AUTOMATED HIGH PRESSURE, HIGH TEMPERATURE FOAM COLUMN TESTING APPARATUS

Dr. Marek Pakulski
BJ Services, Tomball, TX
mpakulski@bjservices.com
NEEDS AND EXPECTATIONS

• Deeper wells - higher bottomhole temperature
• Variable volume of condensate associated with gas production
• Good foamer for deliquification
  – produces low viscosity “wet” foam
  – compatible with brine, condensate, additives and contaminants
  – withstand high temperature and pressure
  – cost effective
FOAM TESTING

- ASTM methods and modifications
- Blenders
- Columns
- Every supplier and most end users have their own bench test method
- None of published methods provide objective and quantitative results at a true gas well environment
SIMPLE BLENDER TEST

Foam Test:
Water
Foamer
Condensate
100 ml liquid
RT, 20 sec.,
T1/2, vol.
Static,
Limited
Temp.
COLUMNS

200 ml brine
HT, Dynamic
N₂ 1 L/min
20 ml cond. =
0.2 mol. C₅ =
6 L vapors

Quantitative
Ambient T
Quantitative comparison of three foamers

![Graph comparing weight over time for three foamers. The x-axis represents time in minutes from 0:30 to 5:00, and the y-axis represents weight in grams from 0 to 160. Three lines represent different foamers, each with a distinct color and symbol.]
NEW CONCEPT OF A FOAM TESTING MACHINE

- Move a field test to the laboratory
- Create a gas well environment that mimics production dynamic conditions below critical velocity gas flow
- Measure foaming agents efficiency by the volume of fluid retained in the well. All liquids and gas introduced into the bottomhole must came out through the top - no drowning.
Schematic Diagram of Foam Transport Column

- 3/4" POLISHED
- Heated
- 15 ft high
- HT 500°F
- Hp 600 psi (5000 psi hardware)
- PC control

GAS

\[ \Delta p \]

FOAM OUT

BRINE & FOAMER

OIL

Feb. 23 – 26, 2009

2009, Gas Well Deliquification Workshop
Denver, Colorado
Prescribed flow schedule automatically executed
FTC DATA

• Dynamic parameters: \( \Delta p = f(\text{liquid rate, gas rate, foamer quality and conc.}) \) four data strings to visualize

• Coleman’s eq.: \( V_c \approx 22 \text{ ft/sec} \) (77 L/min, \( N_2 \), if no foam), 3x less expected for foamer solutions

• Try and error testing to find flow rates giving the best response differentiating products and concentrations
  liquids: 10 - 100 ml/min
  nitrogen: 0.5 - 20 L/min
3D plots
\[ \Delta p = f(\text{gas flow, FM conc.}) \]
\[ \Delta p = f(\text{gas/liquid, foamer}) \]
Standardized conditions

- Flow below critical velocity determined experimentally, best response to changes
- \( N_2 \) 1 L/min std (0.4 L/min at 50 psi/90°C = 0.11 ft/sec), natural gas can be used after some safety upgrade
- Brine 40 ml/min
- Hydrocarbon 0 or 2 ml/min (5%)
- Equal price 0.1 c/L and 0.3 c/L
- Tests can be customized
## Typical flow schedule

<table>
<thead>
<tr>
<th>Gas flow</th>
<th>Cond.</th>
<th>Brine + foamer</th>
<th>Time</th>
<th>Averaged data</th>
<th>Test type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>40</td>
<td>0-20</td>
<td>last 20 pts</td>
<td>Dynamic</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20-25</td>
<td>last 10 pts</td>
<td>Static</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>40</td>
<td>25-40</td>
<td>last 20 pts</td>
<td>Dynamic</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
<td>40-45</td>
<td>last 10 pts</td>
<td>Static</td>
</tr>
</tbody>
</table>

Temperature and pressure set beforehand. Software executes the prescribed flow steps and saves data. Graphs are generated automatically.
\[ \Delta p \] converted to brine column height and deliquification %

**Graph: Water retain, 10 sec sampling freq.**

- **X-axis:** Time, min
- **Y-axis:** Water column, inch

**Key:***
- Water column, low center
- Water column, high center

**Legend:**
- Blue line: \[ h, \text{low cent} \]
- Pink line: \[ h, \text{high cent} \]

**Timeline Events:**
- Column filling
- Burps
- Flow
- Equilibrates
- Static hydrocarbon in
- Dynamic
Foam results in brines

Vertical Foam Test, Synthetic Well Brine 3.5% TDS, cost 0.1 and 0.3 c/L
WHAT CAN GO WRONG

• FOAMER OVERDOSE produces viscous “shaving cream” type foam. Foam friction recorded as false brine retain.

• CORROSION! HT and divalent cations SS 316 is not good enough

• SCALE! carbonates, sulfates, phosphates
FOAMER OVERDOSE = foam friction in the picture

Foam Transport Column,
Foamer 5524 in 3.5% TDS Brine

- % deliq. static
- % deliq. dyn.

Foamer conc, ppm

Deliq. %

Feb. 23 – 26, 2009 2009, Gas Well Deliquification Workshop
Denver, Colorado
Residual phosphates from CI and/or SI deposit on porous titanium gas sparger

\[ Ca_3(PO_4)_2 + M_m \]
Foam Transport Column

SUMMARY

- Capable of testing foaming surfactants performance at gas well conditions.
- Delivers quantitative objective results
- Unique product development tool eliminating potential costly mistakes
- Testing foaming surfactants at well conditions assesses their genuine foaming efficiency; hence, assists end users in selecting the best foaming agents for particular downhole conditions
FTC FULL STORY

• Part 1: this presentation
• Part 3: TBA, SPE, Correlation of Laboratory and Field Foam Assisted Well Deliquification Results, in cooperation with a customer
OUR TESTING IS MORE SOPHISTICATED NOW
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