GE Global Research

Water Desalination Using Multi-Phase Turbo-Expander

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Project Description

This brine freeze desalination process is based on brine cooling by expansion of a compressed gas/brine stream in a turbo-expander. Ice crystals, formed after water in brine freezes and are separated from salt crystals and the remaining brine, consist of pure water.

The most promising application of the technology is treatment of high salinity water. Project goal is to achieve at least 20% reduction in cost of water treatment in comparison with thermal crystallizer.

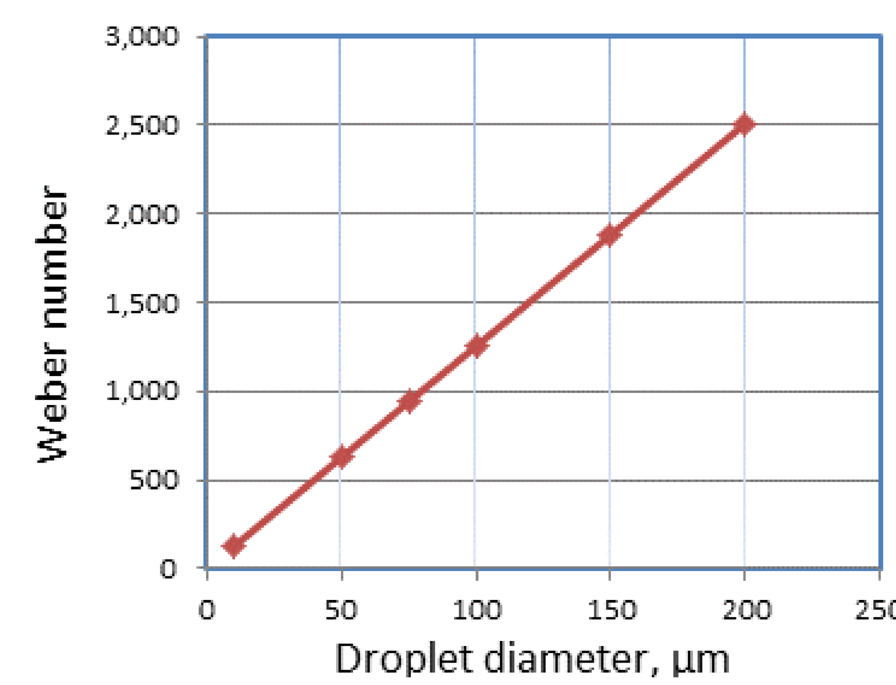
Approach

The 2015 project addresses one of the two major technology risks: ability to freeze brine droplets within limited time available in the turbo-expander. Project activities include heat transfer analysis to estimate optimal brine droplet sizes and conceptual process design to estimate energy requirements and cost of water treatment.

Accomplishments

- Heat transfer analysis suggests that water droplets with diameters up to 200 μm breakup to ~10 μm size when injected with 90% velocity slip (10% of surrounding gas velocity).
- Estimated freeze time of 10 μm droplets is < 10 ms.
- The NaCl properties in Aspen Plus are being modified to match water/NaCl phase diagram.

Heat Transfer Analysis

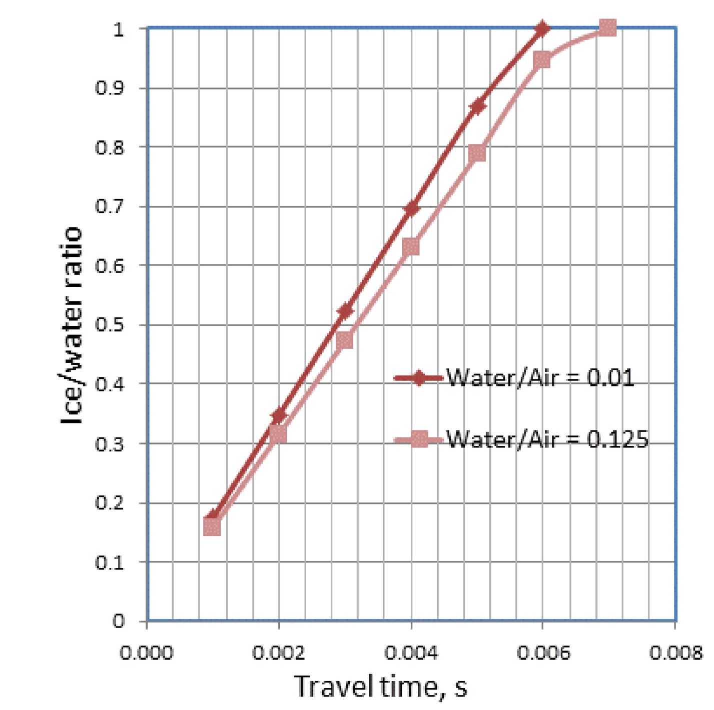


We number for water droplets

The analysis was conducted using ANSYS CFX. The water droplets were injected at 0^0C and slip velocity of 90%. Stability of water droplets can be characterized by We number:

$$We = \frac{\text{Droplet kinetic energy}}{\text{Droplet surface energy}}$$

Analysis of droplets with diameters up to 200 μm has shown that droplets with We number larger 12 are unstable when injected with 90% velocity slip and breakup until droplet size is reduced to ~10 μm

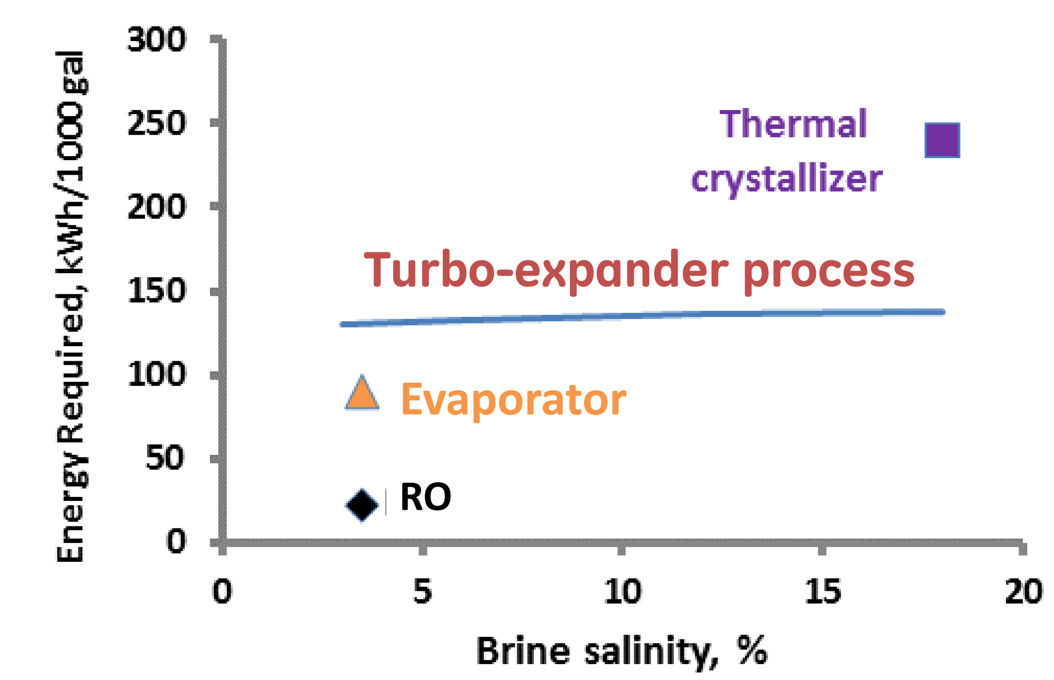


The 10 μm droplet freeze-time

Energy Requirements

A process model was created in Hysys to estimate process energy requirements. Since Hysys does not properly predict formation of solids, additional thermodynamic analysis was performed outside of Hysys to account for water fusion and salt crystallization enthalpies.

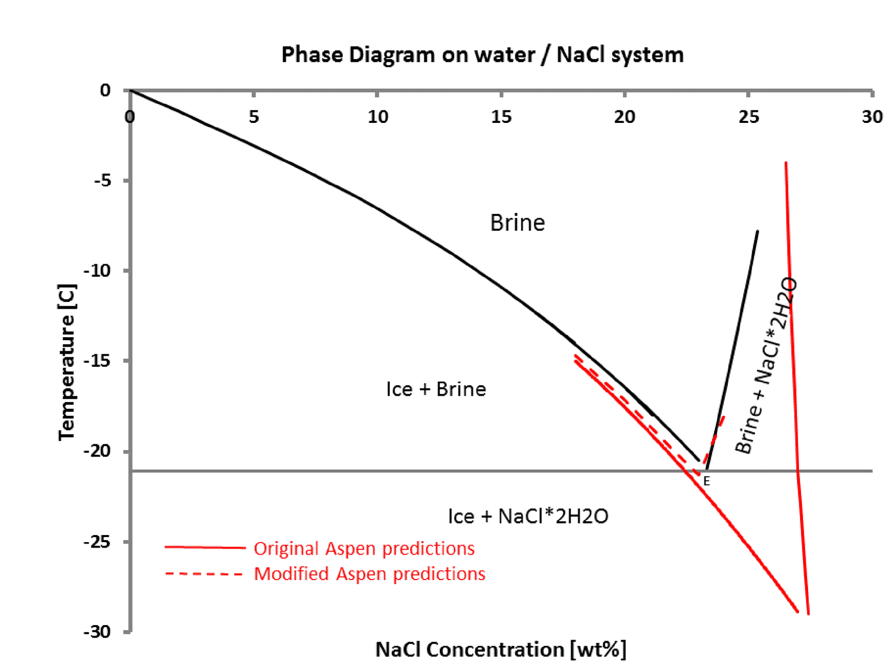
Predicted process energy consumption for 100% water recovery is ~45% less than that for thermal crystallizer and shows little dependence on brine salinity. Ideal application for the technology is treatment of high salinity water.



Process energy requirements

Aspen Model

Transition from Hysys to Aspen Plus was initiated to develop a self-contained process model. Thermodynamic properties package electrolyte NRTL was used in the modeling. It was found that behavior of water/NaCl phase diagram was not predicted properly: eutectic temperature of -29^0C was predicted instead of -21^0C. Activities coefficients in the thermodynamic package have been modified to match eutectic conditions.



Predicted by Aspen Water/ NaCl phase diagram