MICRO-ENVIRONMENTAL CONTROL SYSTEM

Updated: November 30, 2017

TITLE: Micro-Environmental Control System

PROGRAM: Delivering Efficient Local Thermal Amenities (DELTA)

AWARD: $3,199,963

TEAM: Syracuse University (Lead), United Technologies Research Center, Air Innovations, Bush Technical, LLC, and Cornell University

TERM: May 2015 to July 2018

PRINCIPAL INVESTIGATOR (PI): H. Ezzat Khalifa

MOTIVATION

Heating, Ventilation, and Air Conditioning (HVAC) accounts for 13% of U.S. energy consumption. ARPA-E estimates that relaxing building temperature set point requirements from 70°F for heating and 75°F for cooling to 66°F and 79°F, respectively, could reduce annual HVAC energy consumption by 15%. This could be achieved by tailoring the thermal environment around the individual, thereby ensuring comfort and maintaining productivity in this expanded temperature range. ARPA-E's Delivering Efficient Local Thermal Amenities (DELTA) program set performance metrics that localized thermal management systems (LTMS) should remove 23 W of energy from human skin in a cooling setting, and provide 18 W of energy in a heating setting.[1]

TECHNICAL OPPORTUNITY

Almost all existing LTMS developed or sold commercially have relied on pre-conditioned air that goes through a central Air Handling Unit (AHU). The pre-conditioned air is then delivered through ceiling ducts or underfloor plenums, which is intrusive, noisy, high cost, and high energy. Local thermal storage using phase change materials (PCMs) provides a more cost-effective approach. PCMs allow the system to discharge heat at night when the area is unoccupied, shifting the electric load to off-peak hours. Using PCMs eliminates the limitations on placement (i.e. not in a window) and the need to connect to building services other than an outlet.

INNOVATION DEMONSTRATION

The Syracuse team's goal is to develop a compact, quiet, and ergonomic micro-environmental control system, named µX. µX utilizes a thermal storage module containing PCM that freezes at about 60°F to store 10 hours worth of "cooling." This cooling capacity is produced in approximately eight hours at night by a novel, high-performance micro vapor-compression system (µVCS) whose evaporator is embedded in the PCM module. During the day, small fans blow about 20 cfm (ft^3/min) of room air at 79°F through the frozen PCM module, cooling the air to a comfortable 71-72°F, delivering no less than 50 W of cooling to the near-range environment. By freezing PCM at night, the system avoids releasing noise and heat when the workstation is occupied. In the heating season, a heat delivery device is used to add 18 W of heat to a person.

A focus of the project was to build a high-performance micro-compressor to enable system functionality. Among the many compressors, the team chose scroll compressors because they are valveless, quieter, more efficient, and have fewer moving parts. Scroll compressors have a built-in compression ratio, which can be optimized to

1 Detailed calculations of the energy savings and program metrics were laid out in the DELTA Funding Opportunity Announcement (FOA). A synopsis of the FOA can be found at: https://arpa-e.energy.gov/sites/default/files/documents/files/DELTA_ProgramOverview.pdf

match the narrow operating conditions needed to meet DELTA metrics. Because of the small size (<5 cm diameter) and tight tolerances required for high efficiency, developing the compressor presented a significant challenge. Syracuse worked with Bush Technical to design a micro-compressor, and validated its performance experimentally and against the predictions of a proprietary compressor simulation tool developed by United Technologies Research Center (UTRC). The prototype compressor features a small cooling capacity of about 60 W, consumes less than 11 W of electricity, and has fewer moving parts.


Figure 1: Prototype µX product and its under-the-desk setup.

Another challenge was to engineer a PCM/evaporator module. The size and efficiency requirements of µX dictates that the critical design aspects of heat exchanger, refrigerant, and PCM be carefully selected and engineered. Guided by numerical models, the team designed the PCM/evaporator module to meet these requirements. The team optimized air and refrigerant channel sizes and spacings through computational analysis and experimentation in order to achieve desired heat transfer and refrigerant and air flow rates. Experiments confirmed that the PCM/evaporator can meet its performance targets.

Preliminary test results using a prototype of the integrated system with a thermal manikin illustrate that the prototype is able to remove more than 32 W of heat from the manikin, surpassing the DELTA target of 23 W.

IMPACT PATHWAY

The innovative design of the µX is compatible with automated, high volume, cost-effective manufacturing techniques. The first market envisioned is for peak demand reduction in offices that integrate this technology into desks. Because of the technology's potential in load shifting, New York State Energy Research and Development Authority (NYSERDA) provided Syracuse University a follow-on grant of $400,000 to apply the technology in demand reduction prototypes aimed primarily at New York City.

Syracuse University has formed strategic partnerships with Air Innovations (AI) and UTRC and its affiliate, Carrier. AI and UTRC have agreed to terms defining market thresholds for exclusive licenses to the µX technology. Both companies bring distribution channels, extensive experience, and strong relationships with suppliers and subcontractors. The current price point of µX is likely to first suit niche applications, such as mission-critical facilities and historic buildings. Mass production will reduce the price for high-volume markets.

LONG-TERM IMPACTS

A low-cost LTMS using µX technology can reduce HVAC electricity consumption, thereby saving consumers on energy costs, reducing greenhouse emissions, and enabling more sustainable heating and cooling architectures for energy-efficient building design. The thermal storage technology can also potentially enable shifting of the electric load to off-peak hours, further improving the stability of the electric grid.

INTELLECTUAL PROPERTY AND PUBLICATIONS

As of October 2017, the project has generated two invention disclosures to ARPA-E, and two provisional patent applications have been filed on the disclosed inventions. The team has also published the scientific underpinnings of this technology three times in open literature.