a packer the gas production of the well has to be stopped and later again be restarted.

» The well will have a very intermittent flow (from high immediately after the batch till “zero flow” before the next batch.

» The high dose of foamer can deteriorate the separation of condensate and water. Causing a temporary slug of oily water.

» The high dose of foamer can deteriorate the separation of gas and fluids. Causing a foam slug which has to be treated with a anti-foaming agent.
Continuous applications

Can be performed via:

» Injection of Foamer in the annulus for wells without a packer.
   » Very simple and low-cost method

» Capillary strings
   » Best application method to control the liquid unloading of wells
   » Must consider metallurgy
   » Might need Batch for start-up
Continuous applications

Can control foamer injection rate / concentration accurately;

» Foamer concentration is important and more is not always better.
  » Too much foamer can create a foam lock
» Dosage based on projected water volumes from inflow
» Use of a more dilute product might be required due to pumping limitations
Continuous injection of foamer
Typical Injection System in South Texas
Example of a capillary string used to inject foamer down-hole at a very large 7" well in Europe
Case History of a successful start of well unloading with a capillary string

The well removed 8000 liters (about 2000 Gallons) of fluids after the Foamer was injected (5 % in water).

The well came back on stream producing 200,000 Cubic Meters of gas (7,000,000 scf/day) for many weeks with only 75 liters/ day (0.3 – 1 %) of continuous injection of a Foamer down-hole.

According to the concerned oil company this test was a record, as it was the first 7 “gas well ever restarted with a foamer” in the world.
Tested gas well with the 7 " tubing
Well site overview
First foam samples
Foam after 20 seconds
Sample after 60 seconds
New methods are always being developed;

» Work is currently being done on the new application of squeezing foamers into the formation
Synergy of Foamers with Gas Lift

Foamers can be synergistic to other applications;

» Reduce the amount of gas required for gas lift. When a foamer is added to the lift gas in an oil well, the well will start to produce more fluids, as the foam will create a much better dispersion of the lift gas in the fluids then without a foamer.
Opportunities for onshore applications

» Set up costs are low compared to other deliquification methods
» Potential to take well all the way to abandonment
» Some synergy with other mechanical methods
» Combination products provide one solution to multiple problems
Challenges for onshore applications

» Placement of soap stick launchers or caps strings can be difficult
» Environmental and material compatibilities must be considered
» Temperature stability of the foamer might be an issue in very hot wells.
Challenges for horizontal applications

Where to inject the Foamer?

» Foamers work best in elbow region

» Inject as close to the elbow as possible

» Horizontal area difficult to foam unless injection can be right on a slug point
Challenges for offshore applications

» Quality of produced water critical parameter, the use of a water clarifier might be required to keep water in spec
» Handling of large volumes of produced fluids after a foamer batch might overwhelm separation trains; fluid production might have to be limited
Summary Of Foaming

Sen Ubbels
» Foam will greatly facilitate the removal of fluids from the well

» As fluids are removed from the well, gas rate can increase causing a higher gas velocity and thus increasing the amount of fluids removed

» Foamers are easy to use and generally user friendly
» Compatibility of fluids with Foamers should be tested beforehand on lab scale

» Choosing the right wells and application method is important

» Offshore additional challenges apply

» Foamers can be used to boost other unloading techniques
Thank you for your attention