Freezing Seawater with CO_2: A Path to Energy-Efficient Desalination

Infinity Turbine LLC

[TEL] +1-608-238-6001 (Chicago

[Email] greg@infinityturbine.com

https://www.infinityturbine.com/cavgenx-co2-saltwater-ice-desalination.html

Learn how a CO_2 refrigeration cycle can freeze seawater to separate fresh water from salt using ice crystallization and brine rejection.

This webpage QR code

PDF Version of the webpage (maximum 10 pages)

Freezing Seawater for Desalination using CO2 and Solar Thermal or Data Center Waste Heat

Freezing seawater to make fresh water is a natural process that can be harnessed with a CO_2 closed-loop refrigeration system. By forming nearly salt-free ice and separating it from brine, this process provides a low-temperature route to desalination.

Freezing Seawater with CO_2: A Path to Energy-Efficient Desalination

Introduction

Desalination is typically associated with energy-intensive processes like reverse osmosis or multi-stage flash distillation. An alternative approach is freeze desalination, which takes advantage of the natural tendency of ice crystals to exclude salt as seawater freezes. By using a closed-loop CO_2 refrigeration cycle, this process can freeze seawater, separate fresh ice, and produce potable water with minimal thermal stress and potentially high efficiency.

How CO_2 Freeze Desalination Works

1. CO_2 Refrigeration Loop:
   A closed loop of CO_2 serves as the working fluid. It is first cooled and condensed in a heat exchanger, then pressurized by a pump (subcritical) or compressor (transcritical).

2. Expansion and Cooling:
   The pressurized CO_2 is expanded, producing a low-temperature stream that provides the cooling duty for a seawater crystallizer.

3. Ice Formation:
   Seawater exposed to temperatures around –2 to –5 °C begins to freeze. The forming ice crystals naturally reject salt, leaving behind a concentrated brine solution.

4. Separation and Washing:
   The ice slurry is sent to a separator where the brine is drained off. A small amount of fresh melt water is used to wash the ice, ensuring minimal salt contamination.

5. Fresh Water Recovery:
   Washed ice is melted to produce fresh water, while concentrated brine is discharged.

Advantages of Freeze Desalination with CO_2

Intrinsic Salt Rejection: Ice crystals contain minimal salt, simplifying the desalination process.
Lower Scaling Risk: Operating below 0 °C reduces the tendency for mineral scale formation.
Natural Refrigerant: CO_2 is non-flammable and has negligible global warming potential compared to synthetic refrigerants.
Energy Efficiency Potential: Using a liquid CO_2 pump in subcritical mode can reduce power consumption versus conventional compression.

Key Design Considerations

Crystallizer Type: Scraped-surface or suspension crystallizers help maintain ice mobility and control crystal size.

Freezing Seawater with CO_2: A Path to Energy-Efficient Desalination

Introduction

Desalination is typically associated with energy-intensive processes like reverse osmosis or multi-stage flash distillation. An alternative approach is freeze desalination, which takes advantage of the natural tendency of ice crystals to exclude salt as seawater freezes. By using a closed-loop CO_2 refrigeration cycle, this process can freeze seawater, separate fresh ice, and produce potable water with minimal thermal stress and potentially high efficiency.

How CO_2 Freeze Desalination Works

1. CO_2 Refrigeration Loop:
   A closed loop of CO_2 serves as the working fluid. It is first cooled and condensed in a heat exchanger, then pressurized by a pump (subcritical) or compressor (transcritical).

2. Expansion and Cooling:
   The pressurized CO_2 is expanded, producing a low-temperature stream that provides the cooling duty for a seawater crystallizer.

3. Ice Formation:
   Seawater exposed to temperatures around –2 to –5 °C begins to freeze. The forming ice crystals naturally reject salt, leaving behind a concentrated brine solution.

4. Separation and Washing:
   The ice slurry is sent to a separator where the brine is drained off. A small amount of fresh melt water is used to wash the ice, ensuring minimal salt contamination.

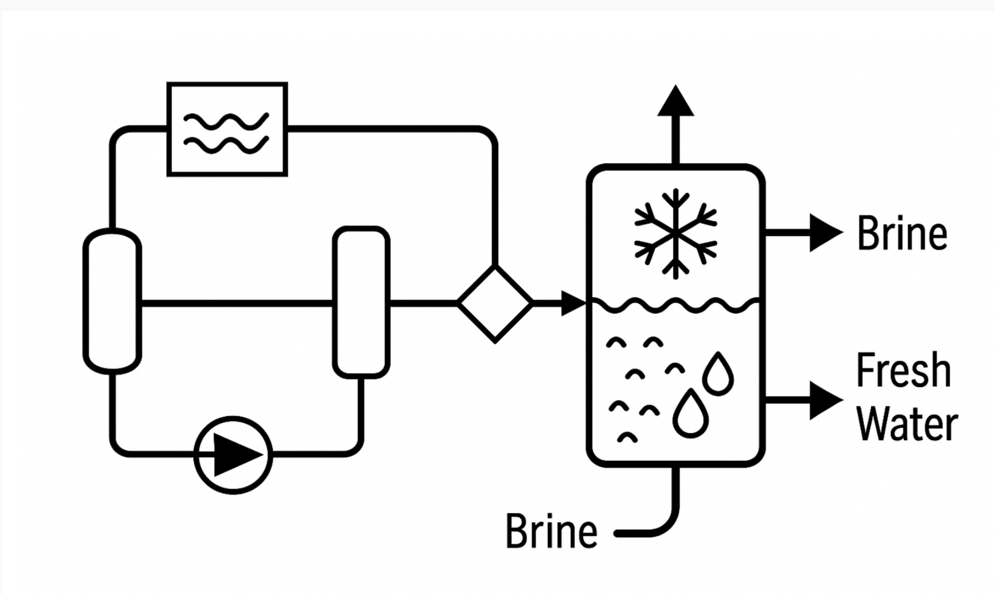
5. Fresh Water Recovery:
   Washed ice is melted to produce fresh water, while concentrated brine is discharged.

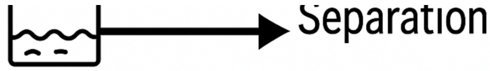
Advantages of Freeze Desalination with CO_2

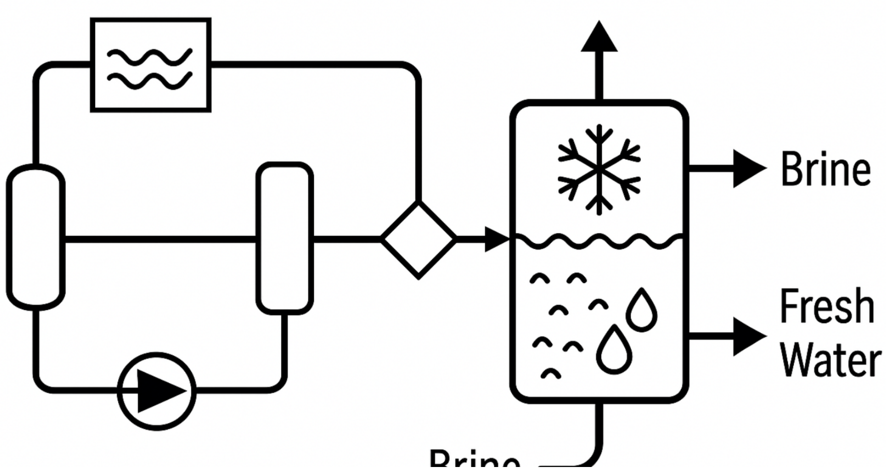
Intrinsic Salt Rejection: Ice crystals contain minimal salt, simplifying the desalination process.
Lower Scaling Risk: Operating below 0 °C reduces the tendency for mineral scale formation.
Natural Refrigerant: CO_2 is non-flammable and has negligible global warming potential compared to synthetic refrigerants.
Energy Efficiency Potential: Using a liquid CO_2 pump in subcritical mode can reduce power consumption versus conventional compression.

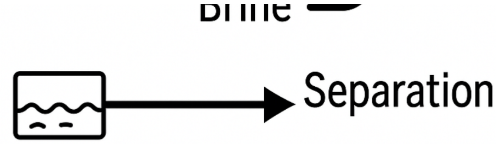
Key Design Considerations

Crystallizer Type: Scraped-surface or suspension crystallizers help maintain ice mobility and control crystal size.
Avoiding Dry Ice: Maintain CO_2 suction pressure above 5.2 bar to prevent solid CO_2 formation.




Separation


Brine
Fresh
Water


Separation