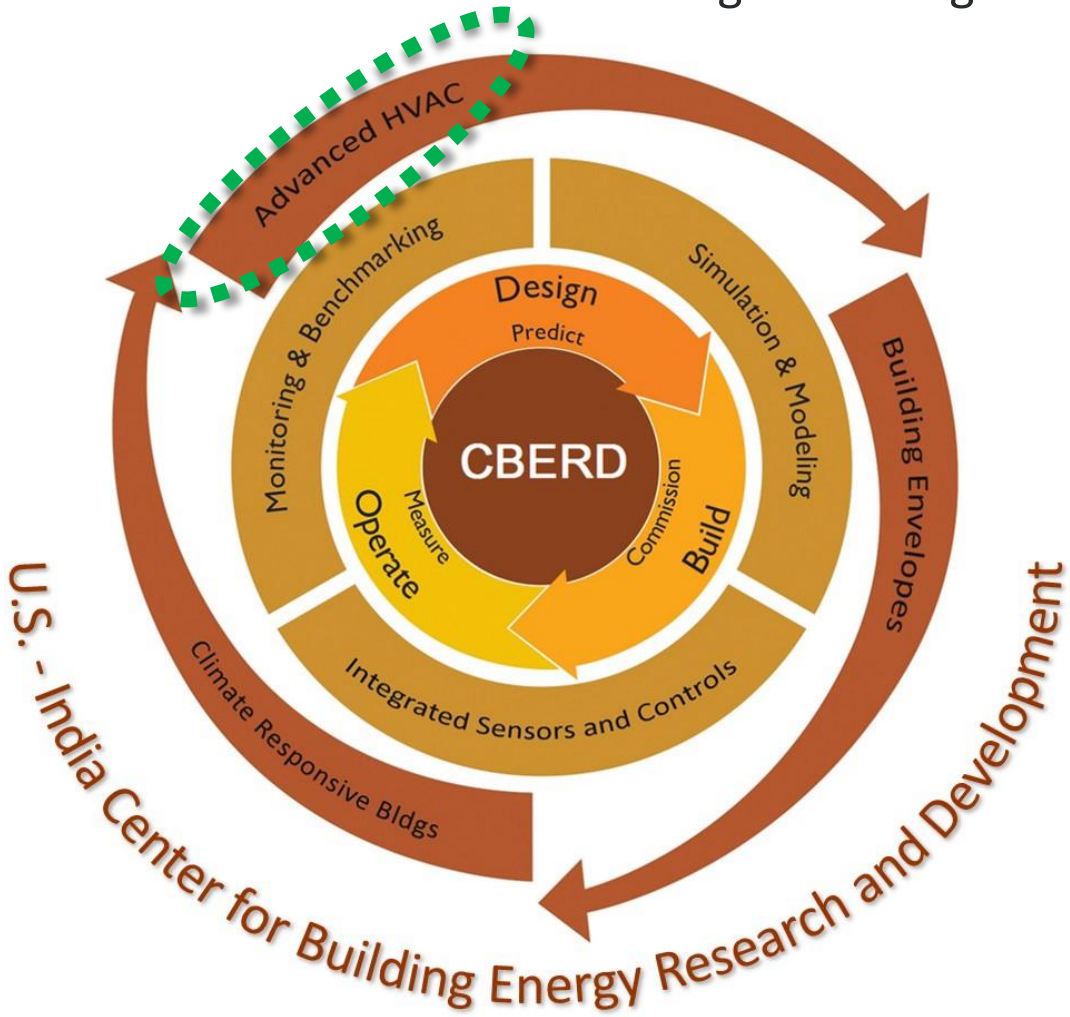
CBERD Advanced HVAC Systems

2017 Building Technologies Office Peer Review



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Project Summary

Timeline:

Start date: Oct. 2012

Planned end date: Sept. 2017

Key Milestones

1. Radiant Cooling Design Guideline (Sept. 2017)
2. Integrated various DOAS configurations (Sept. 2017)
3. Integrated MCHX evaporator 1.5 TR unitary system with R290 (June 2017)

Budget:

Total Project $ to Date:

- DOE: $ 425K
- Cost Share: $ 100K

Total Project $:

- DOE: $500K
- Cost Share: $200K

Key Partners:

Institutional Partners	Industry partners
Malviya National Institute of Technology Jaipur (MNITJ)	Mahle (formerly Delphi), USA
Indian Institute of Technology Bombay (IITB)	Architectural applications, USA
	Oorja, India

Project Outcome:

- Develop a radiant cooling design guideline
- Identify and develop non-compressor based DOAS configurations suitable for different climatic conditions
- Design, test and deploy the MCHX evaporator integrated small split unit with R22 and low GWP refrigerant R290

Purpose and Objectives: Problem Statement

Increasing demand for HVAC in India

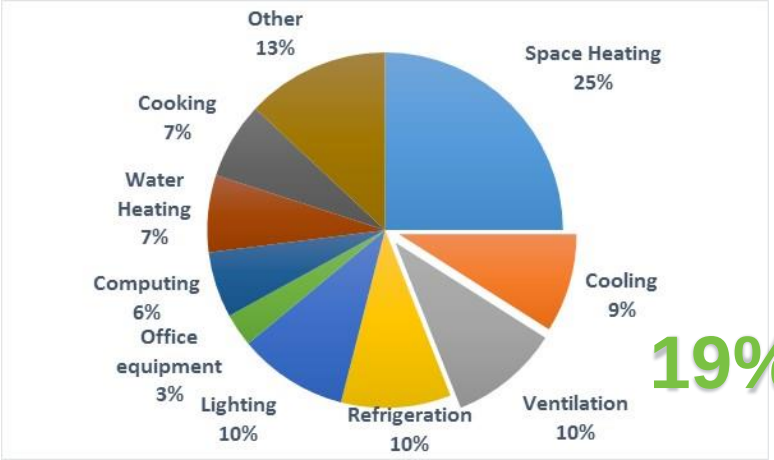
Buildings in U.S.

- 40% of primary energy
- 73% electricity, 34% gas

Buildings in India

- 67% of buildings are yet to be built (2030 projection)
- 33% of total energy
- Growth: 8-10% per year

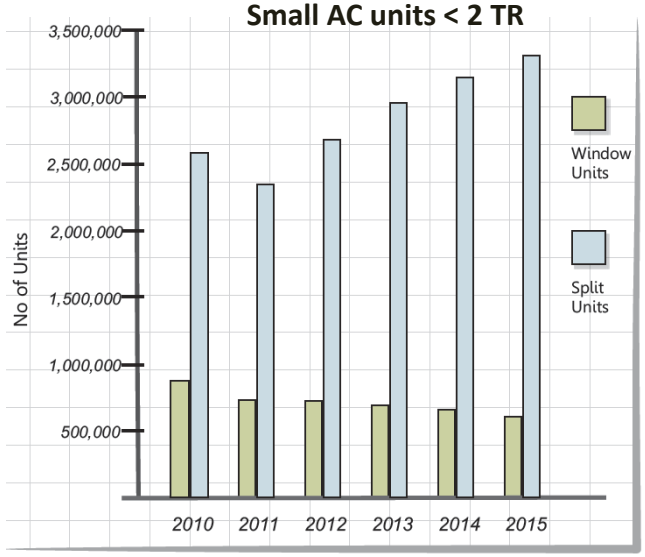
US commercial buildings energy consumption



Need to improve energy efficiency of HVAC systems

- Alternate energy efficient systems – Radiant cooling systems
- Develop improved physical systems
  - To handle fresh air more efficiently
    - » Simplified energy efficient dedicated outdoor air system: non-compressor based
  - Efficient design of small unitary systems (< 2TR)
    - » Micro Channel Heat Exchanger as evaporator: MCHX as condenser are already in use

Small AC units < 2 TR



Source: BSRIA - A multi-client study – India. November 2012

Graph credit: USAID, PACE-D Report

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Purpose and Objectives: Target Market and Audience

Target market contributes to:

- US commercial (mostly retrofit) market: target 20% reduction in energy consumption by 2020; **30% by 2030**
- Indian commercial (mostly new construction) market: **target 60% reduction** in energy consumption; 10% through retrofits

Audience:

- Building owners and operators - **reduced operating cost**
- HVAC Industry: system and component manufacturers - new and improved products for **commercialization** with opening up **new market segment**
- HVAC design community

Purpose and Objectives: Impact of Project

Near Term (during or up to 1 year after project):

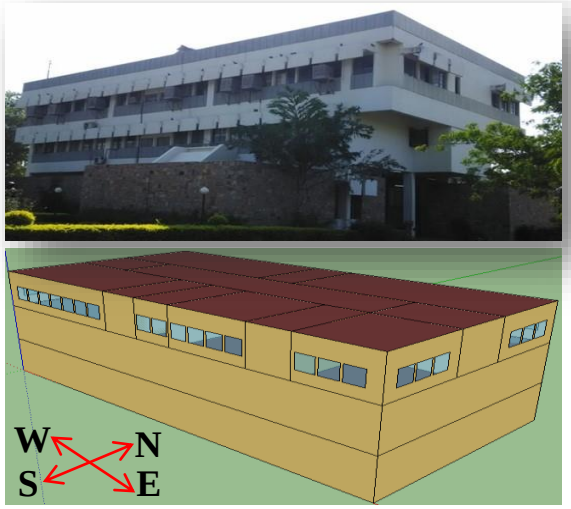
- **Better understanding of radiant cooling systems** - will benefit both US and Indian HVAC manufacturers and users
- Prospects of using non-compressor DOAS in both countries will increase - **new avenues for HVAC industry**
- Better **collaboration opportunities** with Indian industries and institutes

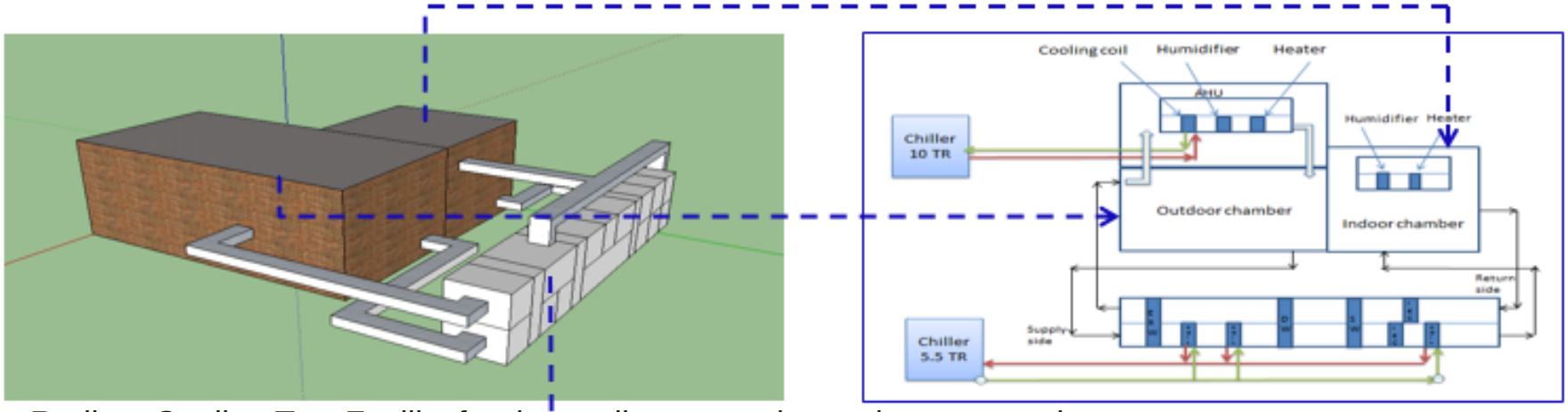
Intermediate/Long Term (1+ years after project):

- Radiant cooling system **validated to provide up to 20% improvement** in commercial buildings
- Innovative dedicated outdoor air system **(DOAS) efficiency is increased by 20%** and design is **simpler and cost effective** than current state of the art
- MCHX evaporator integrated into unitary system validated to be **7-15% more efficient**; providing 30% reduction in weight, **50% refrigerant charge reduction**
- Expansion of MCHX to small capacity evaporators (new area) and **low GWP refrigerants**, can impact millions of AC/HP products

Global Benefits

- State of the art simulation and experimental radiant cooling system test facility in India
- **US industry partners' products in Indian market**
- Efficient DOAS – Potential entry in US market
- **Promote use of low GWP refrigerants**
- New HVAC systems testing lab in India





Radiant Cooling Test Facility for decoupling strategies under construction

Approach

Objective:

- Through **collaborative knowledge and partnership** - investigate the energy **savings potential opportunities** in HVAC systems, **deploy the novel strategies** and technologies in developing energy efficient HVAC systems
- **Capacity building and testing facilities** in the area of HVAC systems
- Deployment path through the **engagement of HVAC industry partners**

Key Issues:

- **Non-availability of guidelines** with respect to the operation and energy savings benefits of radiant cooling systems in commercial buildings
- **Lack of HVAC testing facilities** in India and HVAC modelling capabilities
- Existing non-compressor based **DOAS are complex, bulky, suffer from high pressure drops**, require high parasitic power
- **MCHXs as evaporators** for small unitary systems have not yet penetrated the market due to issues related to **refrigerant distribution, condensate drainage** and form factor

Approach: Distinctive Characteristics

Radiant Cooling System Design Guideline:

- **Hybrid approach**: experiment and simulation analysis for energy savings, sensible-latent decoupling and integration of various strategies

Non-Compressor DOAS:

- **Implement a patented profile** with corrugated enhanced passage extruded aluminium air-to-air heat exchangers
- Explore use of **Potassium Formate as liquid desiccant** using **diabetic contacting devices** to overcome corrosion and carryover issues

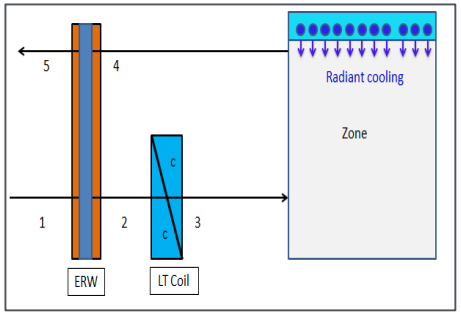
Micro Channel Heat Exchanger (MCHX):

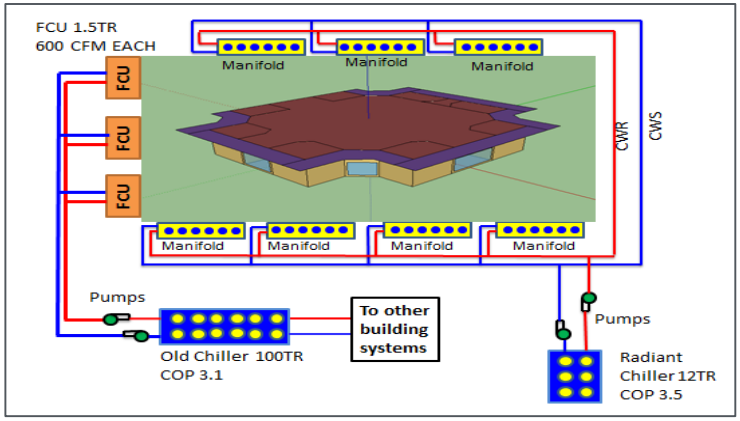
- Integrate MCHX for evaporator in a small unitary system (1.5 TR)
- **Use simulation and measurements** for design optimization
- Measure the performance of the system and study the different ways to improve the performance and shortcomings

Progress and Accomplishments

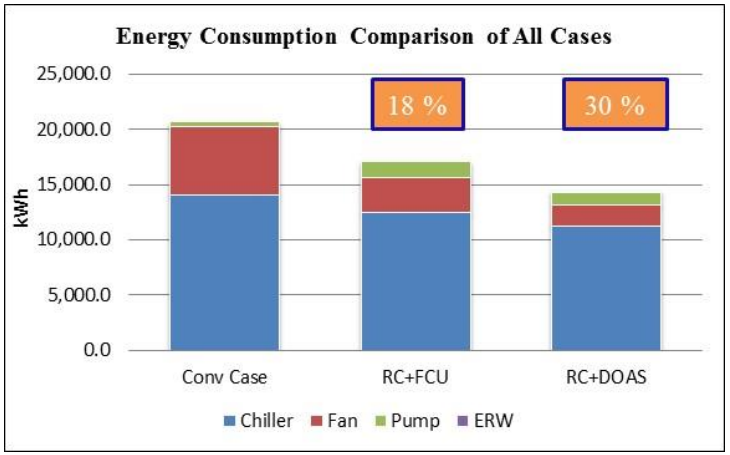
Radiant Cooling System Guideline Development

- **Determination of Performance of Radiant Cooling Systems**
  - Building energy modeling study
  - Model calibration
  - Energy performance in various climates
- **Decoupling Strategies – Simulation and Experiments**
  - Simulation of different configuration of DOAS
  - Experimental analysis
- **Non-Compressor Based Cooling – Experiment/ Measurement:**
  - Analysis of integrating cooling tower with radiant cooling system
- **Radiant Cooling Experiment Lab at MNIT**
- **Present finding at conferences and journals**





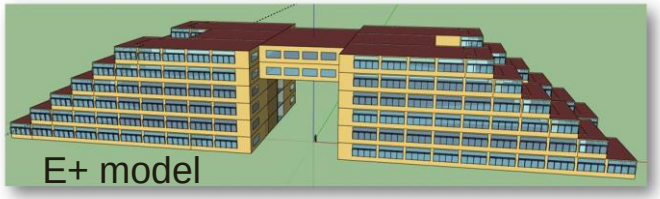
Tech Mahindra – IT Building (3,800 sf) : E+ and CFD

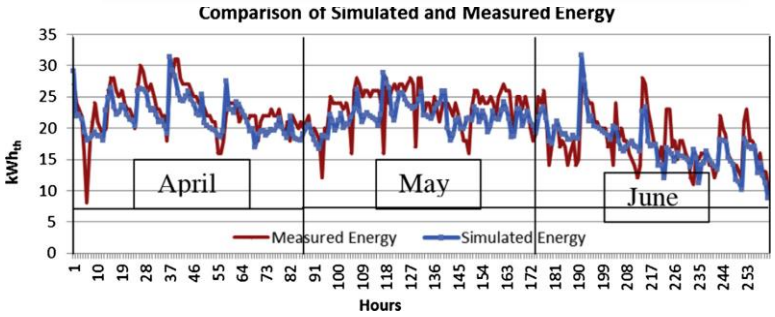


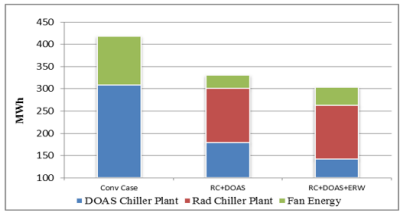
Progress and Accomplishments

Radiant Cooling System Guideline Development

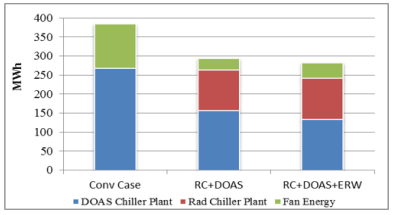
- **Infosys Hyderabad**: Large commercial building (IT) – 6 floors: 250,000 sq. ft., located in Hyderabad, India
- **First radiantly cooled building in India**
- 2 symmetrical wings
- **2 HVAC systems:** Variable Air Volume (VAV) and Radiant Cooling (RC) system coupled with DOAS
- World's largest **HVAC side-by-side comparison**
- **Collaboratively developed a calibrated model**



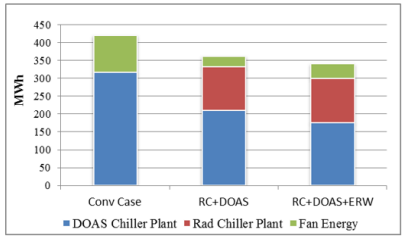




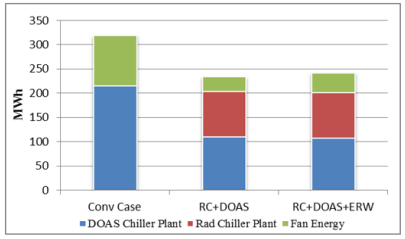
Ahmedabad (Hot and Dry)



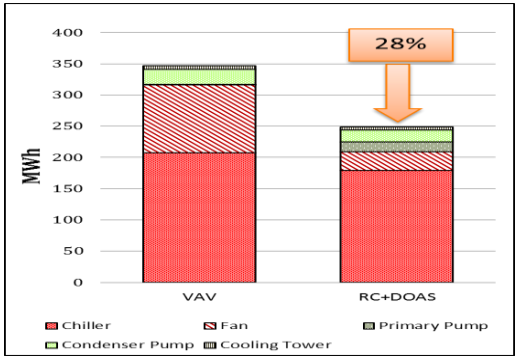
New Delhi (Composite)



Chennai (Warm and Humid)



Bengaluru (Temperate)



Energy savings in different climatic zones

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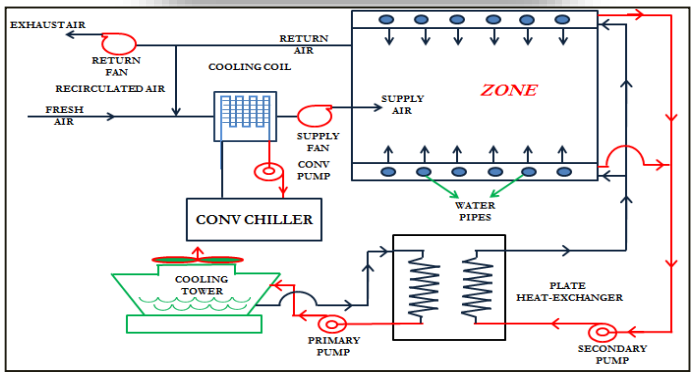
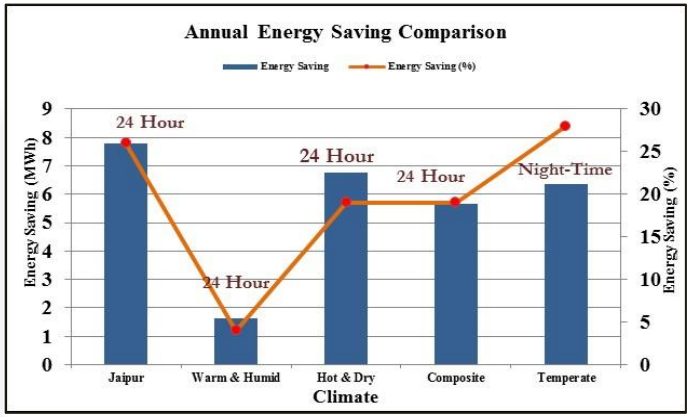
Progress and Accomplishments

- **Designed a personalized radiant cooling system**
  - Modular system
  - Phase change material (PCM) based thermal storage system
- **Radiant cooling system/wind tower integration**
  - Evaluated several strategies
  - Climate based recommendations
- **Radiant cooling system experimental facility**
  - Construction is complete
  - Commissioning phase





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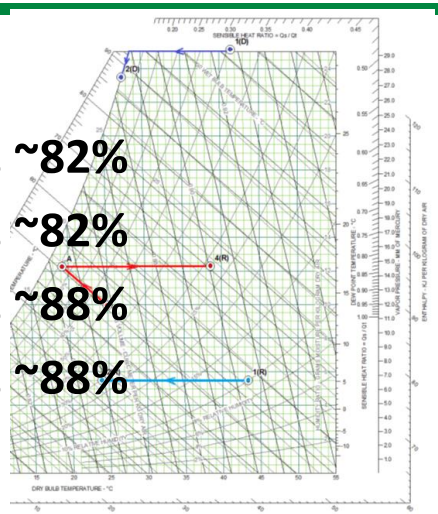
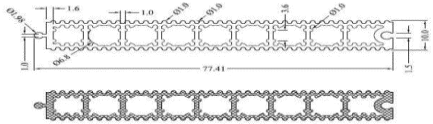
Progress and Accomplishments

- **DOAS – Developed and tested (50 – 2,000 CFM units)**
  - Rotating Contacting Device based Evaporative Precooling
  - Plastic Heat Exchanger, PHE, for AtA HRU
  - Solution Heat Exchangers for LD based dehumidifier
  - Modular AtA HRU enhanced passage Al extrusions
- Compact: HX volume: 12.9 ft^3 for 1000 cfm (~1.5 times lower than conventional)

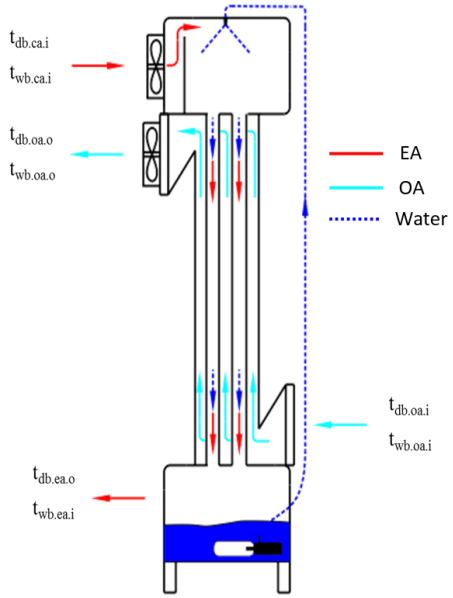




Enhanced passage HX

Rotating Contacting Device

Compact DOAS unit



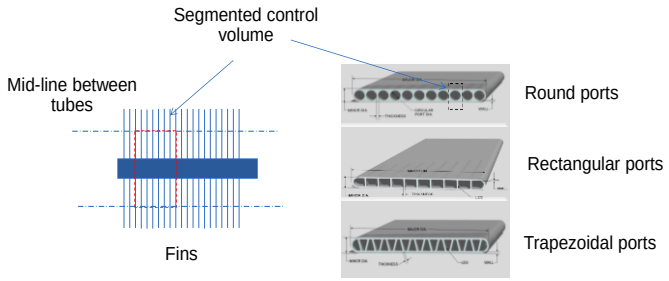
Schematic of prototype DOAS unit

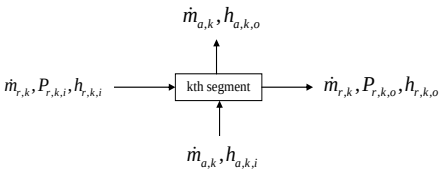
Progress and Accomplishments

Micro Channel Heat Exchanger (MCHX)

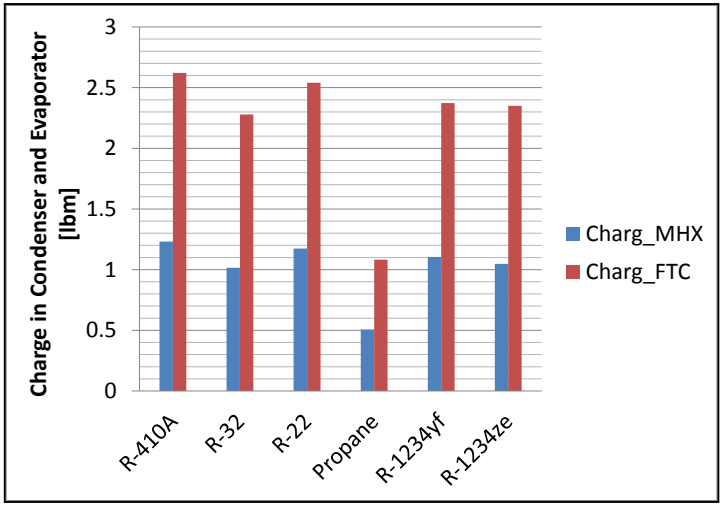
Developed HPDM model of unit:

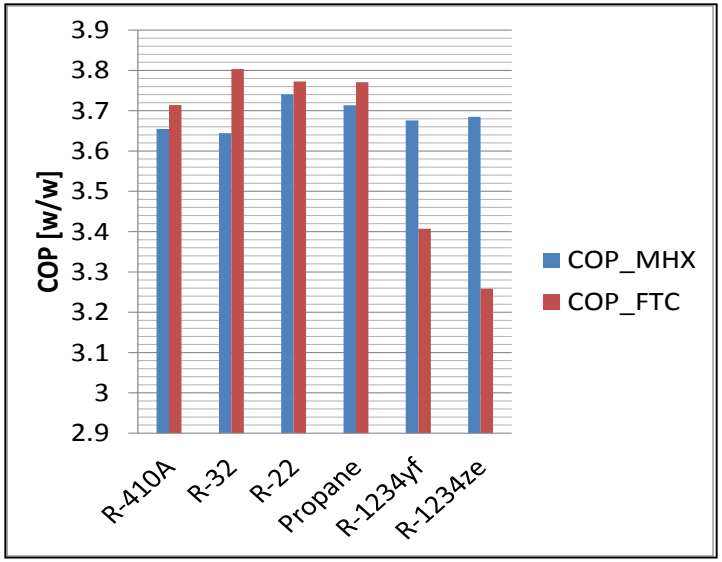
- Segment-to-segment modelling approach
- MCHX effectively **reduces system charge (50%) in HX**
- **Extend the application of flammable refrigerants**
- Preliminary design slightly lower COP for MCHX unit





HPDM model





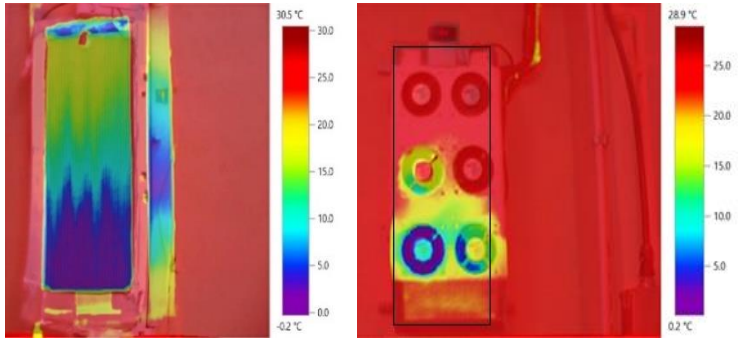
Charge and COP results

Progress and Accomplishments

Micro Channel Heat Exchanger (MCHX)

- **Analyzed** Mahle's MCHX evaporator with 3 TR 410 A unit

- **Prototype**: Integrated the MCHX evaporator, supplied by Mahle, in 1.5 TR unitary system based on HPL design
  - Developed MCHX_E design for 1.5 TR R22 and R290
  - Cost 32% less and size ~50% less than conventional fin tube evaporator
  - COP ~ 3.66 (**8% better than 5 Star** Rating - India's top rating for split AC)



Project Integration and Collaboration

Project Integration:

- Short- and long-term **visits by Indian research** partners to ORNL and other labs
- Monthly phone calls or e-mails and GoToMeeting communications
- US Industry partner, **Mahle, integrated and supplied the MCHX** as per HPL_IITB design
- Indian industry partner, Oorja, is extending support to MNITJ for radiant cooling applications

Partners, Subcontractors, and Collaborators:

- Research partners and main contributors: Indian Institute of Technology Bombay (IITB) and Malviya National Institute of Technology (MNITJ), India
- Research partners in support role: ORNL, USA
- Industry partners: Mahle, architectural application, USA and Oorja, India

Project Integration and Collaboration

Communications (Joint):

Journals:

- Khan, Yasin, Vaibhav Rai Khare, Jyotirmay Mathur, Mahabir Bhandari "Performance Evaluation of Radiant Cooling System Integrated with Air System under Different Operational Strategies". ***Energy and Buildings***. 97 (2015): 118-128.
- Mathur, Jyotirmay, Mahabir Bhandari, Vivek Kumar, Yasin Khan and Prateek Srivastava, "Development of Heat Transfer Model for Ceiling Radiant Cooling Panel through Combined Experimental and Simulation Study" ***ASHRAE Transaction*** Volume 123 Part 1.
- Jyotirmay Mathur, Mahabir Bhandari, Vivek Kumar, Yasin Khan, Prateek Srivastava, "Energy Saving Potential of Radiant Cooling System in Different Climatic Zones of India" ***Science & Technology for the Built Environment*** (accepted).

Conferences:

- ASHRAE Winter Conference, January 23 - 27, 2016, Orlando, FL, USA.
- ASHRAE Summer Conference, June 25 - June 29, 2016, St. Louis, MO, USA.
- 14th International Conference of the IBPSA– BS2015, Hyderabad, India.
- IBPSA - ASIM 2014 international conference, Nagoya -Japan, Nov 28-29, 2014.
- 3rd National Conference on Refrigeration and Air Conditioning (NCRAC-2013) IIT Madras. Chennai, Dec 12-14, 2013.
- 16th International Refrigeration and Air Conditioning Conference at Purdue, July 11-14, 2016.

Thesis work:

- **Two Master's thesis** jointly supervised by MNITJ faculty and ORNL researcher
- **One Ph.D. thesis** is jointly being supervised

Next Steps and Future Plans

- Develop the **radiant cooling system design guideline**
- Demonstrate the performance of **liquid desiccant-based DOAS** compared to **Solid Desiccant Wheels** and **membrane based** DOAS – Testing at MNIT
- Test a lab prototype of **MCHX_E 1.5 TR unitary HVAC system with R290**
- **Calibrate HPDM model** and design recommendations
- Engage industry partners to **accelerate the deployment** both in India and US market

Project Outcome Envisioned:

Radiant Cooling Systems	HVAC Testing & Modeling	Non-compressor DOAS	Micro-channel Evaporators for Unitary AC
Design guideline for practitioners	Establishment of the state of the art HVAC system test facility	Prototype designed and characterized	Two 1.5 TR prototypes characterized with two refrigerants (R22 and R290)

REFERENCE SLIDES

Project Budget

Project Budget: $500,000

Variances: None

Cost to Date: $425,000

Additional Funding: None

Budget History					
FY 2013-2016 (past)		FY 2017 (current)		FY2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$425,000	$400,000	$220,000	$100,000	$500,000	$500,000

Project Plan and Schedule