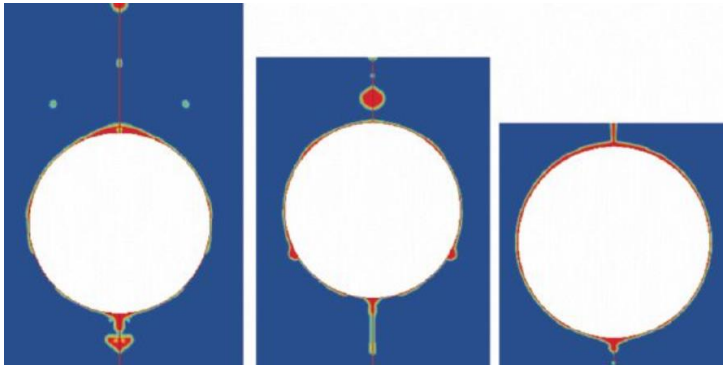
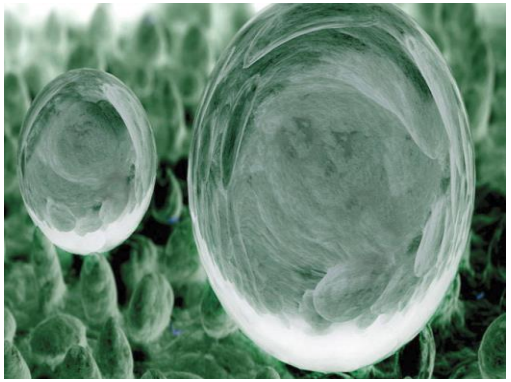
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Ultra-compact and efficient heat exchanger for solar desalination with unprecedented scaling resistance





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Project Summary

Timeline:

Start date: October 2018

Planned end date: October 2021

Key Milestones

1. Development of an heat exchanger with 150% higher performance. (October 2019)
2. Development of an anti-scaling technology (2X reduction in down-time (October 2020)

Project activities:

- Thermal-hydraulic performance evaluation: Numerical analysis and experimental validation of single-phase and two-phase flows in falling-film evaporators
- Material development: Enhanced thermal conductivity, strength, and wetting behavior
- Manufacturing process development: Cost effective and scalable manufacturing for improved durability
- Development of anti-fouling characteristics: Surface energy gradients to mitigate scaling

Key Partners:

University of Illinois at Urban Champaign	Oak Ridge National Laboratory
Isotherm Inc.	

Project Team

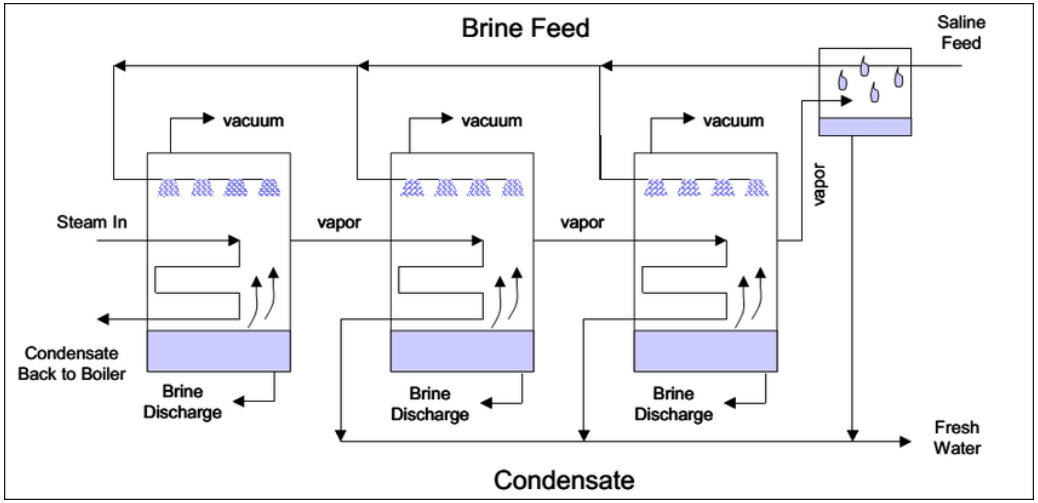
- **University of Illinois at Urbana Champaign**
  - Anthony Jacobi (Professor)
  - Xiaofei Wang (Asst. Professor)
- **Oak Ridge National Laboratory**
  - Kashif Nawaz (R&D staff)
  - Matthew Sandlin (Post-Doc associate)
- **Isotherm Inc.**
  - Zahid Ayub (Research Director)
  - Adnan Ayub (President)



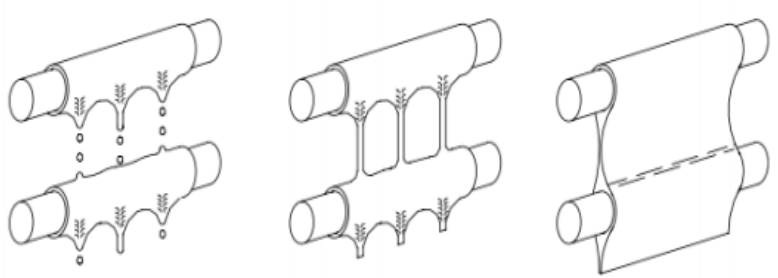



Background

- Heat Exchangers are critical part of thermal desalination systems.
- Falling film evaporators are often deployed in systems deploying multi effect desalination (MED).
- Falling film behavior dictates the performance of the device which directly impacts the efficiency of overall system
- Crystallization fouling and corrosion fouling on tubes in falling film evaporator is a major challenge.
- Tubing materials such as copper-nickel (90/10), aluminum brass, titanium and aluminum alloy 5052 are expensive yet required.



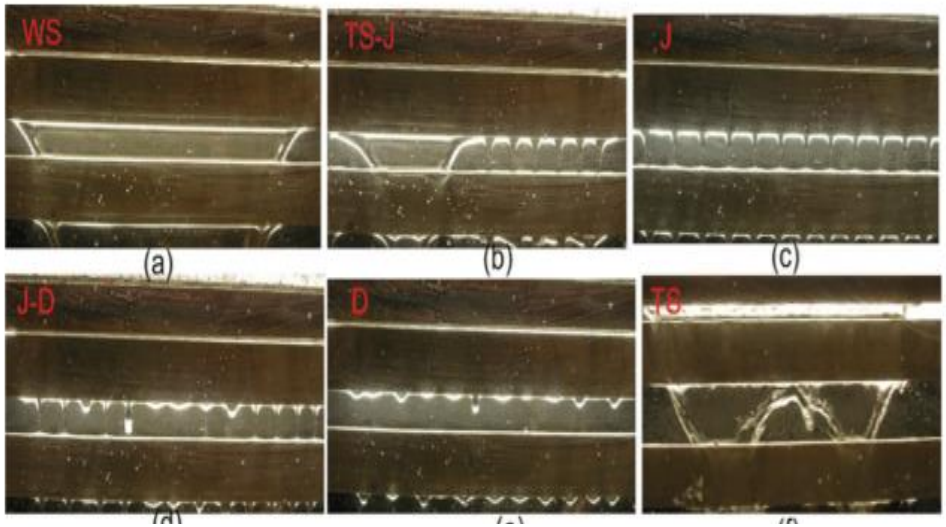
Multi Effect Desalination (MED) process



Various modes of falling film evaporator are critical to analyze the performance

Solution Approach

- Tube geometry and tube bundle optimization can lead to the desired falling film mode for improved evaporation process.
- Anti-scaling surfaces can reduce the maintenance requirements. However a more scalable and durable solution is desired.
- Additive manufacturing process has made it possible to develop materials and structural with unprecedented performance and complexity.



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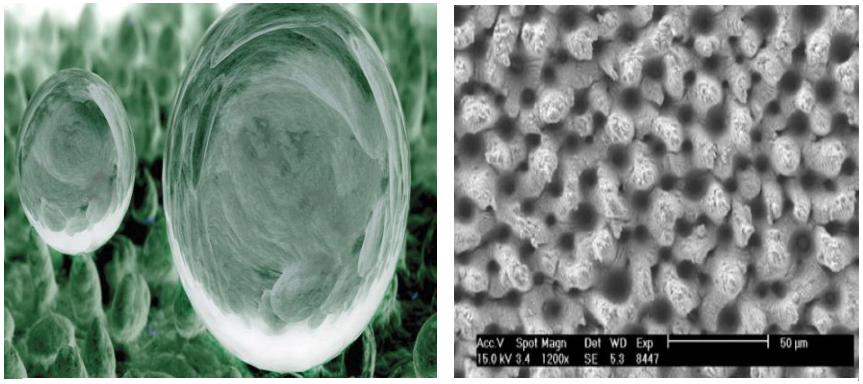


Bio-inspired anti-scaling technology

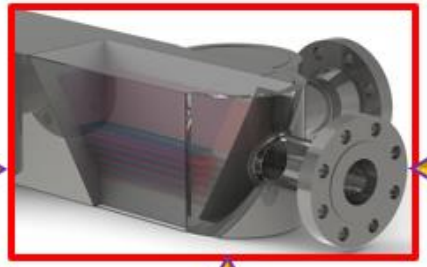
Solution Approach

Phase 0
Feasibility analysis

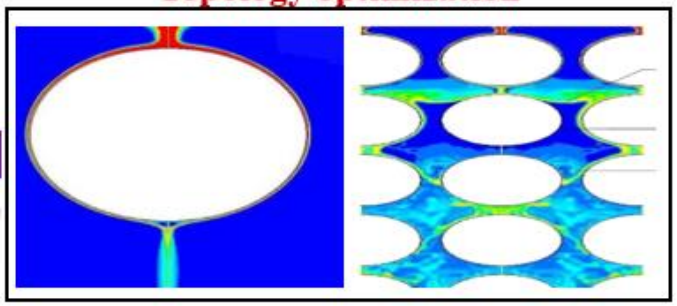
Phase 1
Pre-Commercialization

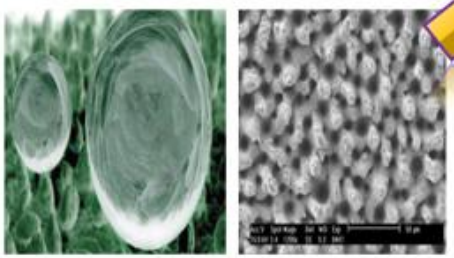
Phase 2
Commercialization

Techno-economic analysis

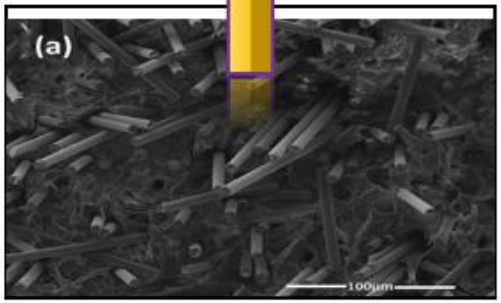


Topology optimization

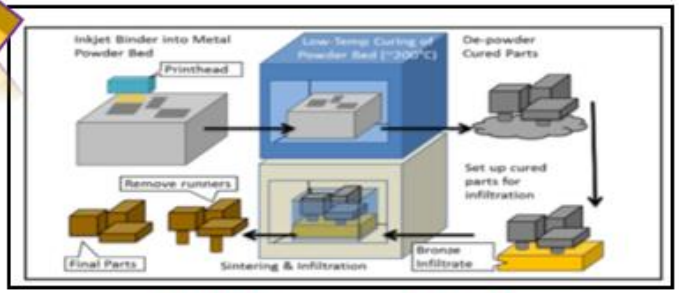




Anti-scaling surface morphology



Material Selection and characterization

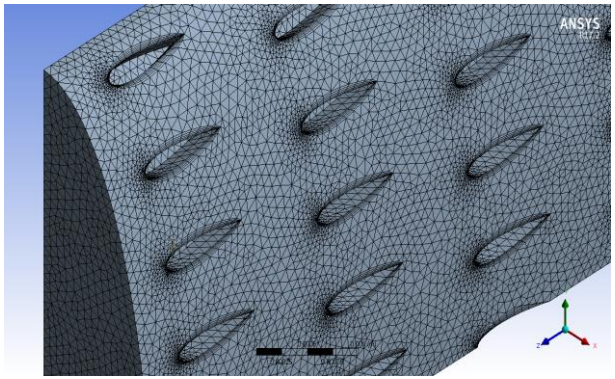


Additive manufacturing

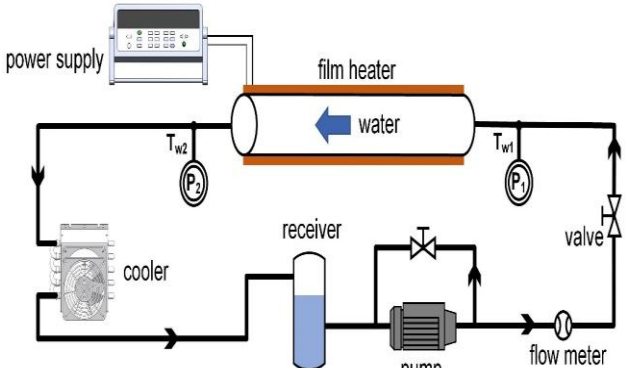
Progress

- Literature review of the state-of-the-art (falling films, materials etc.)
- Thermal-hydraulic analysis of enhanced tubes.
- Evaporation/boiling on super-hydrophobic surfaces
- Preliminary sample preparation using fused deposition process (polymer composite)
- Apparatus for thermal-hydraulic evaluation.

Droplet-Jet mode for falling film evaporator



Numerical model for enhanced tube



Experimental apparatus for tube performance evaluation

Stakeholder Engagement

- **Development of the technology**
  - Discussion on practical implications of technology
  - Durability and Scalability
  - Techno-economic analysis
  - Identification of interested stakeholders
- **Meetings with experts at technical platform**
  - ASHRAE (TC 8.4)
  - ASME (IMECE, SHTC)
  - Purdue, Gordon Research Conference
- **Presentations/Conference papers**
  - Multiple conference papers are planning during 2019/2020
  - Potential journal publication

Design, demonstrate and analyze the performance of a ultra-compact heat exchanger that 150% improvement in UA/volume, a reduction by a factor of 5-10 in $/UA, and remarkable scaling resistance.

Thank You

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