DELTA:
Micro Environmental Control System (μX)

ARPA-E Award: DE-AR0000526

Award Duration: 3 Years (May 1, 2015 – April 30, 2018)

Kick-off Meeting

Portland, OR; May 21-22, 2015

Syracuse University (Lead): H. Ezzat Khalifa (PI), …;

United Technologies Research Center: Frederick Cogswell, …;

Air Innovations: Michael Wetzel, …;

Bush Technical LLC: J. William Bush;

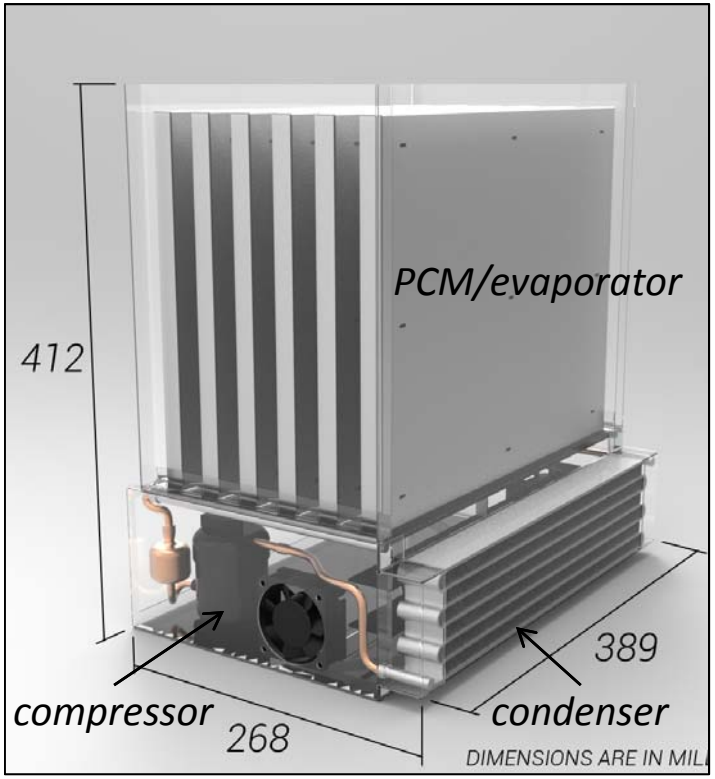
Cornell University: Alan Hedge.

Description of Technology

A near-range LTMS that will transform the way office buildings are thermally conditioned to provide thermal comfort at high efficiency…

μX comprises several innovations:

- A micro vapor compression system (μVCS) capable of delivering ~50W of cooling and ~60W of heating for 10 hours during occupancy period.
- A high-performance micro scroll compressor designed specifically for this application.
- An evaporator embedded in a phase-change thermal-storage material (PCM) with a melting point of ~65°F.
- A heat pump mode for efficient delivery of 60W+ of heat.
- Automation to operate the μVCS during night to freeze the PCM in cooling season and melt it in heating season.
- An air management system that delivers ~20cfm of 72°F air for cooling and ~10cfm of 85°F air for heating.



Skin removed to reveal internals

Value Proposition

μX is a compact, unobtrusive LTMS that achieves a much higher COP than the FOA's 0.35 minimum metric: COP = 2.3 (cooling) & 1.5* (heating).*

Expected system benefits:

- Deliver 500W-h of cooling or 600W-h of heating to the near-range micro environment around a seated office worker during a 10-hour workday in a room temperature of 79°F (summer) or 66°F (winter).
- Use <100W-h for 500W-h of cooling & <150W-h for 600W-h of heating.
- Remove or add at least an additional 23W from or to a seated office worker to restore comfort when the room temperature is raised to 79°F (summer) or lowered to 66°F (winter).
- Comply with applicable safety and ergonomic standards

μX differs from competing LTMS:

- It does not re-circulate room air without cooling or heating it.
- It does not require connection to building air-distribution system via ducts from ceiling or subfloor plenum.
- It does not discharge warm or humid air during summer work hours, nor cold air during winter work hours.
- It does not require that cooling/heating pads be shuttled back and forth from refrigerators or heaters to workstation.
- It does not require office chairs to be connected to air supply or power plug.
- It does not require office workers to wear special clothing.

**These COPs are based on 23W sensible heat removed from, or added to the person. Traditional COP based on actual μX thermal output are >5.0 and >4.0, respectively.*

Validation Plan & Performance Targets

μX benefits to be demonstrated/validated in the lab, in a simulated office environment with a thermal manikin, and in cubicles with human subjects…

Major Milestones & Deliverables:

- **μX-1 breadboard μVCS performance:**
  - *Breadboard μVCS that delivers:*
    ≥60W of cooling & a COP ≥ 4.5 at a 65°F±1°F PCM freezing temperature and a 79°F ambient sink temperature. ***(Q4)***
  - *μX-1 breadboard that removes:*
    ≥50W of heat from for 20cfm±10% of air to cool it from 79°F to 71°F±1°F for >8h. ***(Q4)***
- **Micro compressor performance:**
  - *Micro scroll compressor "α" that delivers:*
    ≥60W of cooling with a COP of ≥5.0 at 62.5°F SET (2°F SH) & 100°F SCT (10°F SC). ***(Q5)***
  - *Micro scroll compressor "β" that delivers:*
    ≥60W of cooling with a COP ≥5.7 at 62.5°F SET (2°F SH) & 100°F SCT (10°F SC) in 3 test samples. ***(Q9)***
- **μX-2 prototype performance:**
  - *μX-2A prototype μVCS that:*
    delivers ≥60W of cooling to freeze PCM at 65°F±1°F in <9h with a μVCS COP ≥5.0, while rejecting heat to a room at 79°F; PCM module designed to remove ≥50W of heat from 20cfm±10% of air to cool it from 79°F to 71°F±1°F for >8h. ***(Q7)***
    delivers ≥60W of heating at a COP ≥5.5 with PCM freezing at 65°F±1°F, while heating ≥11cfm of room air from 66°F to 78°F±1°F for >8h. ***(Q7)***
  - *μX-2B prototype μVCS that:*
    delivers ≥60W of cooling to freeze PCM at 65°F±1°F in <9h with a μVCS COP ≥5.4, while rejecting heat to a room at 79°F; PCM module designed to remove ≥50W of heat from 20cfm±10% of air to cool it from 79°F to 71°F±1°F for >9h. ***(Q10)***
    delivers ≥60W of heating at a COP ≥6.0 with PCM freezing at 65°F±1°F, while heating ≥11cfm of room air from 66°F to 78°F±1°F for >9h. ***(Q10)***
- **μX/ATD performance / manikin test *(Q11)*:**
  - *μX-2B/ATD demonstration prototype that:*
    increases manikin heat loss by ≥23W in 79°F room & decreases it by ≥23W in 66°F room.

Help from the DELTA Community

The major challenges reside mostly in the PCM/Evaporator module and the micro-scroll compressor. Help in the following areas is most appreciated…

Technical:

- *Sources of reliable thermo-physical properties of low-temperature (16-19°C freezing point) phase change materials (PCM).*
- *Alternative vendors who can fabricate the unique prototype microchannel PCM/Evaporator developed in this project.*
- *Alternative suppliers of high-efficiency BLDC motor of 10-20W output @ ~3000 rpm.*
- *Compressor calorimeters for capacities of 50-100W.*

- **TEA/T2M:**
  - *Other market segments that can benefit from the proposed μX technology (e.g., peak shaving).*
  - *Utilities that offer incentives for demand management and who may be interested in the μX technology for that purpose.*
  - *Learning curve slopes for small refrigerators & air-conditioners (manufacturing cost vs. cumulative production volume).*