Highly-Efficient Microemulsion-Based Absorption Chillers For HVAC Application

Performing Organization(s): University of Maryland, College Park
PI Name and Title: Bao Yang, Professor
PI Tel and/or Email: 3014056007, baoyang@umd.edu

Project Summary

Timeline:

Start date: June 1, 2019

Planned end date: May 31, 2022

Key Milestones:

1. Finish the temperature cycling testing of the microemulsion and estimate the expected life of the microemulsion; September 30, 2019.
2. Demonstrate the absorption chiller with a cooling capacity of 400 W and COP of 1.8; December, 2020.
3. Develop collaboration with interested companies for commercialization; May 31, 2022.

Budget:

Total Project $ to Date:

- DOE: $353,135
- Cost Share: $92,428

Total Project $:

- DOE: $640,000
- Cost Share: $160,000

Key Partners:

University of Maryland, College Park

Project Outcome:

- This project will advance the understanding of the area of adsorption and/or absorption cooling technology and its application in HVAC applications.
- This project will demonstrate the feasibility of developing the new generation of absorption chillers based on the microemulsions that have the potential to break the limits on COP.
- This project aims to develop a prototype heat-driven absorption chiller, with a cooling capacity of 1.5kW and a coefficient of performance (COP) of 2.0, which is 200% higher than the state-of-the-art single-effect absorption or adsorption chillers, for the application of space cooling.

Team

Dr. Bao Yang is a Professor in the Department of Mechanical Engineering at the University of Maryland, College Park, and currently directs the Micro/Nanoscale Heat Transfer and Energy Conversion Laboratory at the Center for Environmental Energy Engineering (*CEEE*). He is the first inventor of the microemulsion cooling technology and serves as Principal Investigator in this project.

Microemulsion Absorption Cooling Research at UMD

- B. Yang, Novel working pairs for absorption/adsorption refrigeration and heat pump, PS-2010-101, 2010.
- B. Yang, Innovative, Microemulsion-enabled absorption/adsorption chiller and heat pump, PS-2012-083, 2012.
- B. Yang, R. Radermacher, and B. Shi, Application of microemulsion-enabled absorption/adsorption chiller in power plants, PS-2013-077, 2013.
- B. Yang, R. Radermacher, F. Cao, and B. Shi, Application of Microemulsion-enabled Water Capture and Recovery Technology in Power Plants, PS-2013-076, 2013.
- B. Yang, R. Radermacher, F. Cao, and B. Shi, Application of microemulsion-enabled water capture and recovery technology and absorption/adsorption chiller in power plants, U.S. Provisional Patent, 61/867509, 2013.
- B. Yang and R. Radermacher, Innovative, microemulsion-enabled water capture and recovery technology, U.S. Provisional Patent, 61/987,280, 2014.
- B. Yang, R. Radermacher, and B. Shi, Microemulsion-enabled heat transfer, International Non-Provisional Patent Application, PCT/US2014/051690, 2014.
- B. Yang, R. Radermacher, F. Cao, and B. Shi, Microemulsion-enabled water capture and recover, International Non-Provisional Patent Application, PCT/US2014/051700, 2014.

Technical Points of Contact: Dr. Bao Yang
Phone: 301-405-6007; Email: baoyang@umd.edu
Business Points of Contact: Ms. Danette Boone
Phone: 301-405-6269; Email: dboone14@umd.edu

Challenge

- An absorption chiller uses low grade heat (e.g., waste heat from factories, a fossil-fueled flame, or solar heat) to generate cooling.
- In the 1950s, the single-effect water/lithium bromide absorption chillers were commercialized in US. Their COP was about 0.7.

  Ref: "Absorption cooling process. A critical literature review," R. T. Ellington, G. Kunst, R. E. Peck, J. F. Reed, Research bulletin 14, 1957.
- In 2019, the COP of the single-effect absorption chillers is still about 0.7.

  Ref: https://www.energy.gov/sites/prod/files/2014/05/f16/steam14_chillers.pdf
- Cooling COP of Carnot Cycle

  Case study:

$$COP_{Carnot} = \left(\frac{T_{cold}}{T_{envir} - T_{cold}}\right) \times \left(\frac{T_{hot} - T_{envir}}{T_{hot}}\right)$$

$$Given: T_{hot} = 363K, T_{envir} = 307K, T_{cold} = 296K$$

$$COP_{Carnot} = 4.2$$

$$\frac{\boldsymbol{COP_{actual}}}{\boldsymbol{COP_{Carnot}}} = \mathbf{17\%}$$

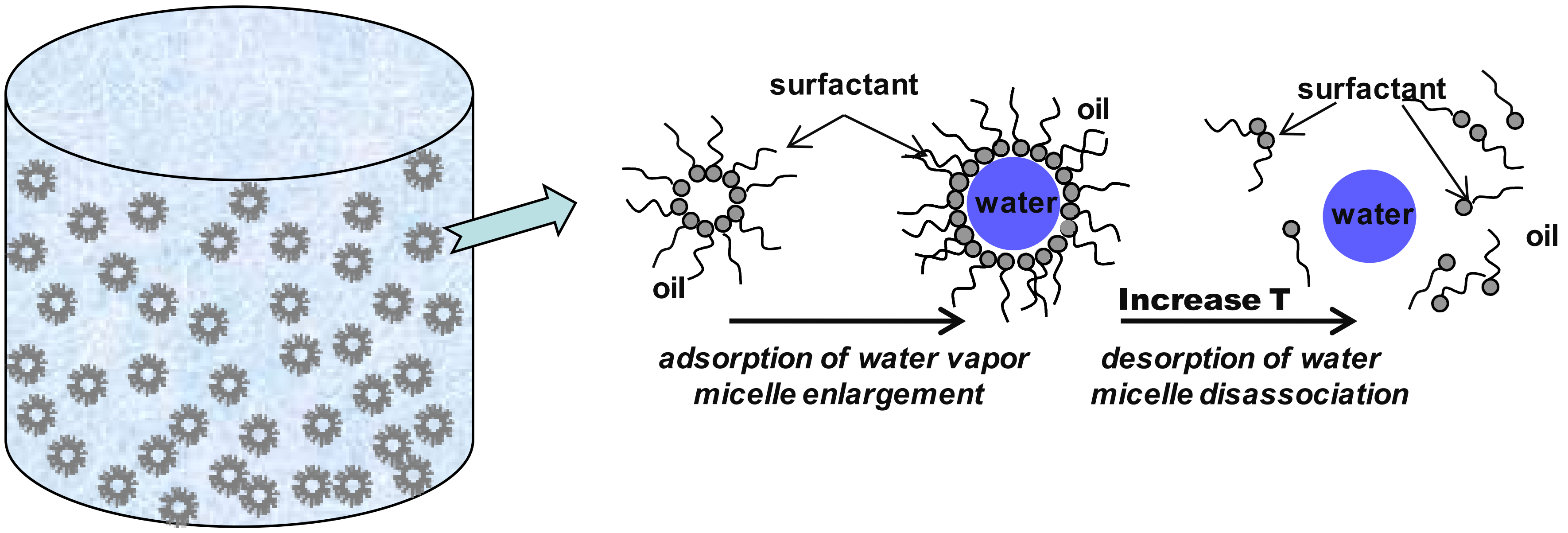
Challenge

State-of-the-Art Absorption Chillers

Refrigerant/ Absorbent	H_2O/LiBr (single effect)	H_2O/LiBr (double effect)	H_2O/LiBr (triple effect)	NH_3/H_2O (single effect)
Operating pressures	Low	high	high	High
COP	~0.7	1.0~1.2	~1.5	~0.5
Regeneration Temperature	~110°C	~150°C	~180°C	~120°C

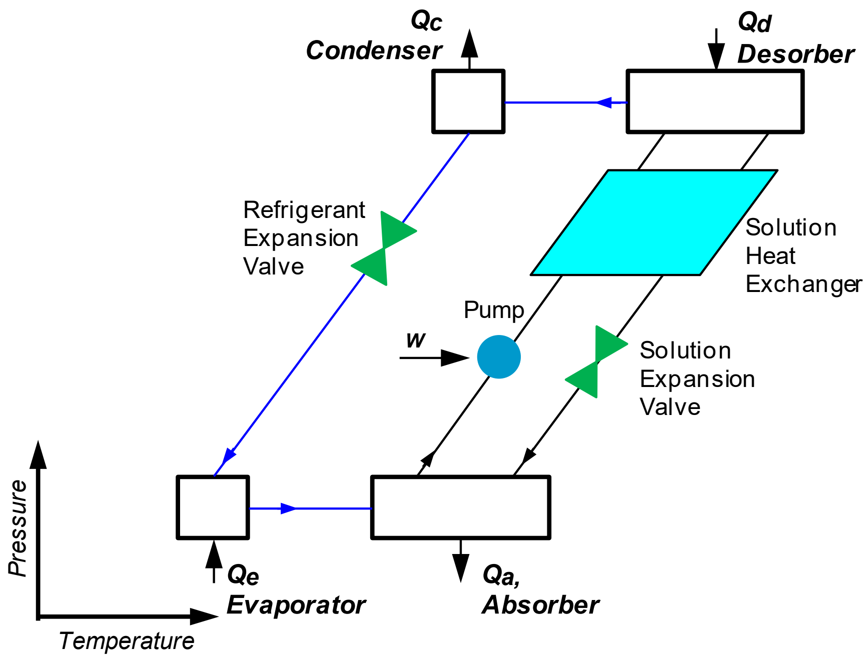
The term “double effect” (or triple effect) refers to the fact that the heat input at the high temperatures is used twice (or three times) within the cycle to generate vapor.

Approach

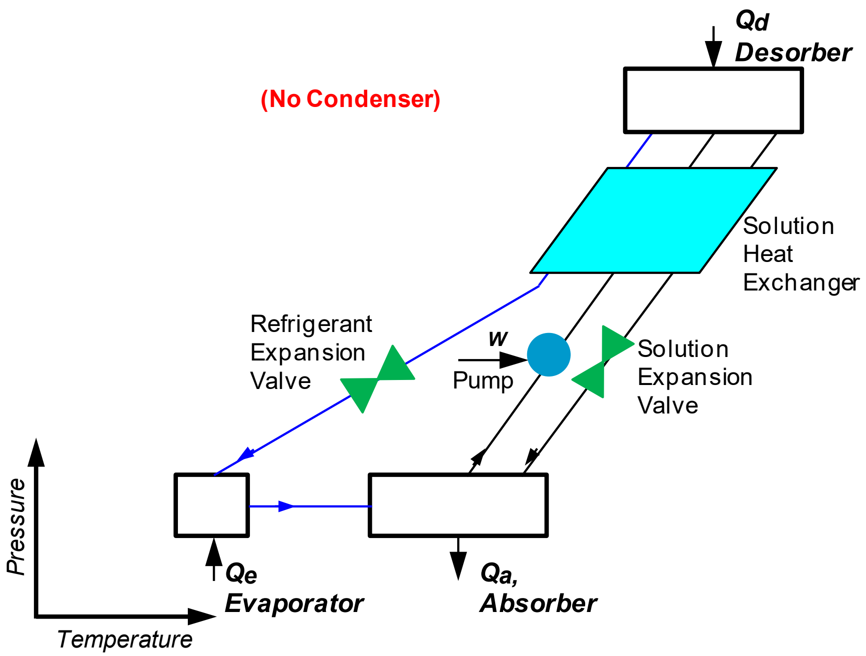


- Schematic drawing of the microemulsion absorbent and the inverse micelles of amphiphilic surfactant dispersed within oil.
- When heat is supplied to the microemulsion solution in the desorber, the refrigerant water is separated *as a liquid without vaporization or boiling*. The heat required to do this separation is much less than that if the water was vaporized. This is the primary innovation of the new absorption cooling cycle.

Approach



(a)



(b)

(a) Conventional "ideal" absorption Cycle

(b) New Ideal absorption cycle

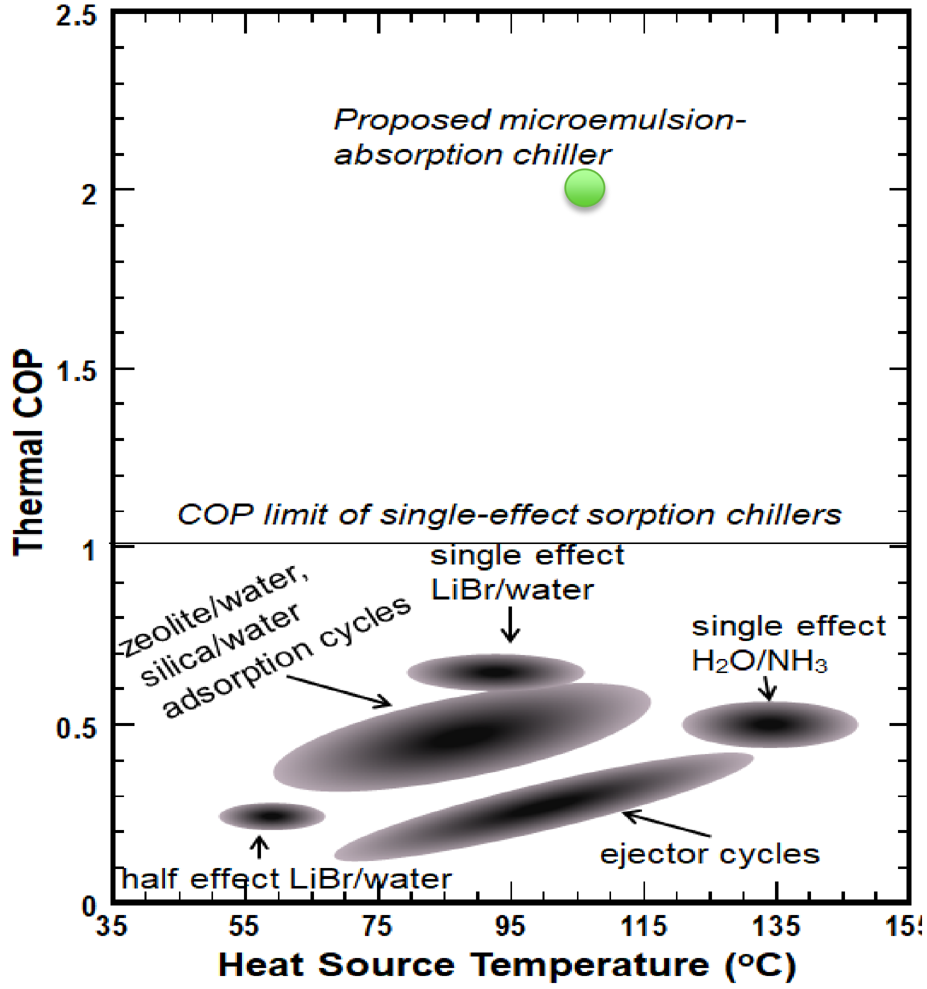
Advantages:

$$COP_{limit} = \frac{Q_e}{Q_d + W} = \frac{h_{fg}}{h_{fg} + \Delta h_{mix} + W} < 1$$

X >

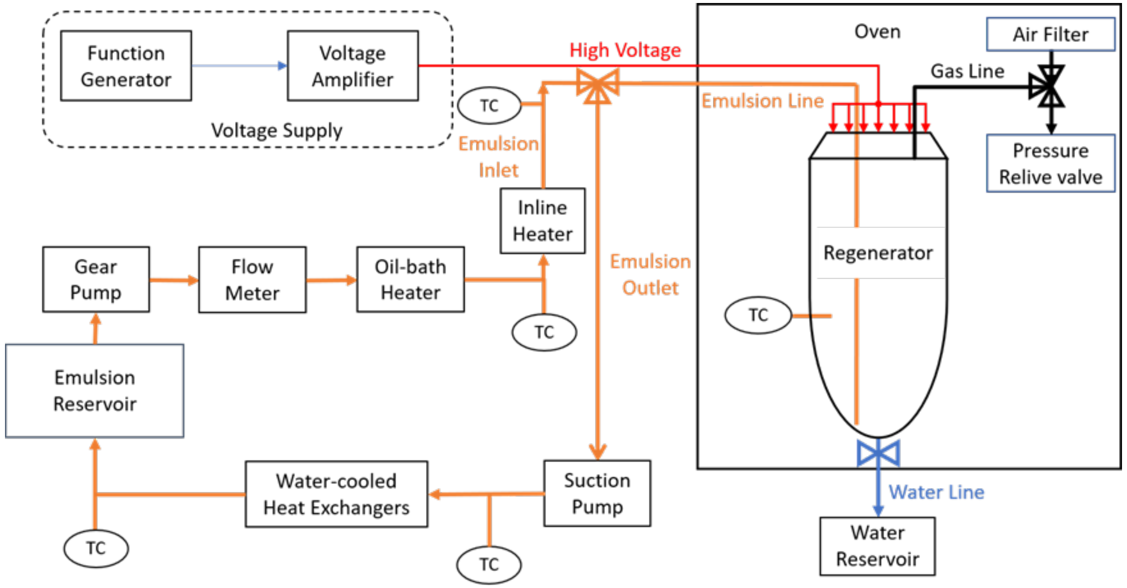
Impact

- Absorption technology is currently experiencing a resurgence of interest from end users in the US who need a dependable heat-driven heat pumping technology.
- The traditional absorption heat pumps (with COP~0.7) are limited to niche applications, such as water chiller for air-conditioning in commercial buildings.
- According to 2030 projections developed with the BTO Baseline Energy Calculator, rooftop cooling HVAC equipment (excluding heat pump, chiller, and window A/C) used in commercial buildings, in relevant climate zones (1-5), represents a primary energy use of 972 trillion BTUs. The "2030 Energy Market Size" is 972 trillion BTUs .
- The targeting Coefficient of performance (COP) of the proposed microemulsion-based absorption chillers is 200% higher than that of the state-of-the-art single effect absorption chillers.
- The proposed microemulsion-based chiller system, when at 43% market penetration in 2030, can help save 250 trillion BTUs, i.e., 0.25 Quads.



COP and heat source temperature of conventional single-effect absorption and adsorption chillers and other heat-activated cooling technologies.

Progress



Schematics of the electrostatic desorber

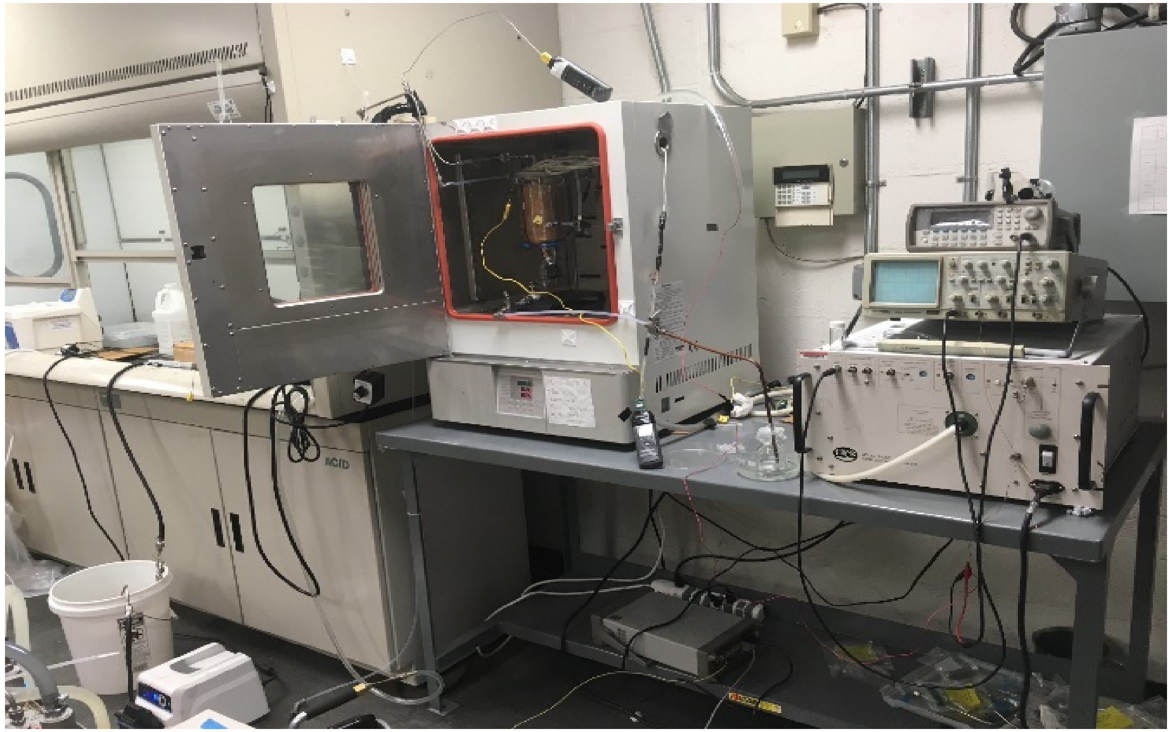
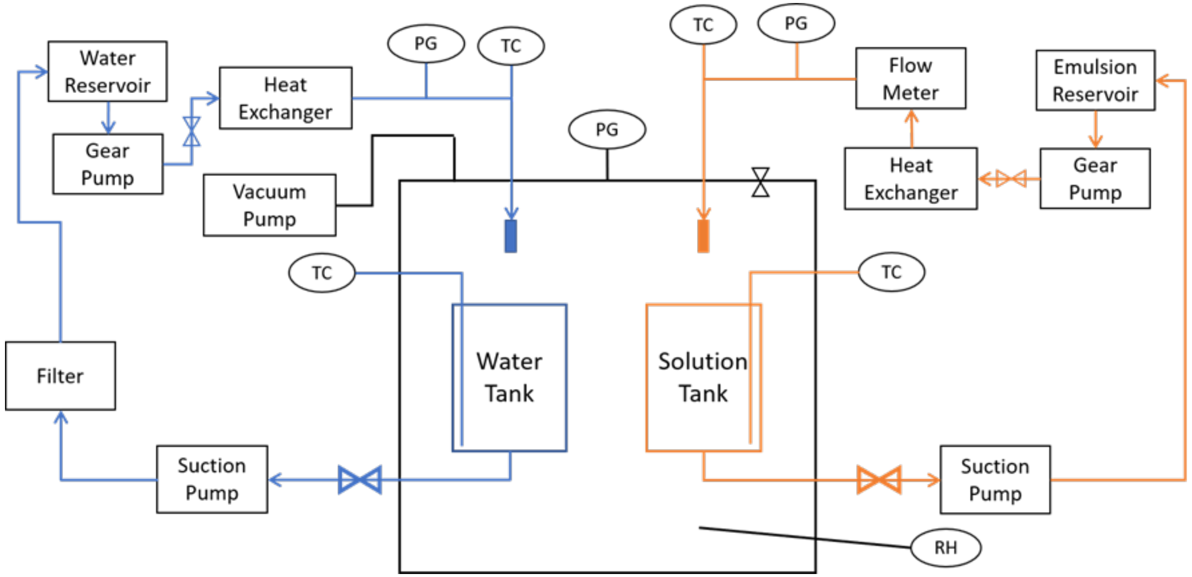


Photo of the developed desorber

In Task 4.0 of this project, a novel electrostatic-coalescence desorption technology was developed to accelerate the water droplet separation from the microemulsion. The analytical analysis and numeric simulation were performed to study the electrostatic field and its effects on the water droplet separation in the desorber. An electrostatic desorber was designed and manufactured to optimize the electrode configuration and electric field and to mitigate the leak and corrosion issues.

Progress



Schematics of the absorber and evaporator

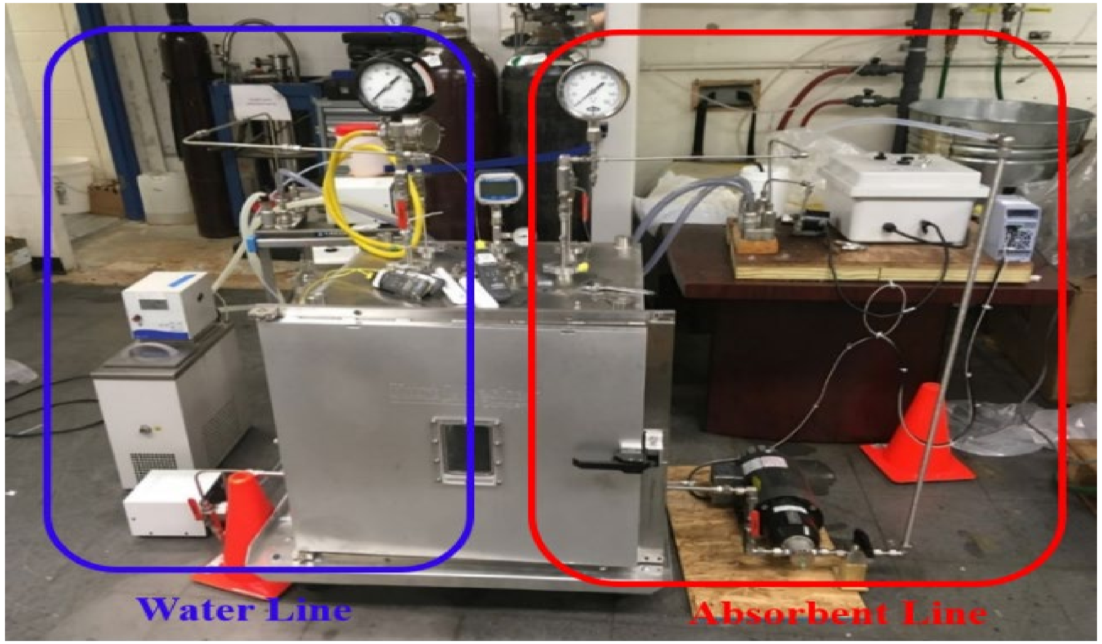


Photo of the developed absorber and evaporator

In Task 5.0 of this project, an advanced absorption technology was developed to improve the vapor absorption rate in microemulsion. Theoretical modeling was performed, which showed the microemulsion droplet size impacts the absorption rate significantly. A combined absorber and evaporator system together with balance of system components was designed and built.

Progress

Photo of the developed prototype absorption chiller which utilizes the microemulsion-water as the working pair.

In Task 6.0 of this project, the world's first absorption chiller that doesn't have a condenser component was developed. Unlike the traditional absorption chiller, this chiller was composed of just three major components: an electrostatic desorber, an evaporator, and an absorber. The cooling power and COP of this chiller were found to be 142W and 1.96, respectively.

Stakeholder Engagement

- **Stakeholder Engagement will be preformed in Task 11 in Year 3 of this project. It is in early stage of the project.**
- **The UMD team has started to contact the potential stakeholders.**
- **Types of Stakeholders**
  - Business Associations
    - American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), American Society of Mechanical Engineers (ASME), Electric Power Research Institute (EPRI), etc.
    - Engagement: conferences, publications and tech briefs.
  - HVAC technology developers and system integrators
    - Johnson Controls Inc., Carrier, United Technologies Research Center (UTRC). etc.
    - Engagement: collaboration, tech briefs.

Remaining Project Work

- Task 7.0: System-Level Modeling of the Chiller - Continued (M19-M21)
- Task 8.0: Development of Microemulsion Desorber with Electrostatic Coalescer – Continued- (M19-M24)
- Task 9.0: Development of Microemulsion Absorber with Atomizing Spray Nozzles – Continued (M25-M30)
- Task 10.0 Manufacturing and Testing of the Chiller – Continued (M31-M36)
- Task 11.0: Tech-to-Market Analysis – Continued- (M31-M36)

Thank You

Performing Organization(s): University of Maryland, College Park
PI Name and Title: Bao Yang, Professor
PI Tel and/or Email: 3014056007, baoyang@umd.edu

REFERENCE SLIDES

Project Budget

Project Budget: DOE: $640,000. Cost Share: $160,000
Variances: N/A.
Cost to Date: DOE: $353,135. Cost Share: $92,428
Additional Funding: N/A

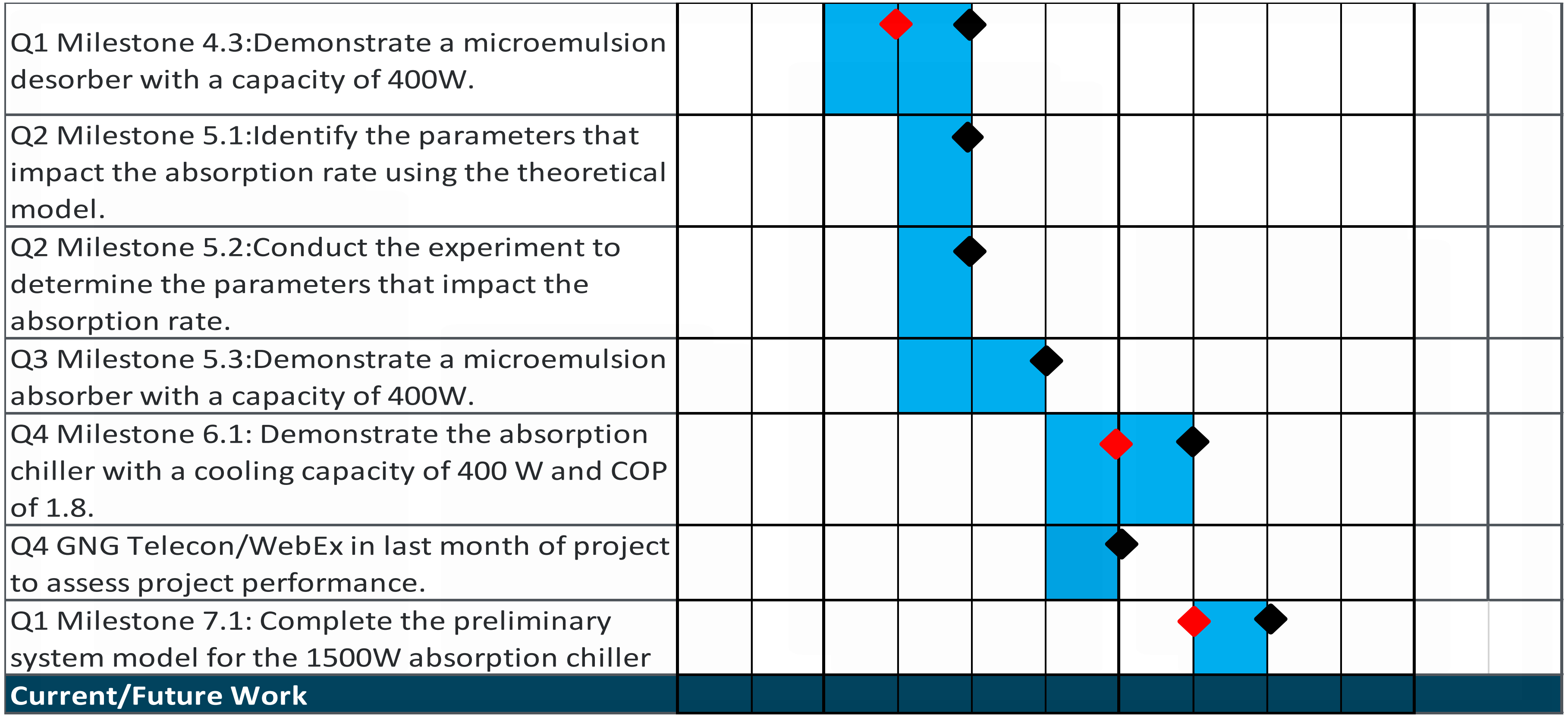
Budget History					
1/1/2020 – FY 2020 (past)		FY 2021 (current)		FY 2022 – 5/31/2022 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$210,573	$54,202	$215,109	$51,705	$143,432	$33,786

Project Plan and Schedule

Project Schedule		
Project Start: June 1, 2019		Completed Work
Projected End: May 31, 2022		Active Task (in progress work)
		Milestone/Deliverable (Originally Planned)
		Milestone/Deliverable (Actual)

	FY2019		FY2020				FY2021				FY2022	
Task	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar)	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar)	Q2 (Apr-Jun)	Q3 (Jul-Sep)	Q4 (Oct-Dec)	Q1 (Jan-Mar)	Q2 (Apr-Jun)
Past Work												
Q3 Milestone 1.1: Develop the initial overall system configuration of the microemulsion-based absorption chiller and estimate its capital cost.												
Q3 Milestone 2.1: Finish the temperature cycling testing of the microemulsion												
Q3 Milestone 3.1: Complete the preliminary system model for the 400W absorption chiller												
Q4 Milestone 4.1:dentify the parameters that impact the desorption time using the simulation model												
Q4 Milestone 4.2:Conduct the experiment to determine the parameters that impact the desorption time.												

Project Plan and Schedule



Project Plan and Schedule

Current/Future Work												
Q2 Milestone 8.2: Demonstrate a microemulsion desorber with a capacity of 1500W												
Q3 Milestone 9.1: Demonstrate a microemulsion absorber with a capacity of 800W												
Q4 Milestone 9.2: Demonstrate a microemulsion absorber with a capacity of 1500W.												
Q1 Milestone 11.1: Develop market strategy that details a path forward towards commercialization.												
Q2 Milestone 11.2: Develop collaboration with interested companies for commercialization												
Q2 Milestone 10.1: Demonstrate the absorption chiller with a cooling capacity of 1500 W and COP of 2.0												