Development of the Auto-fill Brine Evaporation Bag (BEB) System

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Outline

• Description of the BEB System
• Early development of the Continuous-fill BEB System
• Lessons learnt and improvements
• Final working Continuous-fill BEB System
• Solidification of brine residue
• Polyurethane compatibility
• The BEB balloon
• The Brine Evaporation Bag (BEB) System is a brine dewatering system.
• It is composed of the BEB and the BEB Evaporator.
• The BEB contains the brine and keeps it contained during the entire process.
• The BEB has a membrane installed within its sidewall which allows for the water to be removed by the vapor phase keeping the liquids and solids contained within the BEB.
• The BEB Evaporator is the “box” which provides the structural support for the BEB and provides the vacuum and heating required to effect the low temperature boiling condition within the BEB.
• BEB Evaporator (left) and BEB (right)
• BEB Evaporator provided heat, vacuum, structural support, and secondary containment
• BEB provided primary containment and separation of volatiles and non-volatiles
• Initial design concept was for a continuous-fill system
• Later experiments and system requirements determined that a batch mode was optimal.
• Batch mode eliminates the vacuum line to the ARFTA
0.1 micron PTFE membrane has a 4 atm water intrusion pressure

1 atm membrane ΔP resulted in membrane leakage

Brine surface tension must be dramatically reduced compared to water

After brine breakthrough, the leakage stops
The plot shows an extrapolated surface tension of brine derived from a urine dilution experiment.

Reduce brine surface tension results in a reduced brine breakthrough pressure.

- Explains cause of brine leakage
- Give guidance to remedy:
  - Reduced $\Delta P$
Breakthrough and Scabbing

- Breakthrough occurs at a lower than expected $\Delta P$
  - $\Delta P = 2\gamma/r$ (Young-Laplace Equation)
    - Decreasing the surface tension ($\gamma$) reduces the $\Delta P$ of breakthrough

- Why does the breakthrough stop leaking?
  - $P = P_0 e^{2\gamma V_m / rRT}$ (Kelvin’s Equation)
    - Increased vapor pressure of the curved surface results in an increased vapor pressure and faster dewatering
      - “Scabbing”
Scabbing

- Leakage has a higher vapor pressure (P) because:
  - Closer to heater
  - Greater surface curvature
Solutions to Breakthrough

- Reduce the $\Delta P$
- Build a double membrane construct
• Greatly reduced breakthrough
• Breakthrough reduced with improvements - A) through C)
  • A) Leakage due to stress caused by the BEB hanging from upper corner
  • B) Changed geometry to reduce bag stress reducing leakage
  • C) Eliminated stress and reduced pressure – NO LEAKAGE
• D) Early double membrane construct
• A ΔP of 100-150 torr works well
Double Membrane BEBs

- Six different Gen3 Double Membrane Constructs
- Images taken after the run
- No sign of leakage
- 3M Cr Swab with ppm detection was non-detect for CR
Double Membrane

• To guarantee no brine leakage, a double membrane construct is used
• The Double Membrane Construct did not leak through the second membrane
Solidification of Brine Residue

• If the Brine Residue is dried for 3 additional days past the normal end point for water removal, the Brine Residue is converted from a viscus liquid into a solid.

• The images show two such BEBs
  – The top image still standing vertically with “square” corners even after 6 months.
  – The bottom image is more extensively dried and has turned brown in color.
Polyurethane Compatibility

- Polyurethane is generally not rated well for use with acids.
- The BEB (right) with 50% dewater brine shows no sign of polyurethane degradation even after 12 months.
To demonstrate BEB ability to withstand pressure, a BEB “balloon” was built and inflated.

It inflates like a balloon at 3-5 psig.
A Double Membrane Continuous-fill BEB System has been developed

- Keeps 100% containment
- Can dry the brine to a solid
- Polyurethane compatible with Cr brine
- Polyurethane can balloon, i.e., not rupture, in the event of a pressurization event