Miniaturization of Heat-Actuated Cooling Using Microchannels

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MICROPRODUCTS BREAKTHROUGH INSTITUTE
OREGON STATE UNIVERSITY
Pacific Northwest National Laboratory

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Security Applications
Personnel Cooling

- Nuclear, biological, and chemical (NBC) protective clothing
- First responders
- Bomb disposal units

Man-Portable Cooling
A technology need with no solution!

"I have read the article on the portable air conditioning unit for chemical suits in June's issue of Popular Science [sic]... My name is Bill Nelson and I am a US Army soldier deployed to Iraq. This is a good technology to develop... For current use, the main areas of heat is the body armor and the kevlar helmet. This would be a more useful and demanded product than for the chemical suit. If you need any testing I would be excited to field test anything you may have. I would appreciate any information you can provide. Thank you in advance." -- Bill Nelson

"I read about a heat exchanger that the military may be using for bio-chemical suits, to help with cooling inside the suits for extended wear. Due to our involvement in the Homeland Security, and first response to events, I would like to find out more about this product and if it is available for local government use."

-- Battalion Chief Daniel West, Hazardous Materials Response Team

Security Applications

Shelter

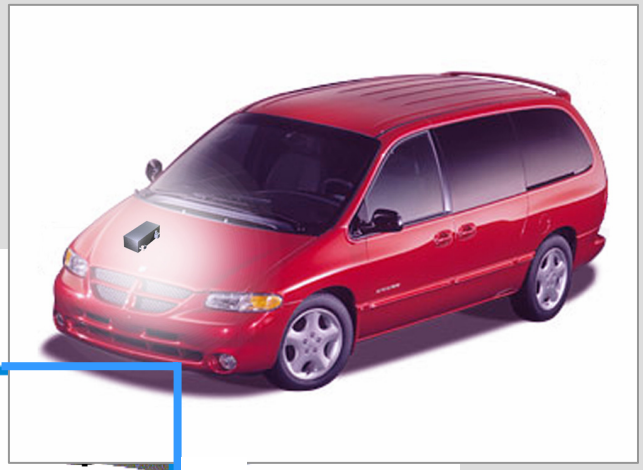
- Mobile command centers
- Habitat cooling

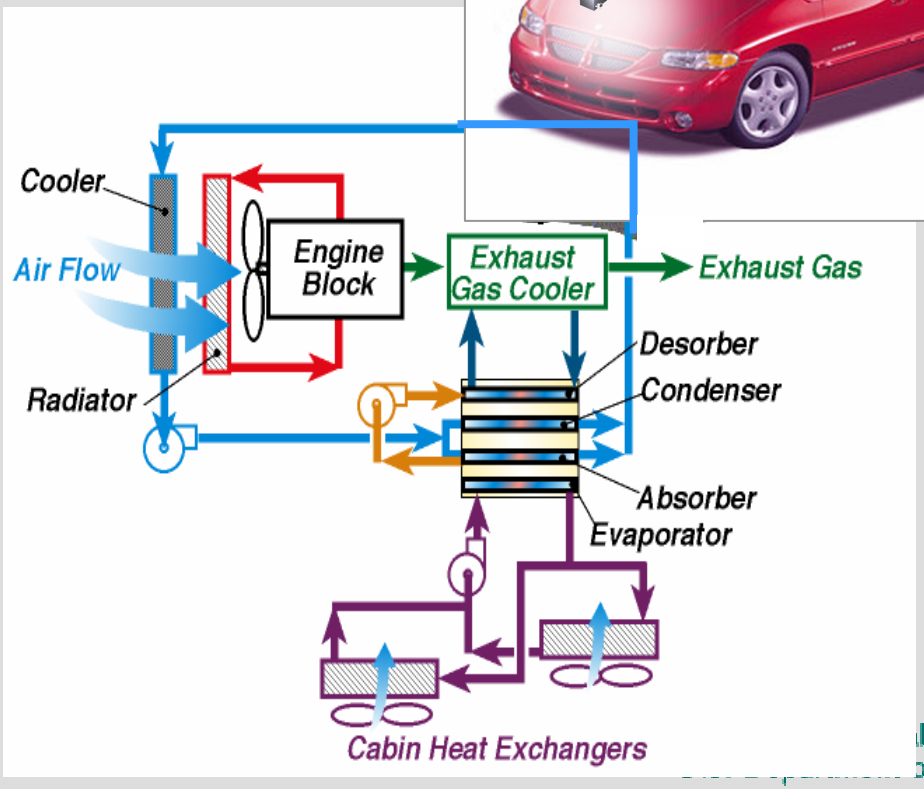
Tactical Shelters

Mobile Kitchens, Tents

Other Applications
Transportation Cooling

- Use of waste heat
- Off-load motive power
- Improved fuel efficiency





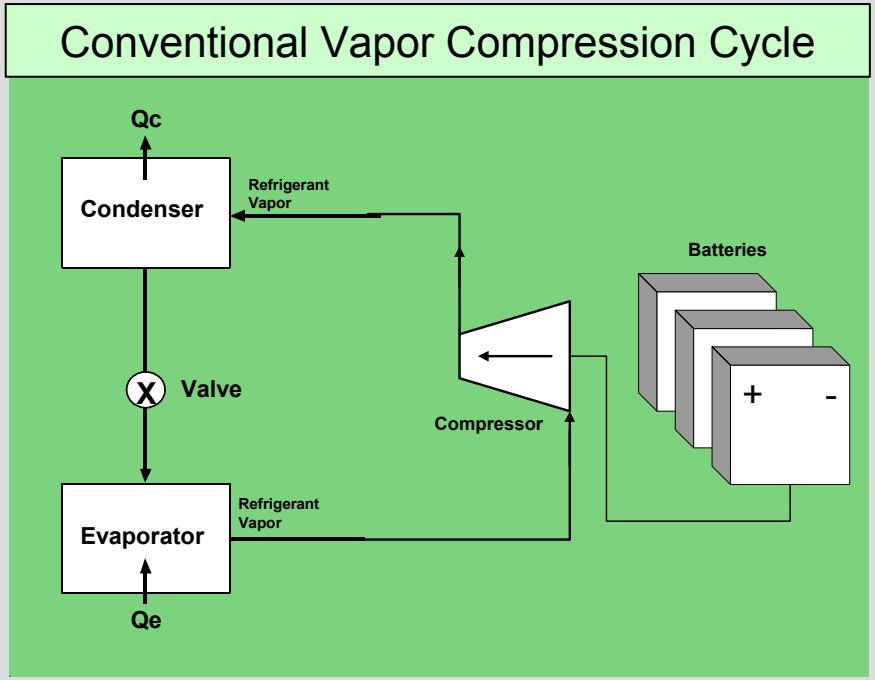
Other Applications
Space Exploration

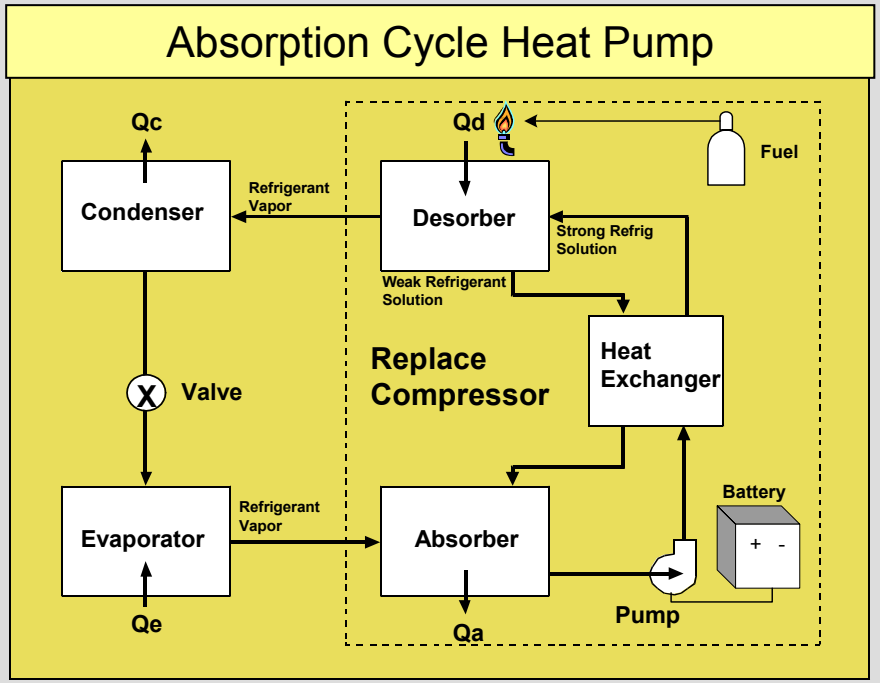
- Closed-loop cooling
  - EVA – displace water sublimation
  - Reduce radiator area
- Integrated heating, cooling, and power

Research Overview

- Heat-actuated cooling
- Microchannel approach
- Wicking absorption
- Breadboard demonstration

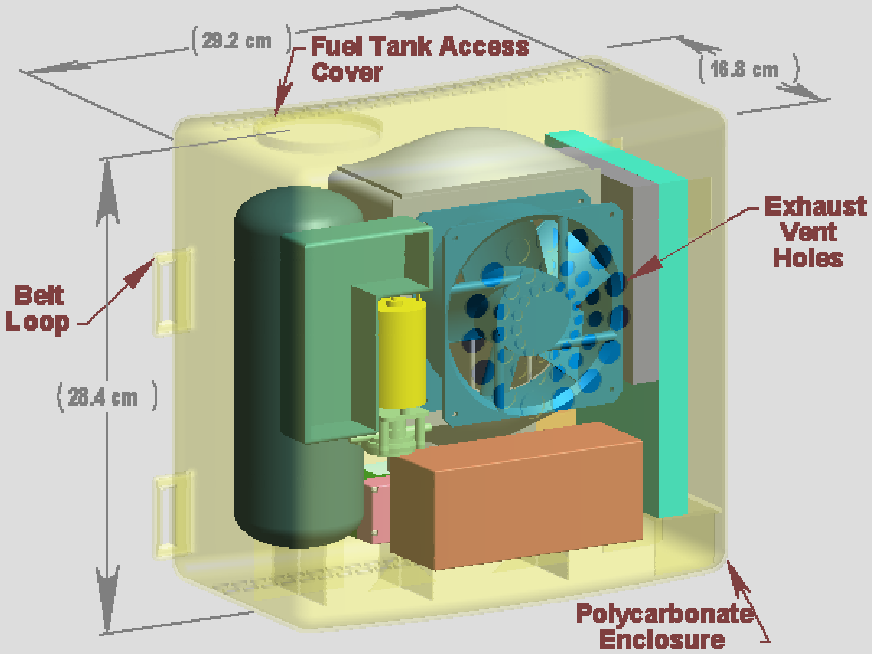
Heat-Actuated Cooling





Heat-Actuated Cooling

"Small" Commercial Absorption Heat Pump
5,000 W of Cooling

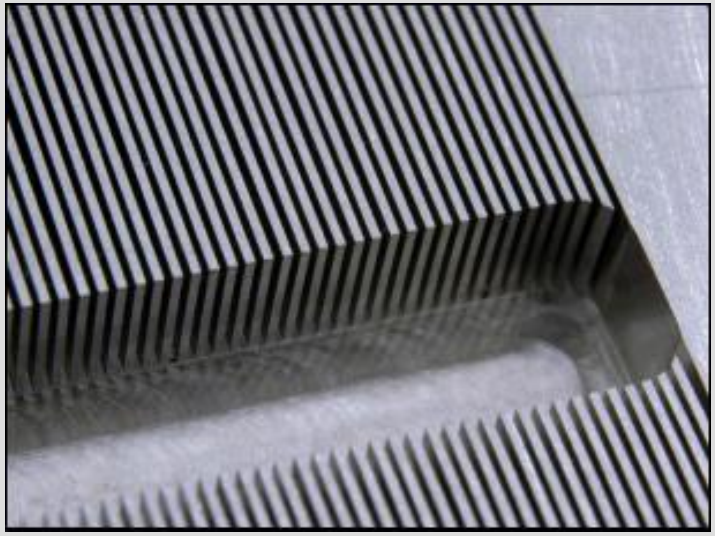


Small Microchannel Absorption Heat Pump
350 W of Cooling

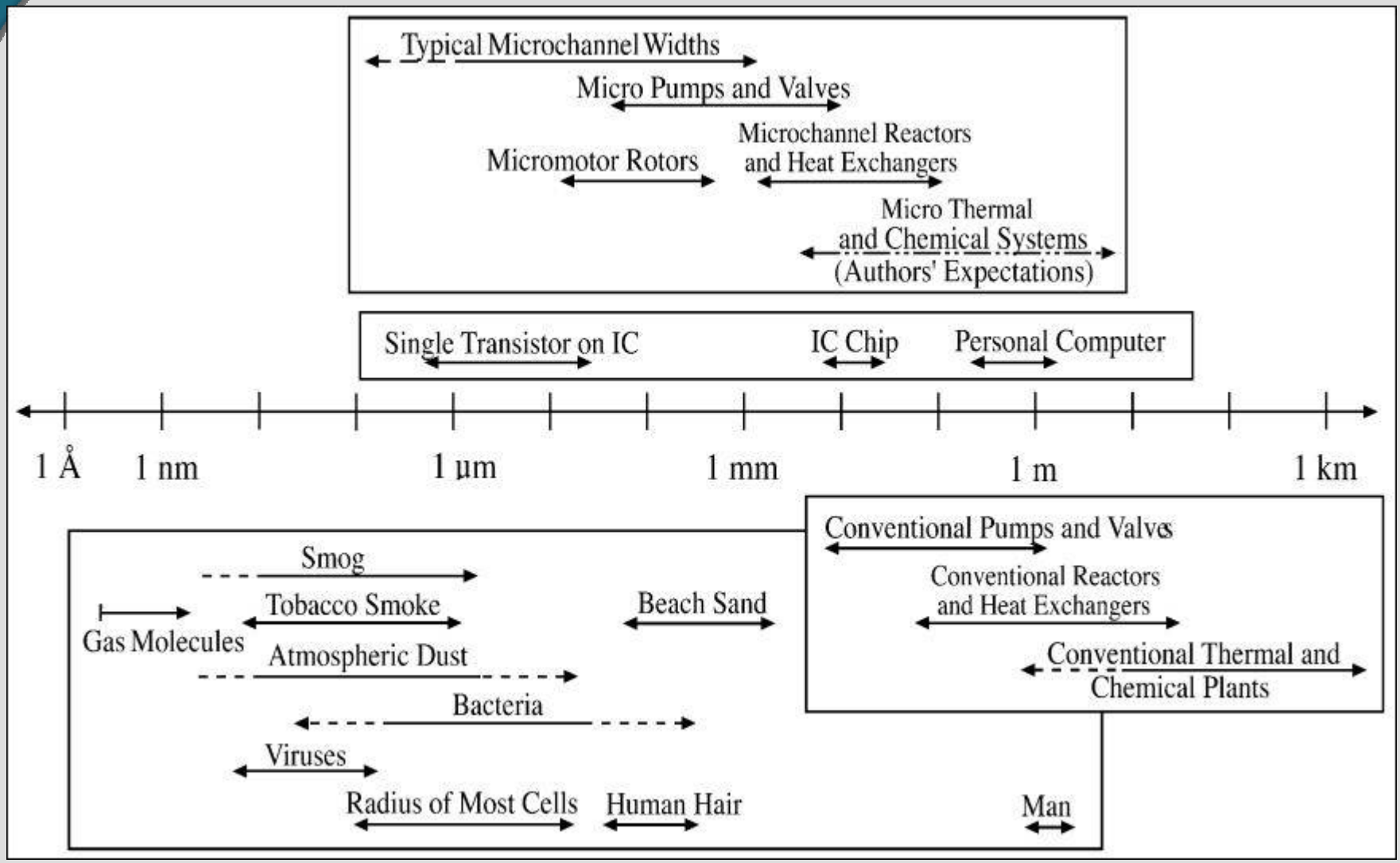
Microtechnology-Based Heat and Mass Transfer

The conventional absorption cycle has not been successful for portable applications because of size and orientation.

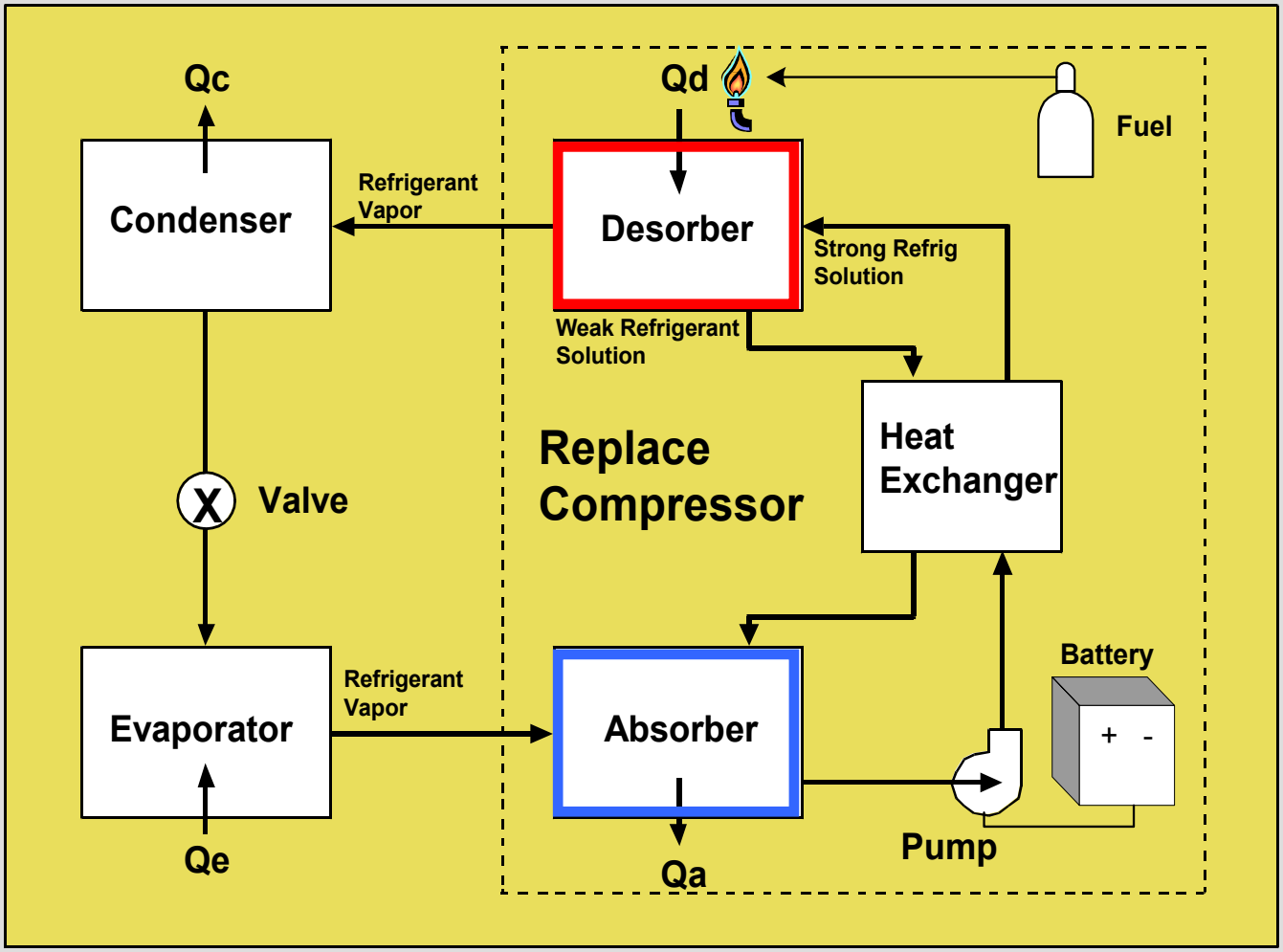
- Solution – Microchannels
  - Reduces the relevant length scales for heat and mass transfer to ~100 μm
  - Decreases required residence time
  - Reduces component size by a factor of 5 to 10 for same capacity
  - Components can operate in any orientation because surface and hydrodynamic forces more important than gravity



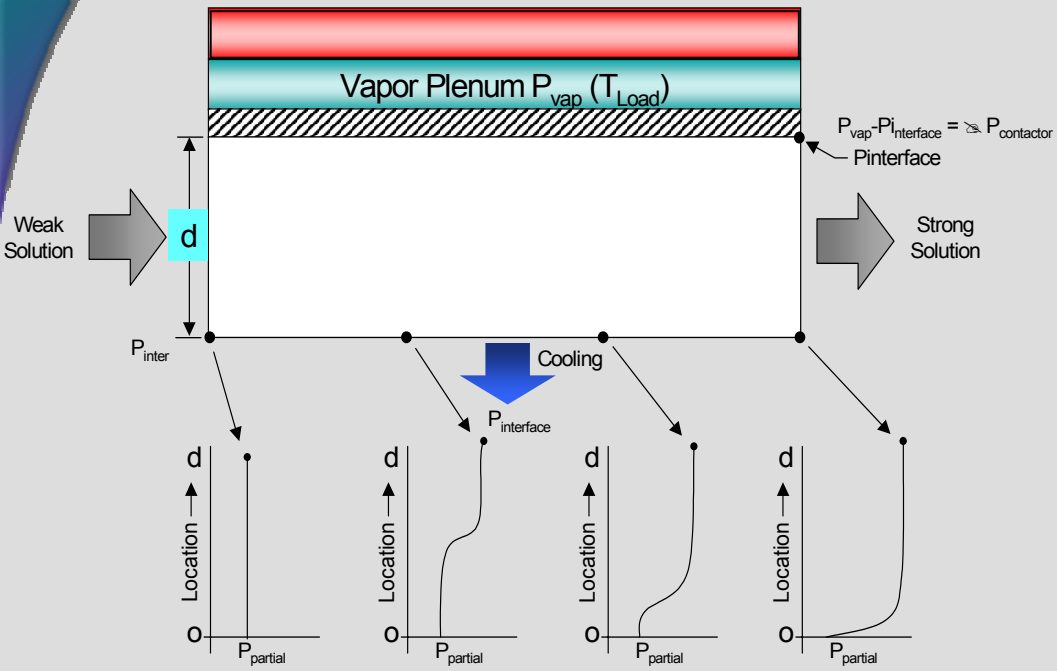
Length-scales

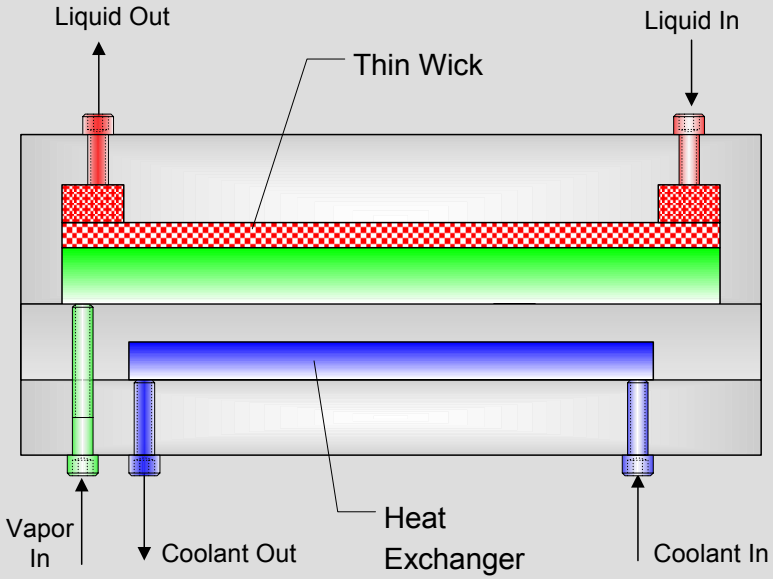


Absorption Cycle Cooling
Challenges

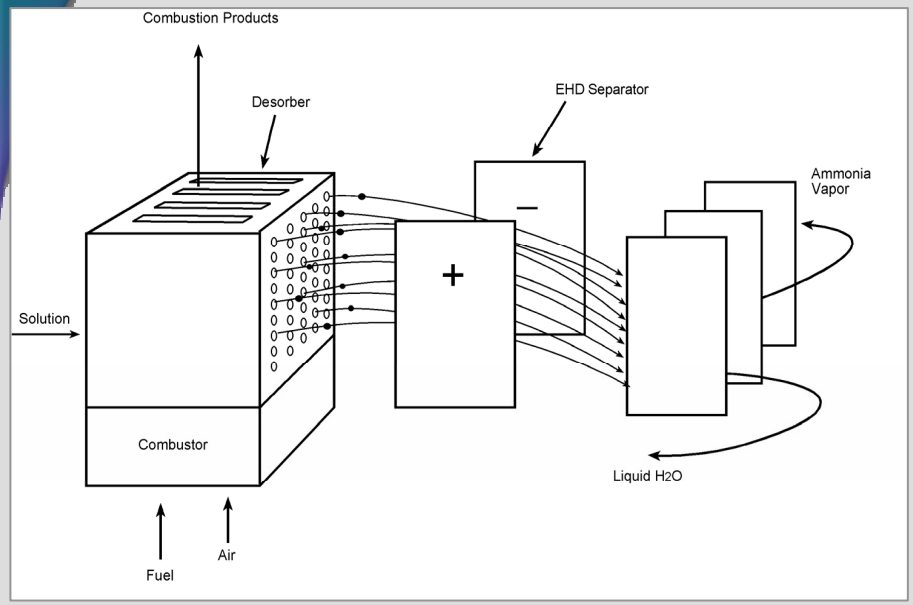


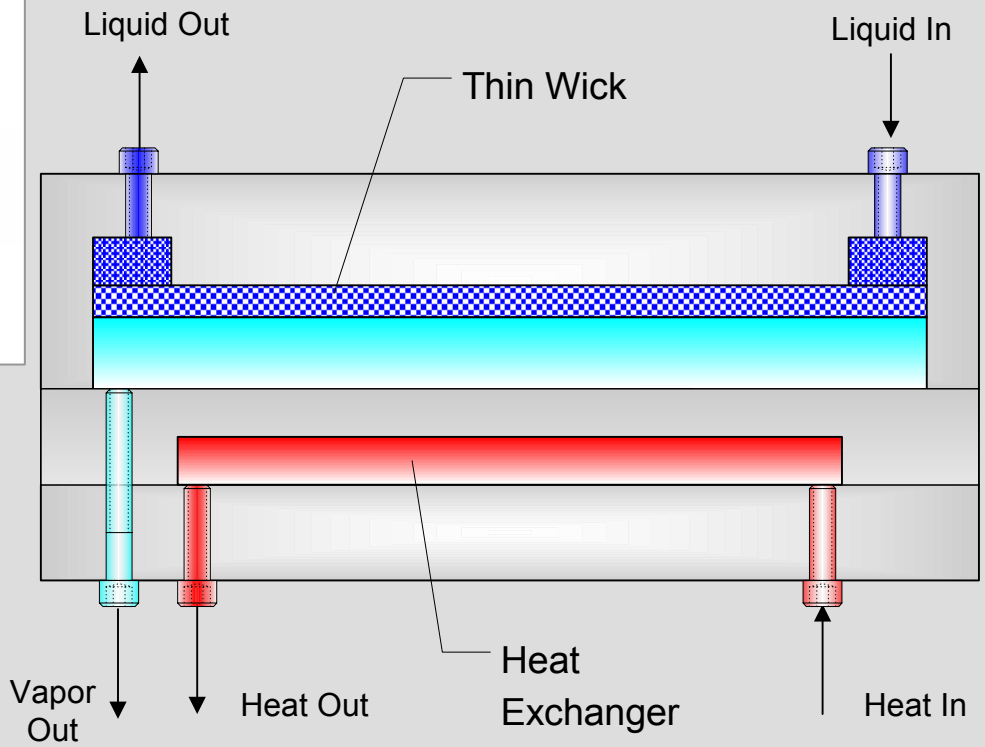
Portable Heat Pumps Absorber Concepts



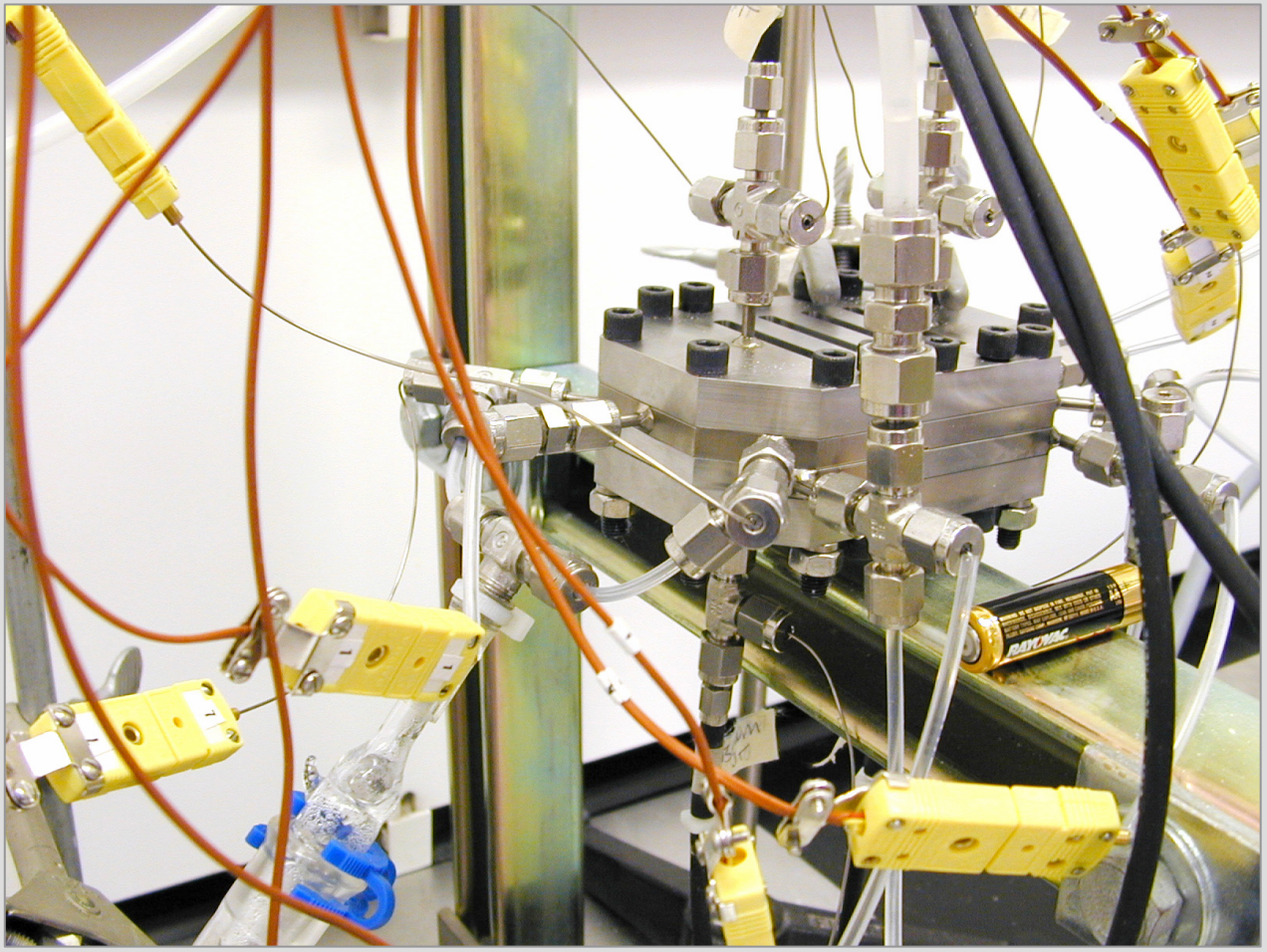


Portable Heat Pumps Desorber Concepts

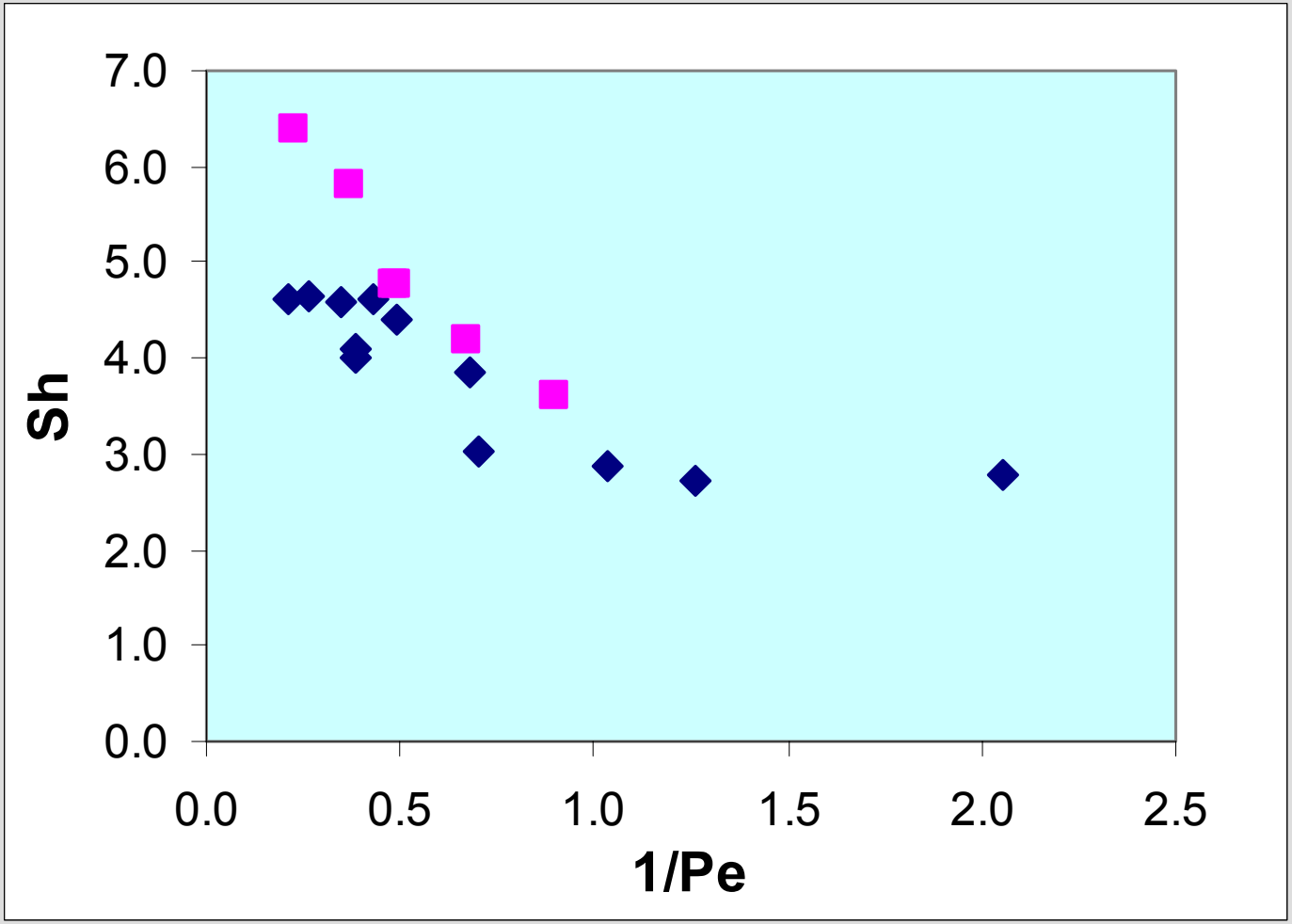




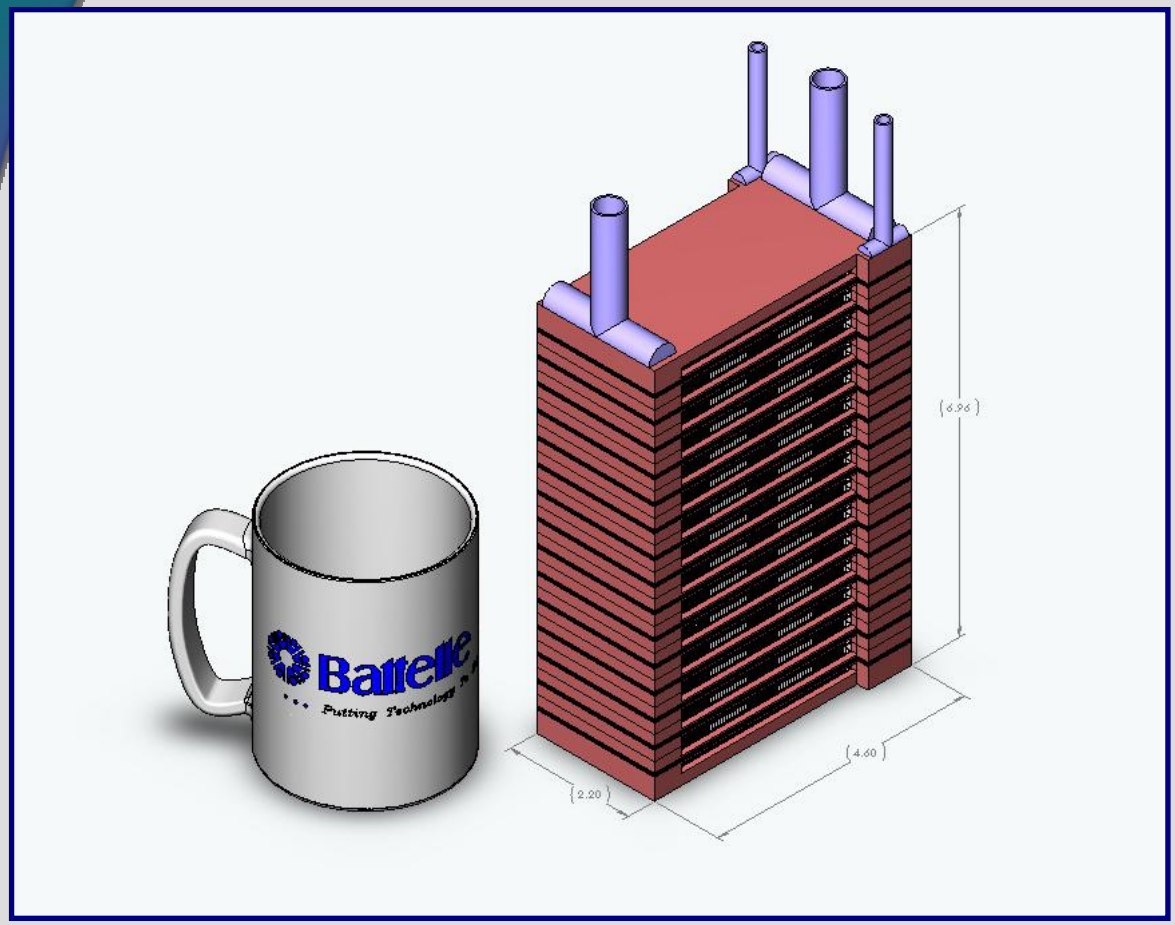
Microwick Mass Transfer Device



Absorption Microwick Mass Transfer

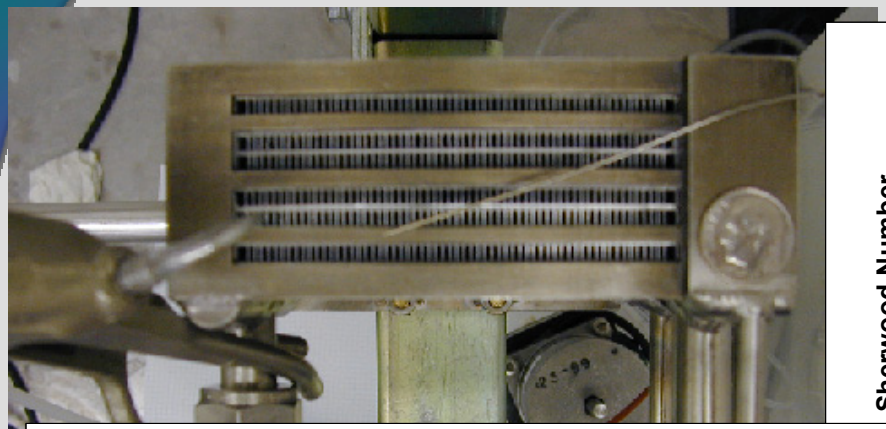


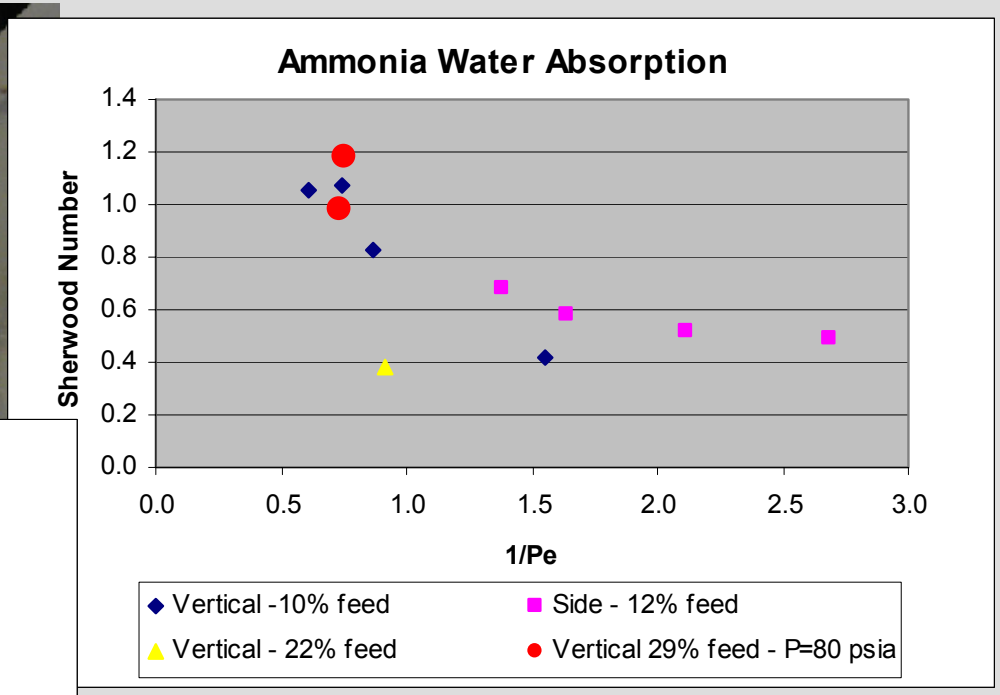
Air-cooled Absorber Design

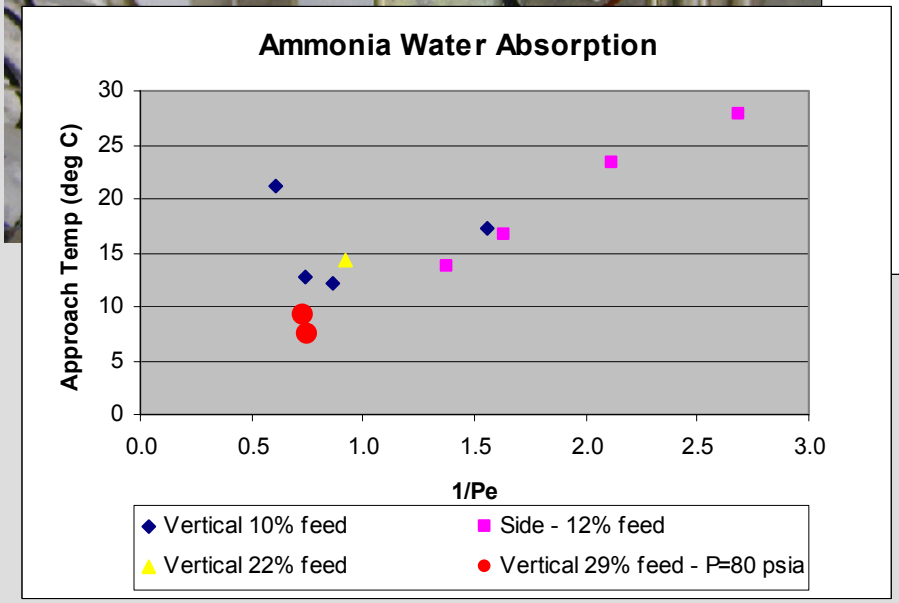


- 250 Watt cooler prototype
  - Possibly 2 needed
  - Total volume = 2.4 L
  - Core volume = 1.3 L
  - Air-cooled by a fan

Multi-channel Absorber Prototype

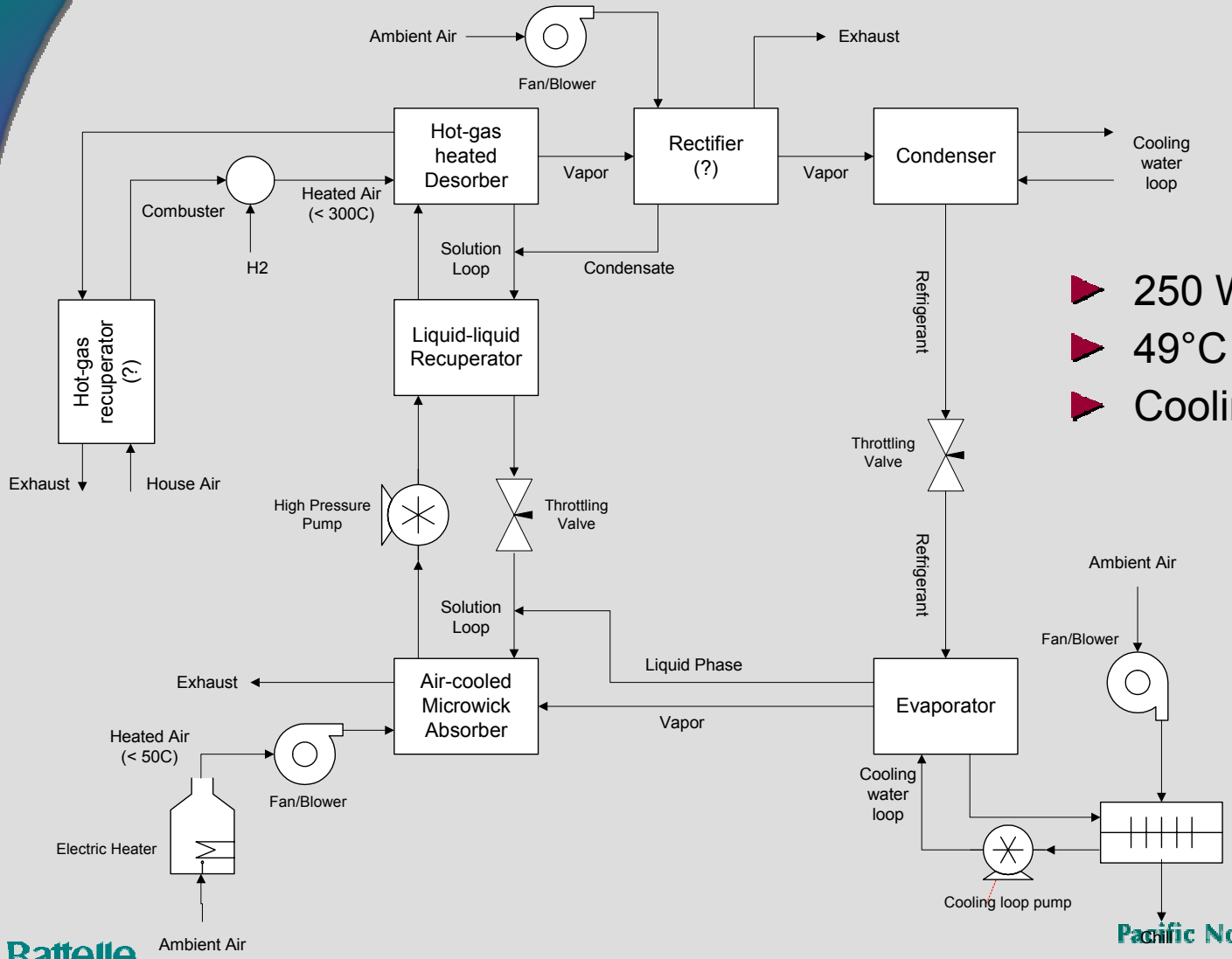






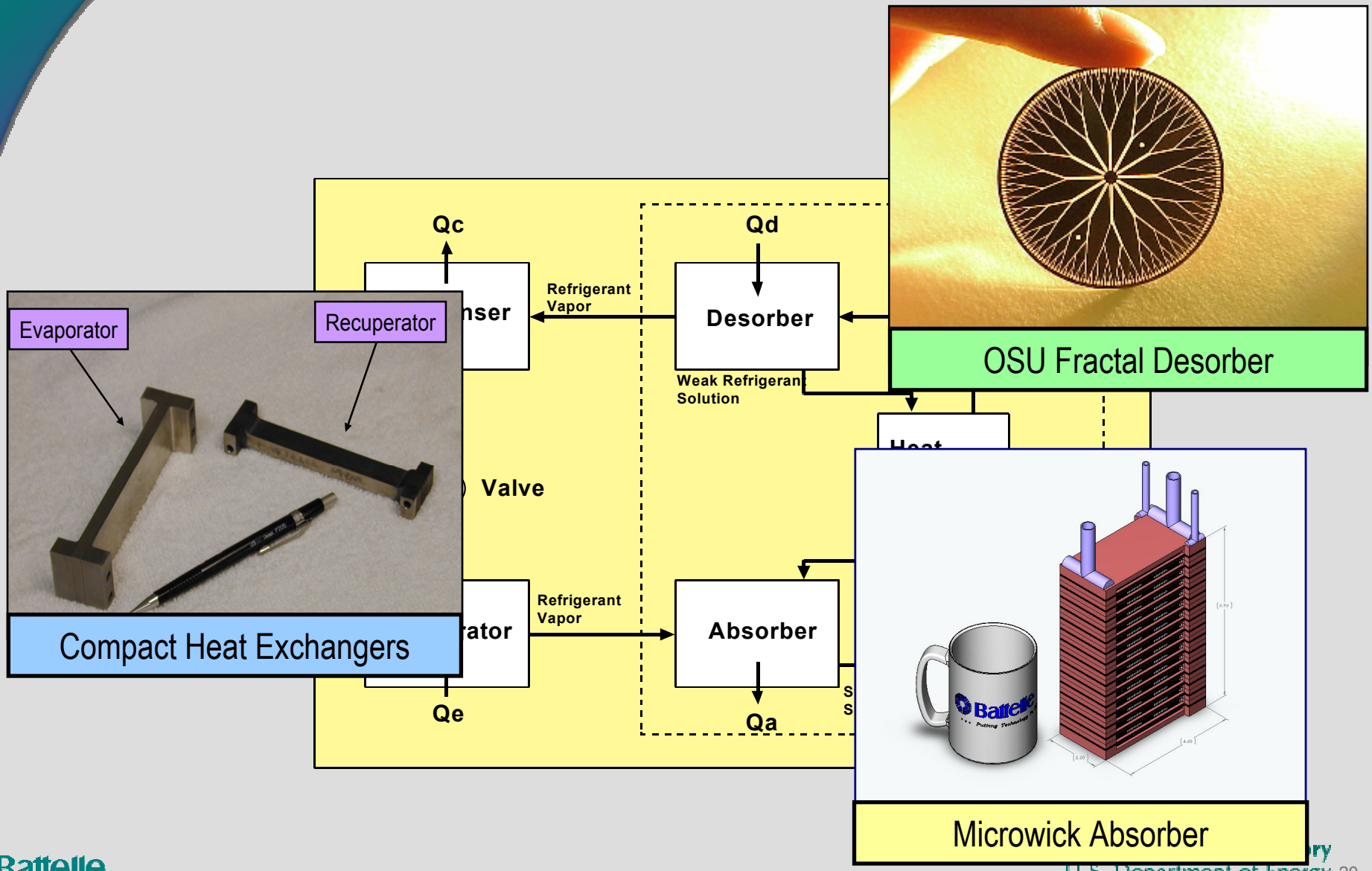
- Refrigerant mass uptake at 80 psia is 2 g/min
- Approx. 1/7th of 250 We scale

Ammonia/Water Breadboard Process Diagram

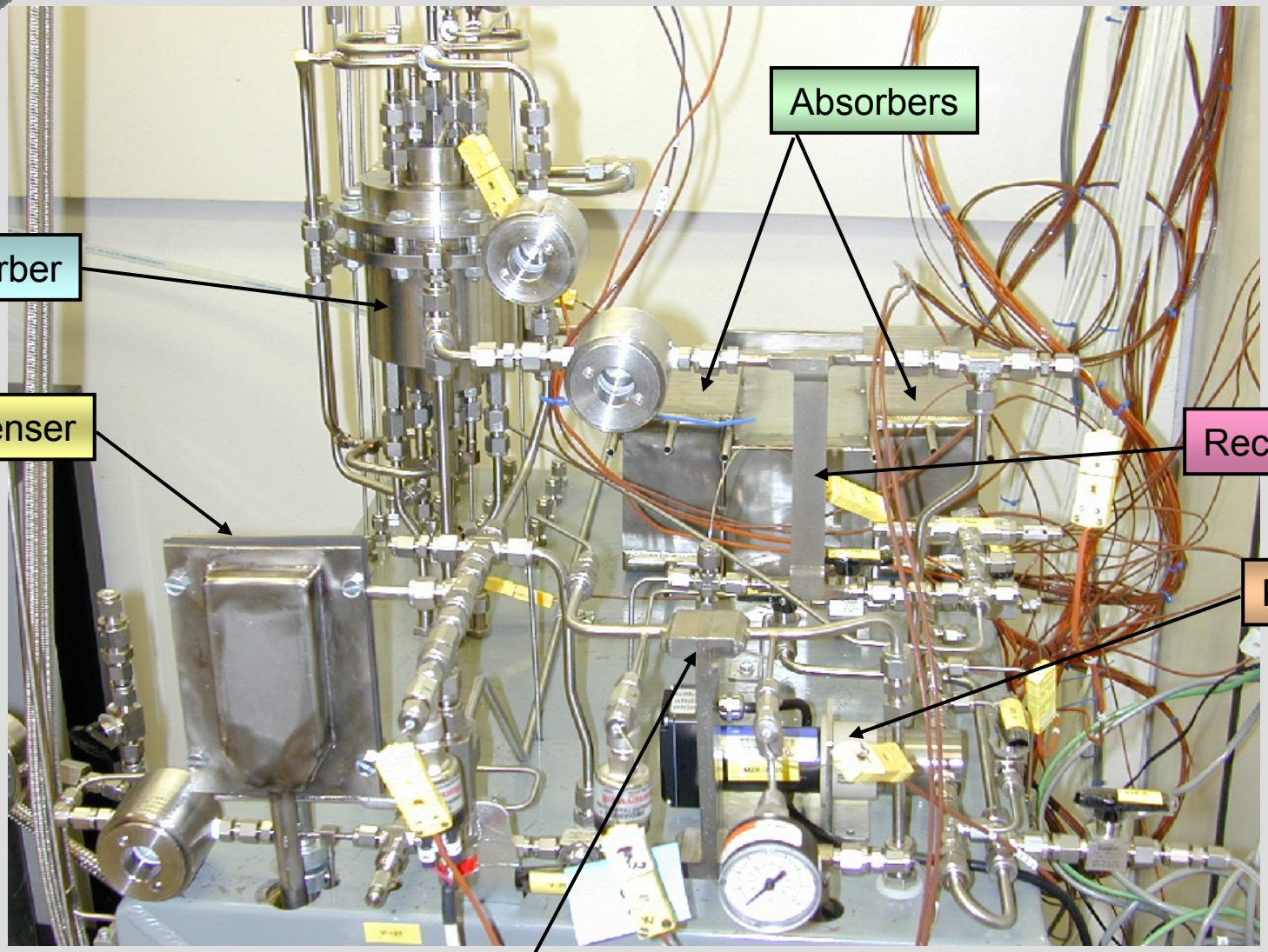


- 250 Watts Cooling Duty
- 49°C Reject Temperature
- Cooling to 10°C

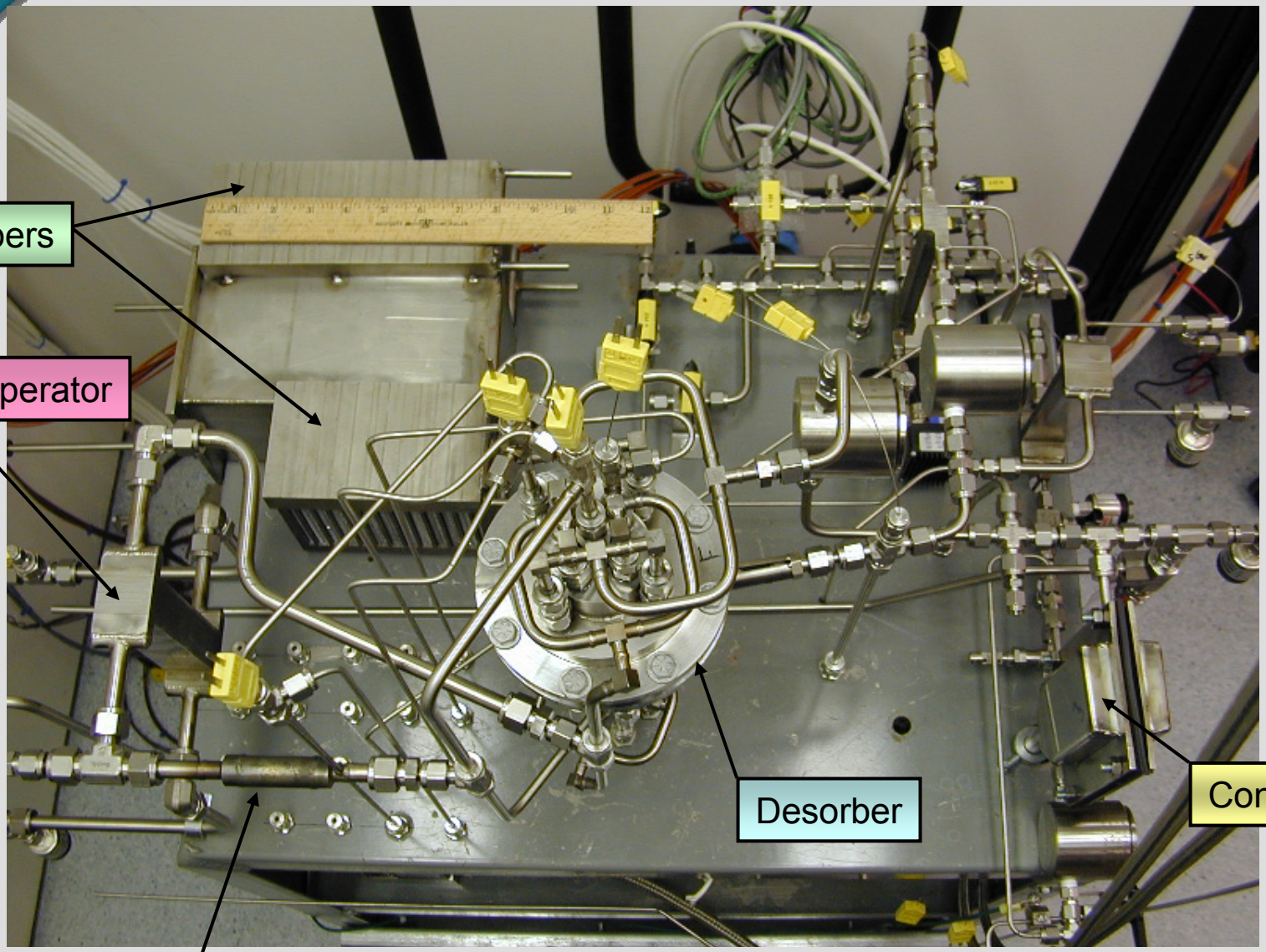
Microchannel Heat-Actuated Heat Pump



Breadboard Assembly



Breadboard Assembly



Conclusions

- ***Breakthrough:***
  - Feasibility demonstrated and characteristic performance data acquired for components critical to heat pump miniaturization.
- ***Status:***
  - A breadboard demonstration of a 250 Watt, integrated system is assembled. Testing is underway.
- ***Future:***
  - Scale-up to portable applications – 2-5 kW cooling
  - Systemization and packaging of prototype systems
  - Further component miniaturization