

The background of the slide is a dark space scene. On the left, a large, dark, spherical planet or moon is partially visible, showing a subtle gradient from dark to light. In the upper right corner, a smaller, dark, spherical planet or moon is visible. The overall background is a deep black with a faint, reddish-pink glow emanating from the right side, suggesting a distant star or nebula.

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

Lance Delzeit

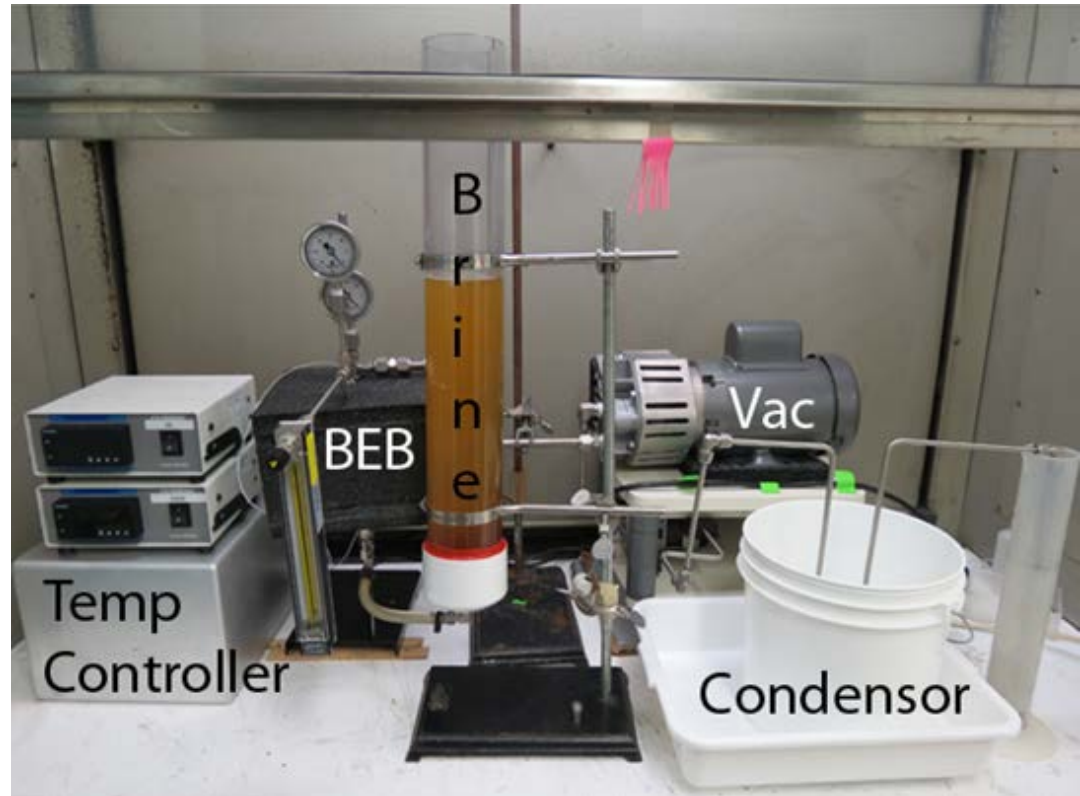
NASA Ames Research Center

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

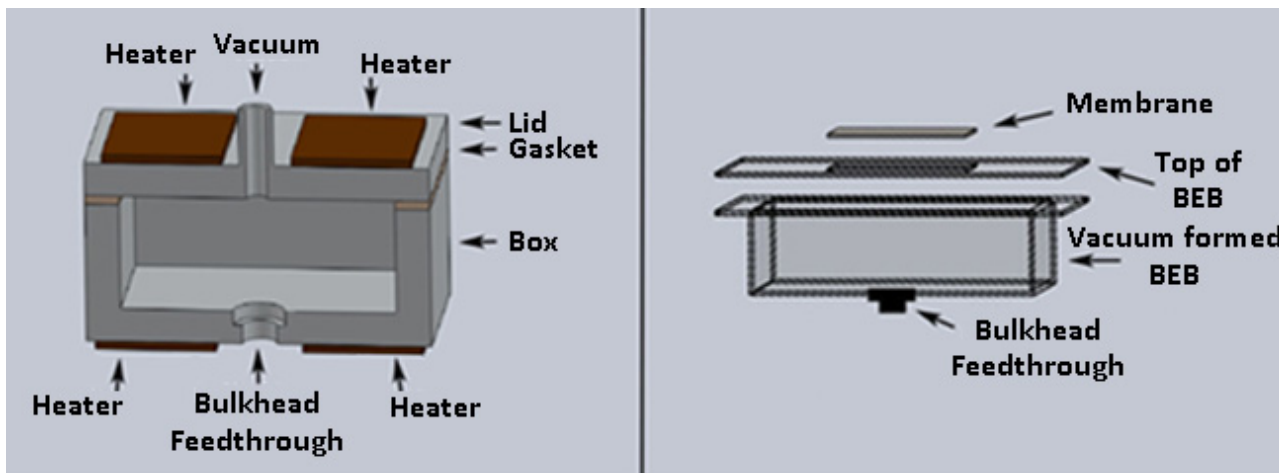
General Description

- 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.



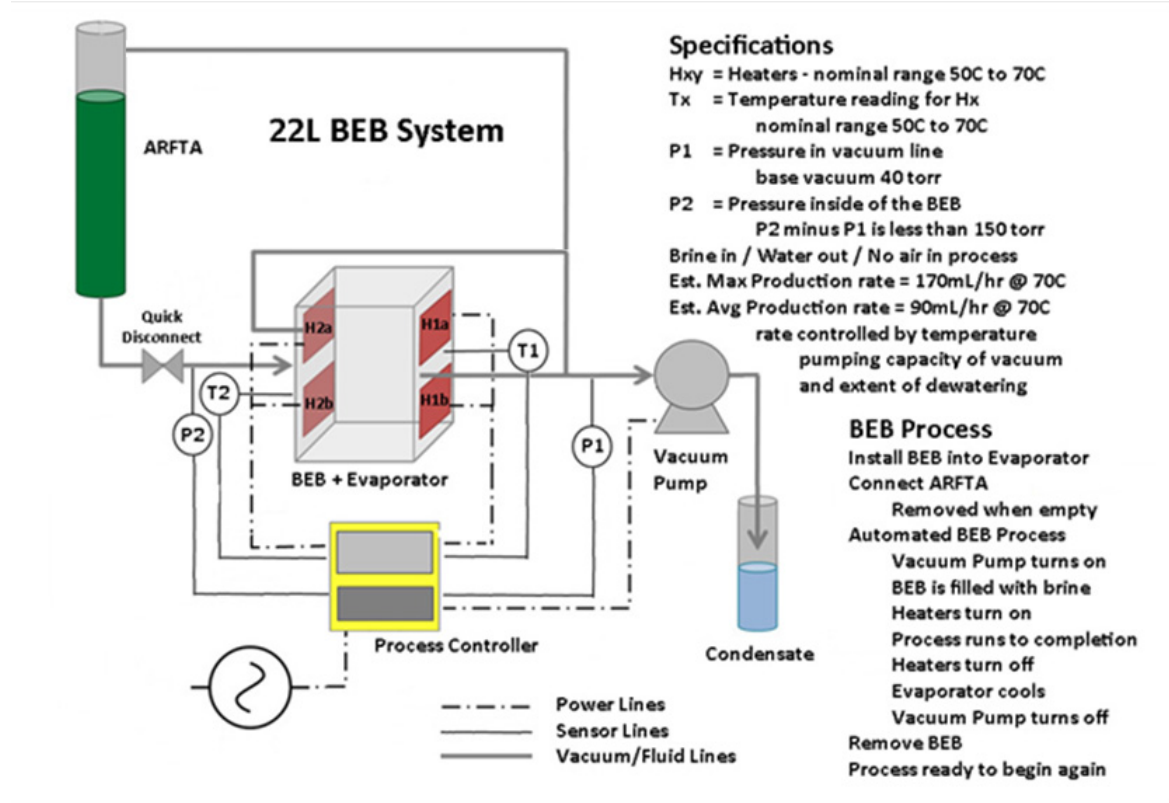
BEB System

- 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



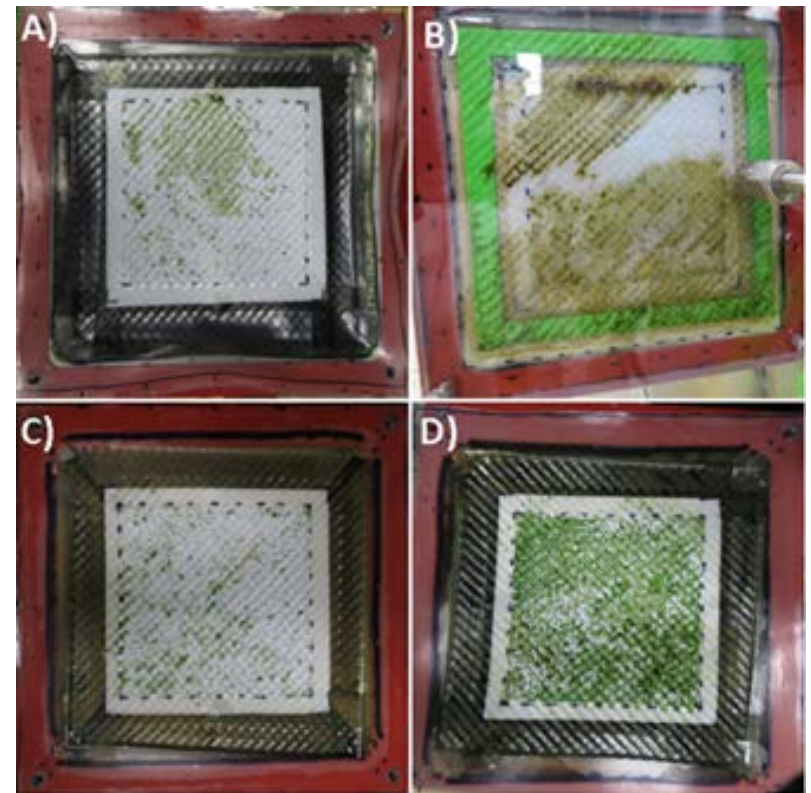
Schematic of Continuous-fill BEB System

- 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



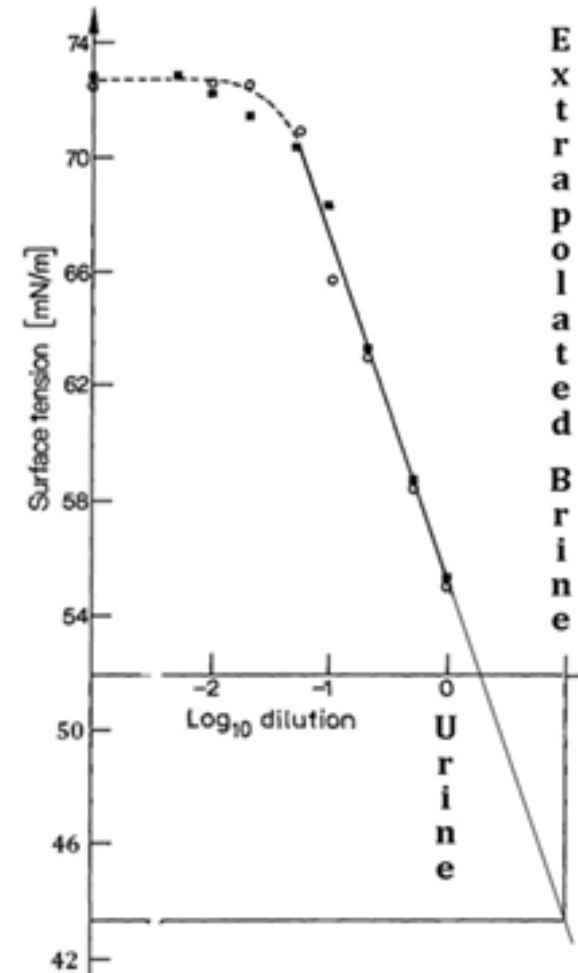
1 ATM ΔP

- 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



Surface Tension of Urine

- 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 ΔP

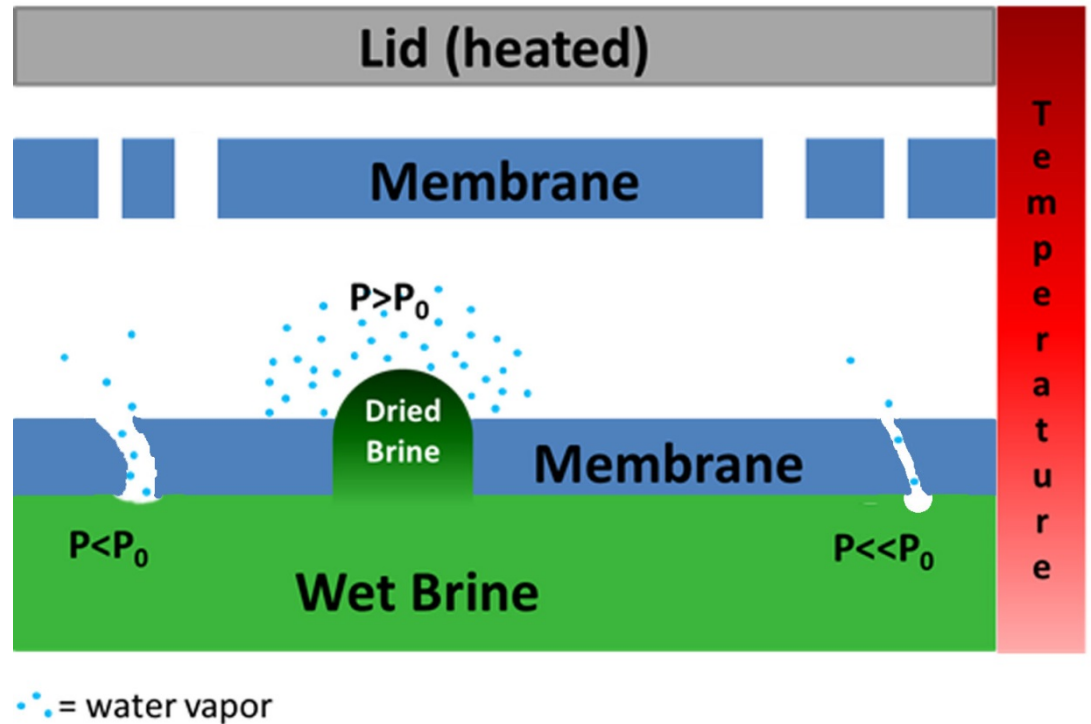


Breakthrough and Scabbing

- Breakthrough occurs at a lower than expected ΔP
 - $\Delta P = 2\gamma/r$ (Young-Laplace Equation)
 - Decreasing the surface tension (γ) reduces the ΔP of breakthrough
- Why does the breakthrough stop leaking?
 - $P = P_o e^{2\gamma V_m / rRT}$ (Kelvin's Equation)
 - Increased vapor pressure of the curved surface results in an increased vapor pressure and faster dewatering
 - “Scabbing”

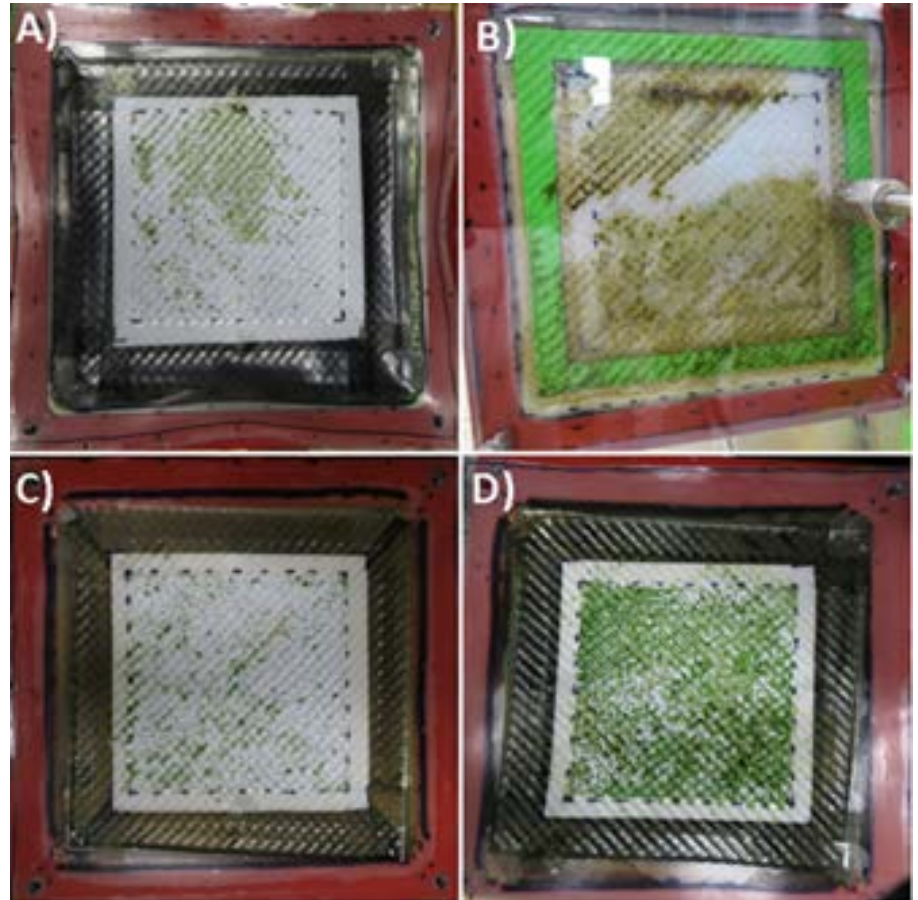
Scabbing

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



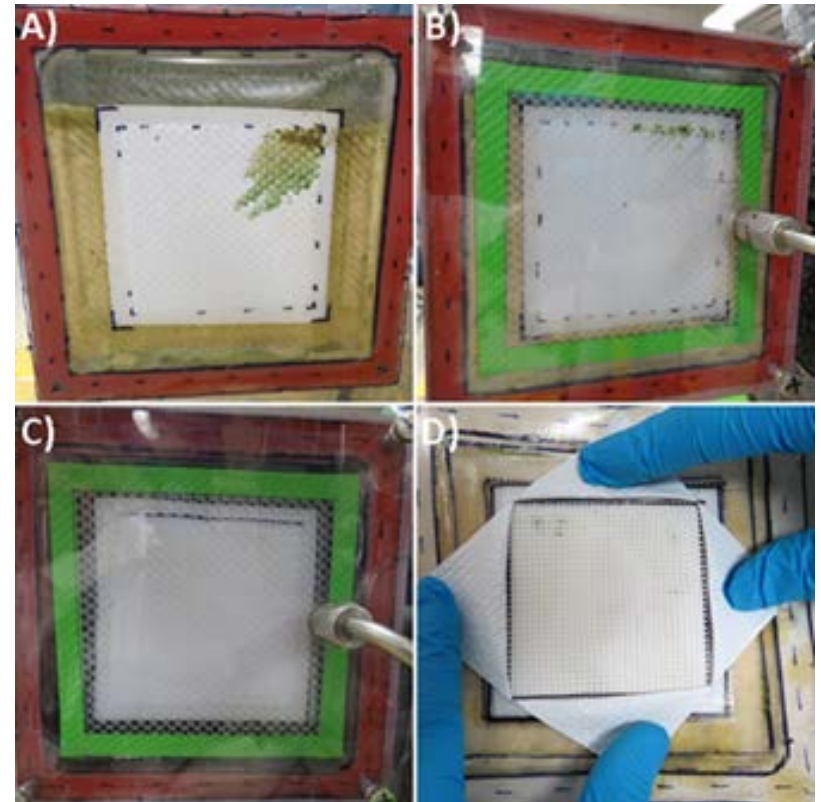
Solutions to Breakthrough

- Reduce the ΔP
- Build a double membrane construct



Sub ATM ΔP

- 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



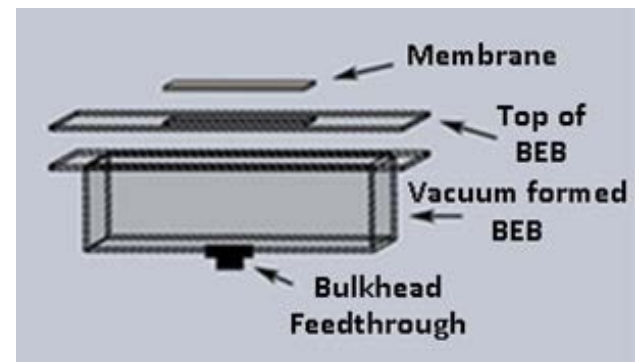
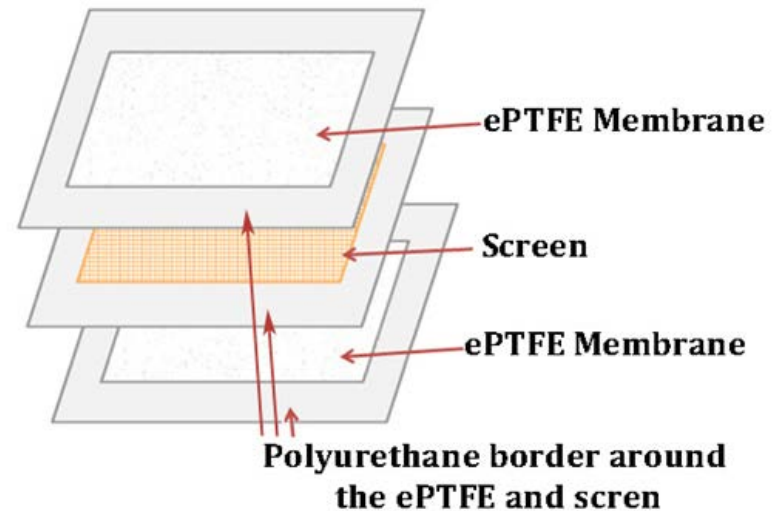
Double Membrane BEBs

- 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



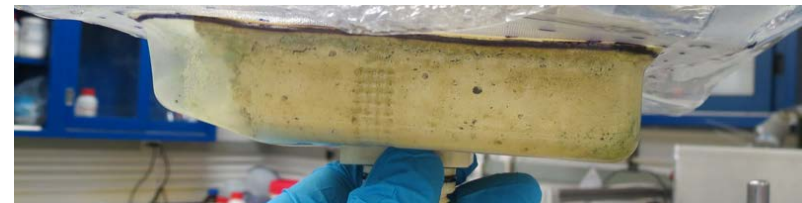
Double Membrane

- 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 viscous 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



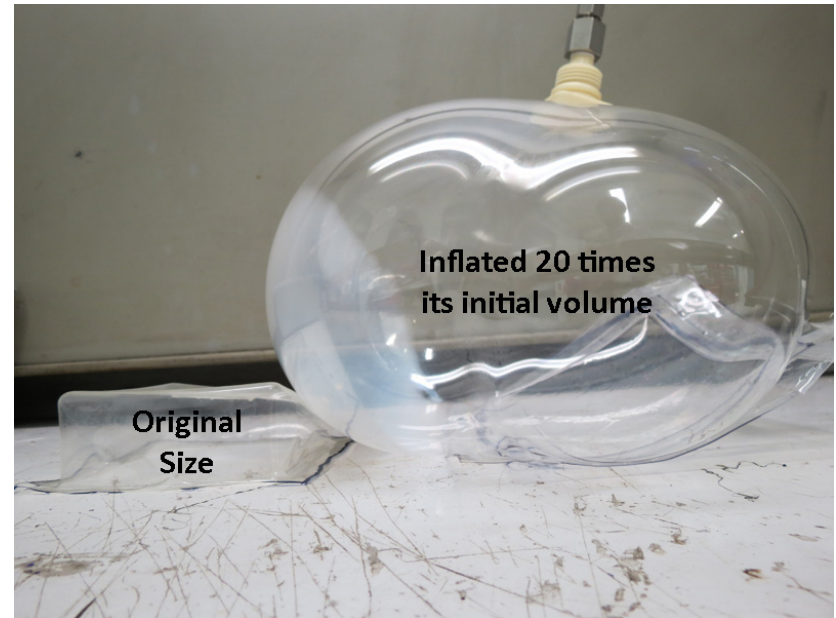
Polyurethane Compatibility

- 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



BEB Balloon

- To demonstrate BEB ability to withstand pressure, a BEB “balloon” was built and inflated.
- It inflates like a balloon at 3-5 psig



Conclusion

- 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