University of Oklahoma

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Energy-Efficient Treatment of Oil and Gas Produced Water for Sustainability

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OU Water Day

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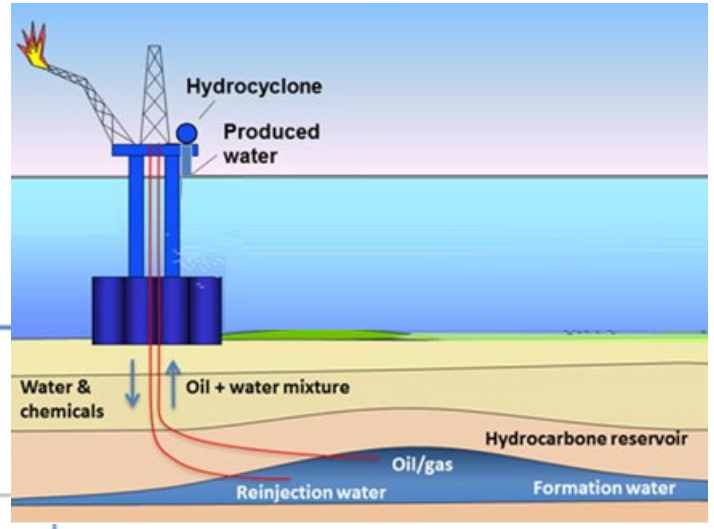
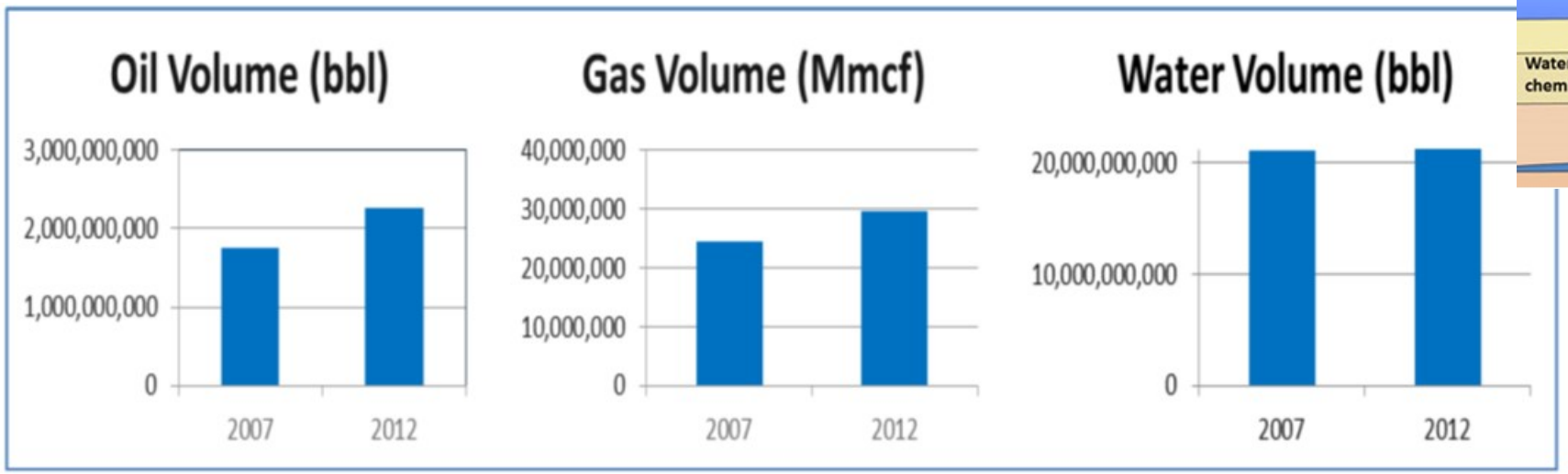
Oil and Gas Produced Water

Produced in the extraction of hydrocarbon energy resources +
Recovered water originally used for hydraulic fracturing

- **9-10 bbl of water/bbl of oil**



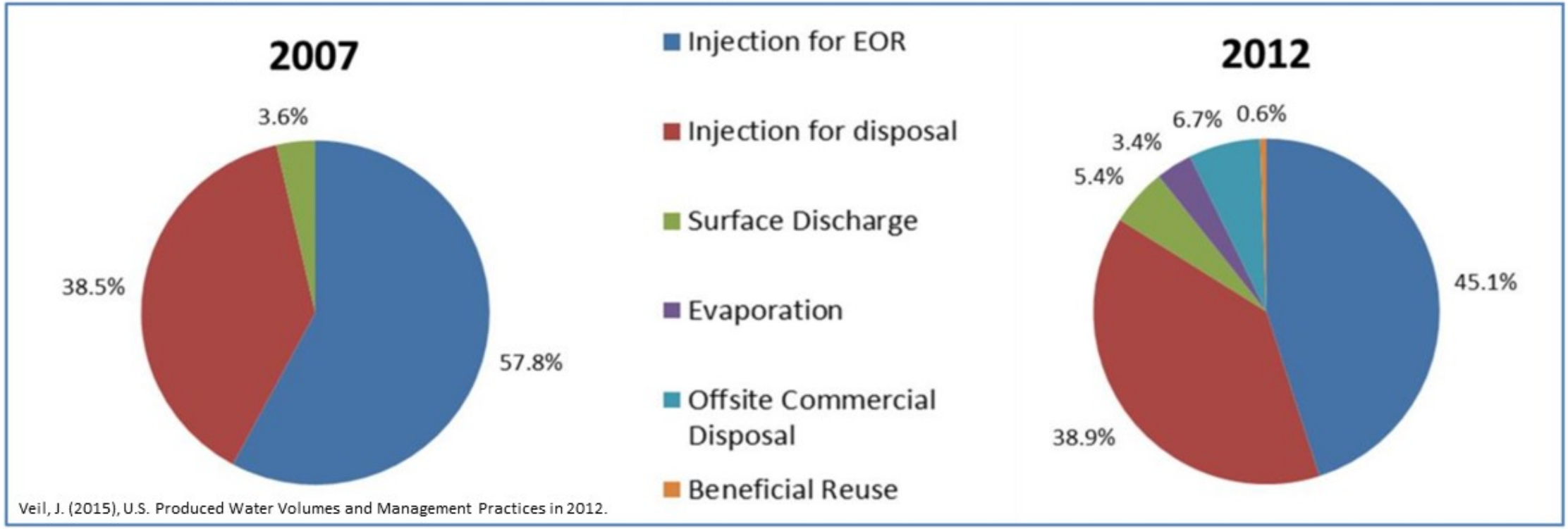
Volumes of Oil, Gas, and Water Produced in 2007 and 2012



Veil, J. (2015), U.S. Produced Water Volumes and Management Practices in 2012.

Produced Water Management

Water Management Practices by Percentage in 2007 and 2012

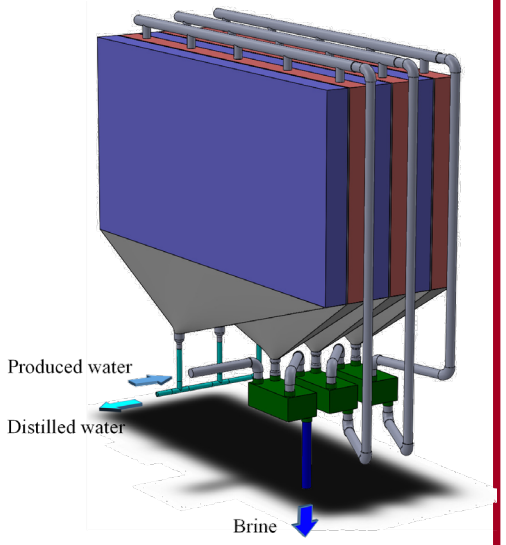


Veil, J. (2015), U.S. Produced Water Volumes and Management Practices in 2012.

Produced Water Treatment

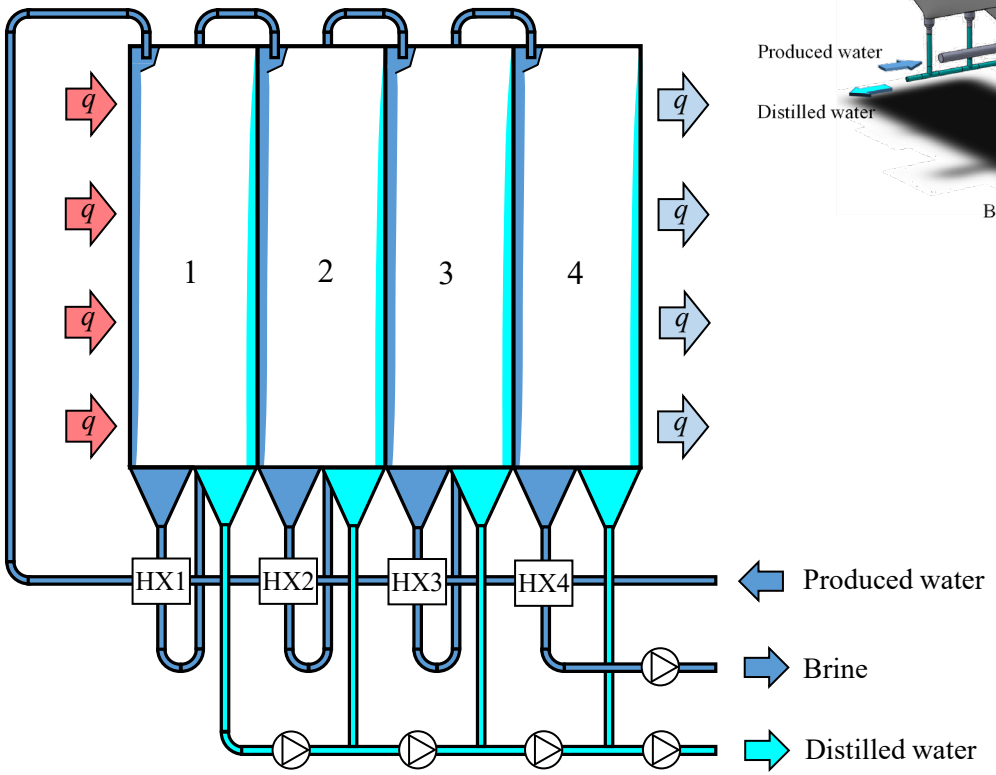
- Multiple Effect Vapor Chamber Distillation
- Freeze Desalination

Multiple-Effect Vapor Chamber Distillation



Compared to Competing Technologies:

- About 3 times greater evaporation heat transfer coefficients
- About three times larger effective condensation surface area



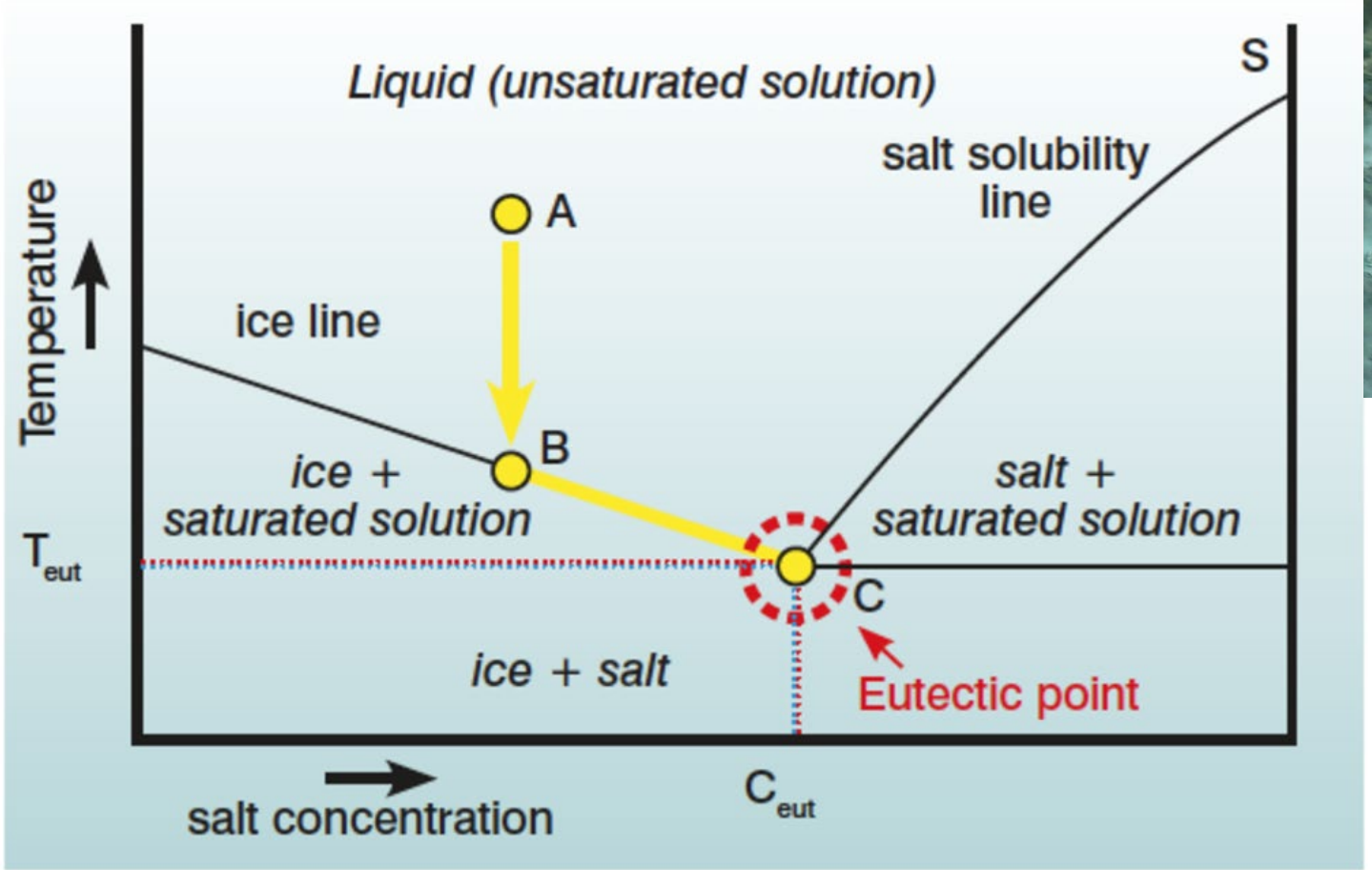
$$P_1 > P_2 > P_3 > P_4$$

$$T_1 > T_2 > T_3 > T_4$$

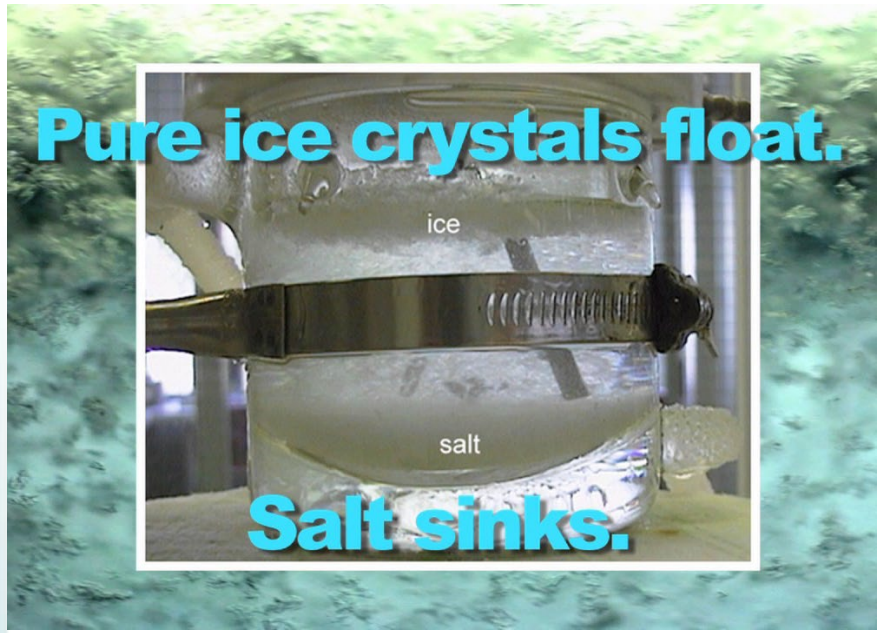
Current Status:

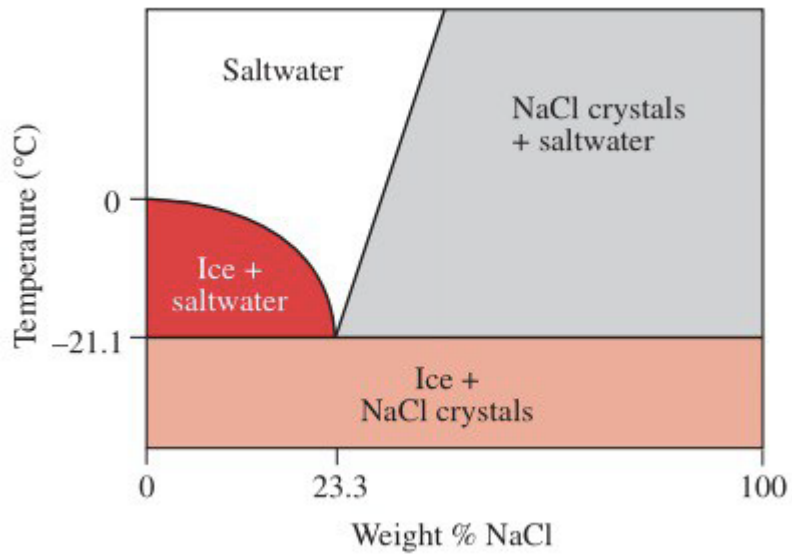
- Patent Filed
- Prototype Design and Model Development

Eutectic-Freeze Desalination



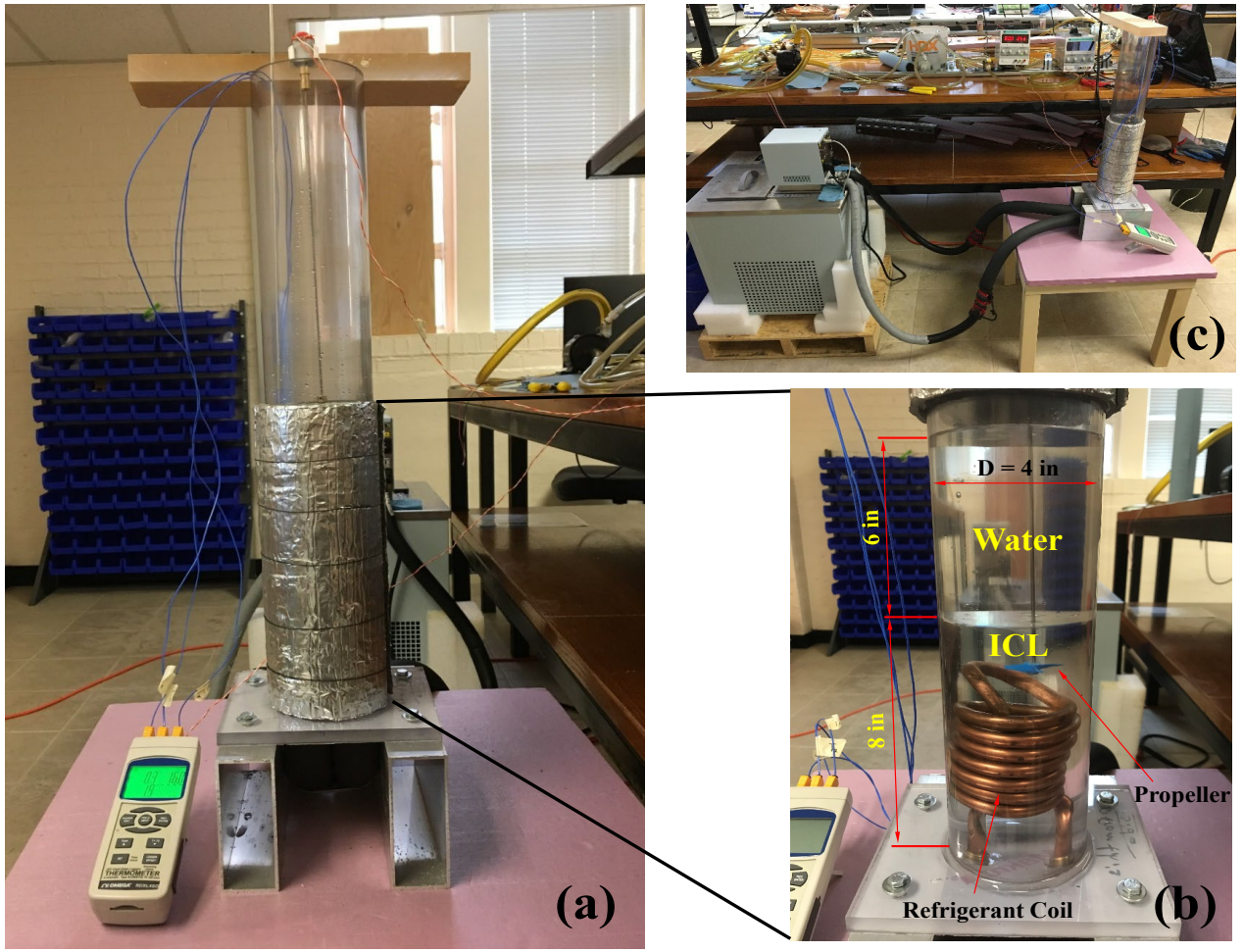
Phase diagram of a binary salt-water system





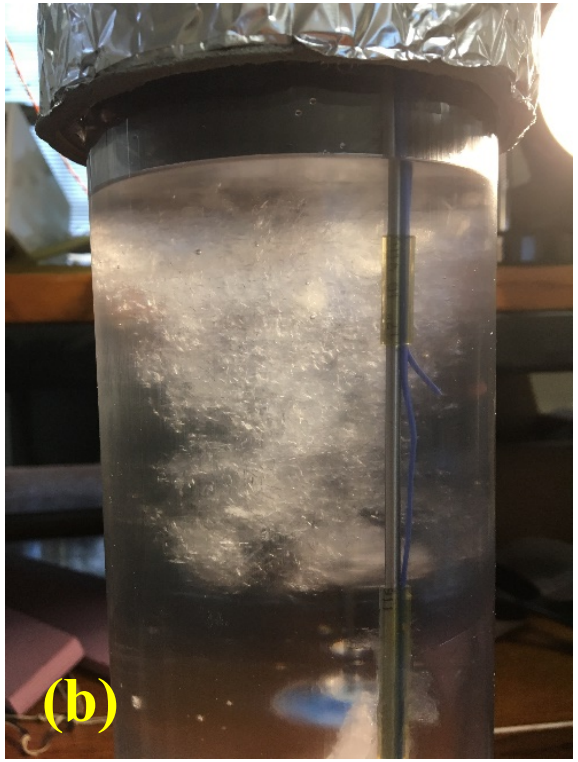
Freeze Desalination Technology

- Utilizes an inert liquid (ICL) to remove heat from the brine
- The "cold liquid" is 50% heavier than water
- Benefits from the superior heat transfer of direct contact freezing systems
- No water quality degradation due to chemical bonding



(a) crystallization tank, (b) immiscible ICL and brine,
(c) the experimental setup connected to the refrigeration unit

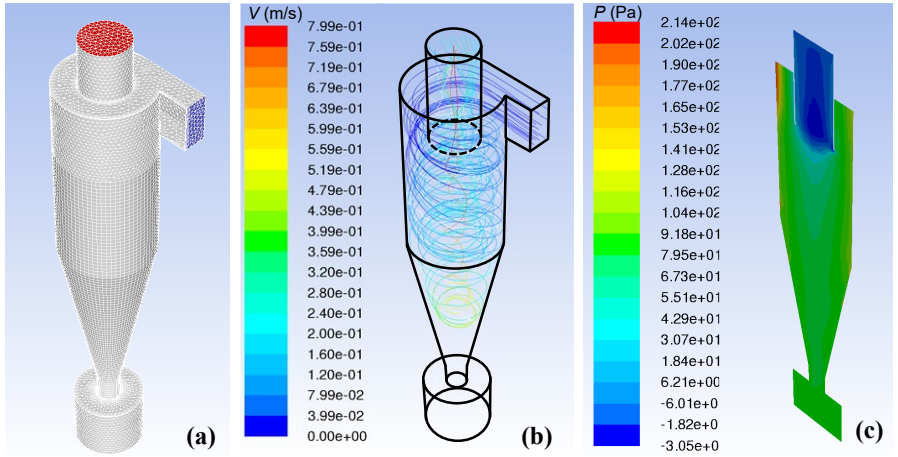
Preliminary Results



Formation of ice crystal at (a) earlier and (b) later stages of the freezing process

Material Identification

Fluid	Boiling point (°C)	Freeze point (°C)	Density at 25°C (kg/m³)	Viscosity at 25 °C (Ns/m²)	Specific heat at 25°C (J/(kg K)
Novec 7000	34	-123	1400	0.45×10^{-3}	1300
Novec 7200	76	-138	1420	0.58×10^{-3}	1214
Novec 7500	128	-142	1614	1.24×10^{-3}	1100



CFD results for liquid-gas separation using a conical cyclone;
(a) computational mesh, (b) velocity streamlines, and (c) pressure contour at the middle plane.

Market Research

- Oil and Gas Industry
  - Produced water disposal
  - Reuse of treated water
- Agricultural Sector
  - Irrigation
  - Livestock
- Power Sector
  - Use the treated water for power plant cooling
- Reverse Osmosis Plants
  - Disposal of the rejected bribe

Thank You