Next Generation Rooftop Unit

2017 Building Technologies Office Peer Review

CRADA project with Trane, Ingersoll Rand, US Commercial HVAC Equipment OEM

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: 10/01/2010

End date: 10/30/2016

Key Milestones

1. Lab prototype reached 21.6 IEER using R-410A; Sept. 2014.
2. Reached 22.6 IEER using R-452B; May 2015.
3. Field investigation of a prototype RTU; Oct. 2016.

Budget:

Total Project $ to Date:

- DOE: $1,535K
- Cost Share: Partner in-kind cost share exceeds DOE cost

Key Partner:

CRADA with Trane, IR

Project Outcome:

- A 14-ton prototype RTU met the project goal, i.e. reaching 21.6 IEER.
- Assessed R-452B (DR-55) as low GWP replacement, achieved 22.6 IEER.

A highest IEER RTU; contribution to evaluation of R-452B (DR-55).

Purpose and Objectives

Target Market/Audience:

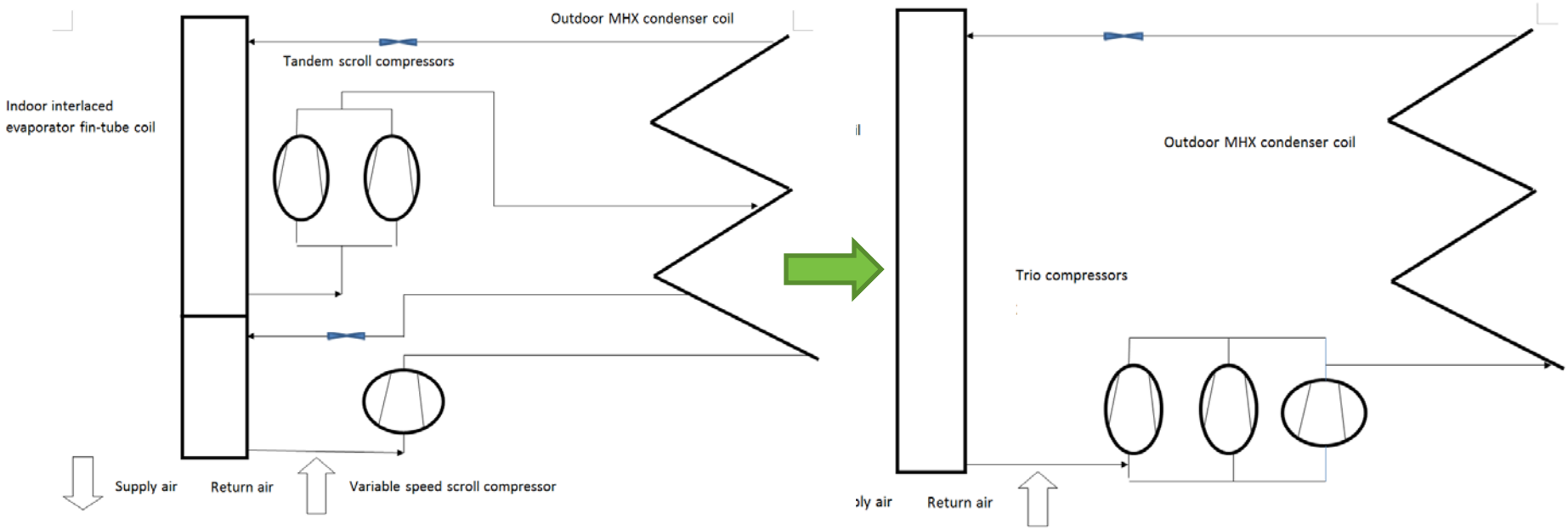
More than half of US commercial building space is cooled by RTUs. Existing rooftop HVAC units consume more than 1.3% of total US energy annually (1.0 quad source energy). If built to meet the target specification of 22 IEER, ORNL estimates that these units would reduce energy use by as much as 50% over current standards. Nationwide, if all 10- to 20-ton RTUs met the IEER goal, ORNL estimates businesses would save over $1 billion each year in energy costs, helping American companies better compete on a global scale.

US Department of Energy sponsors Oak Ridge National Lab to collaboratively work with Trane developing the highest efficiency RTU, i.e. 22 IEER.

IEER = 0.020*A + **0.617*B** + **0.238*C** + 0.125*D (ANSI/AHRI Standard 340/360)
A = EER at 100% net capacity at AHRI standard rating conditions – 95°F OAT
B = EER at 75% net capacity and reduced ambient – 81.5 OAT
C = EER at 50% net capacity and reduced ambient – 68.0 OAT
D = EER at 25% net capacity and reduced ambient – 65.0 OAT

→design for high part-load efficiency

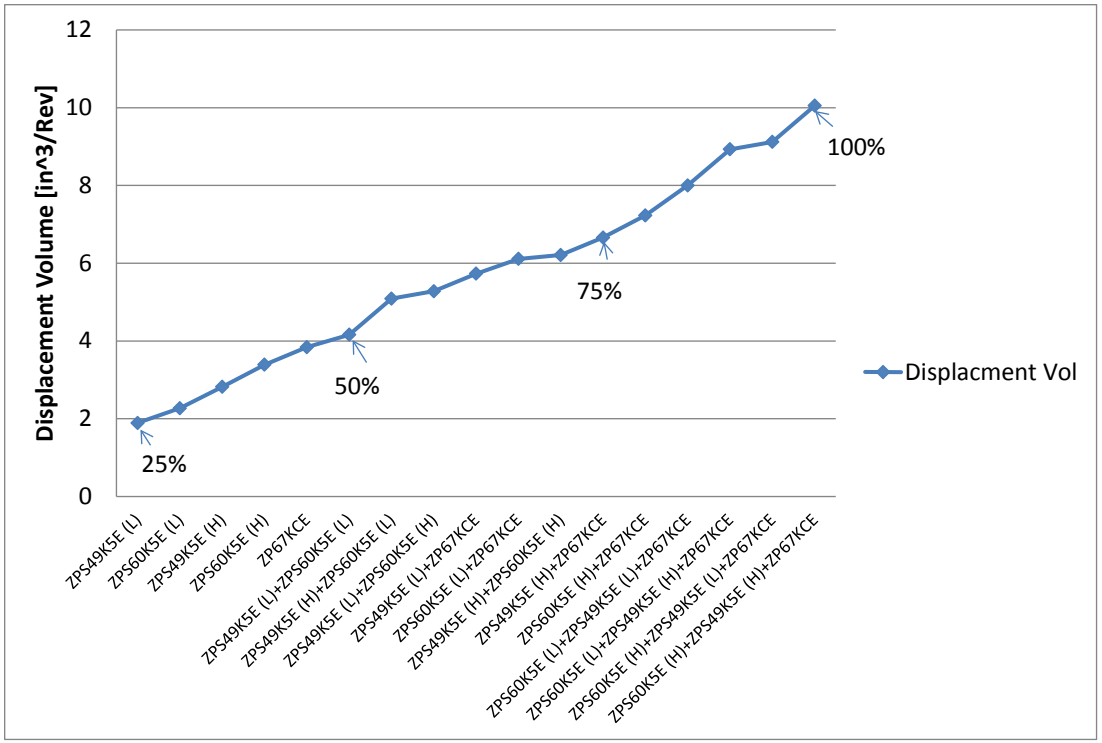
Approach - Single refrigeration system and trio compressors - Baseline Trane RTU, 17.9 IEER



Trane baseline **Improved design**

- Single refrigeration system: Utilize all heat exchanger area at all the capacity levels.

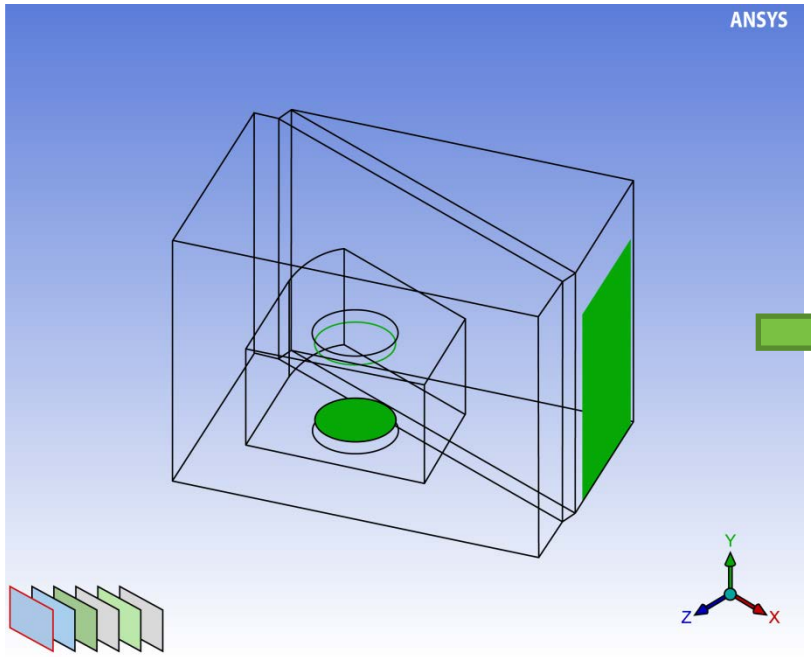
Approach: Low-cost capacity modulation-trio compressors



- Two 2-stage scroll compressors + one single-speed compressor.
- Provides 17 capacity levels without using inverter driven compressors.
- More cost effective and energy efficient option.

Approach – Improve indoor air flow and heat transfer

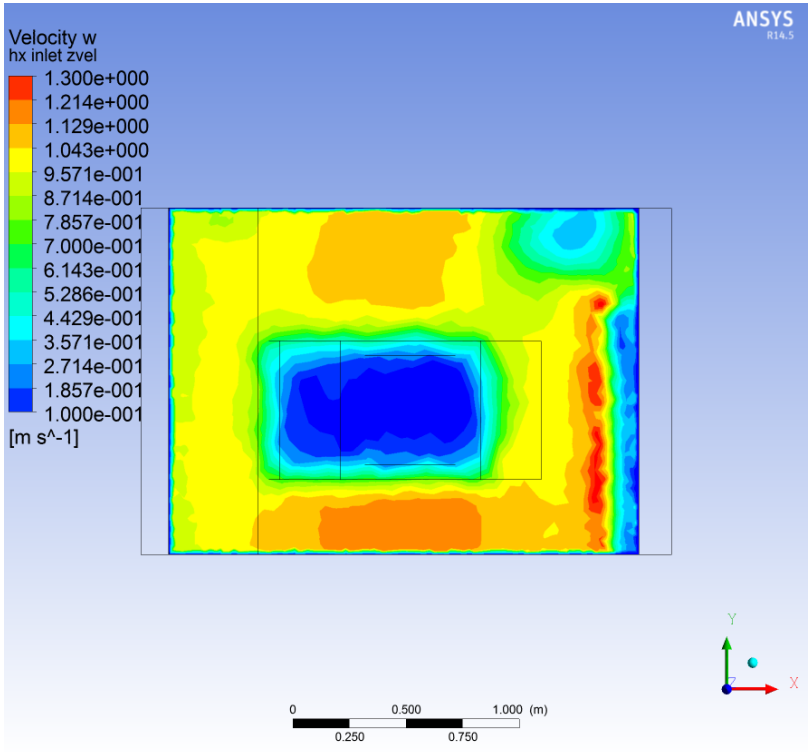
Original Trane design



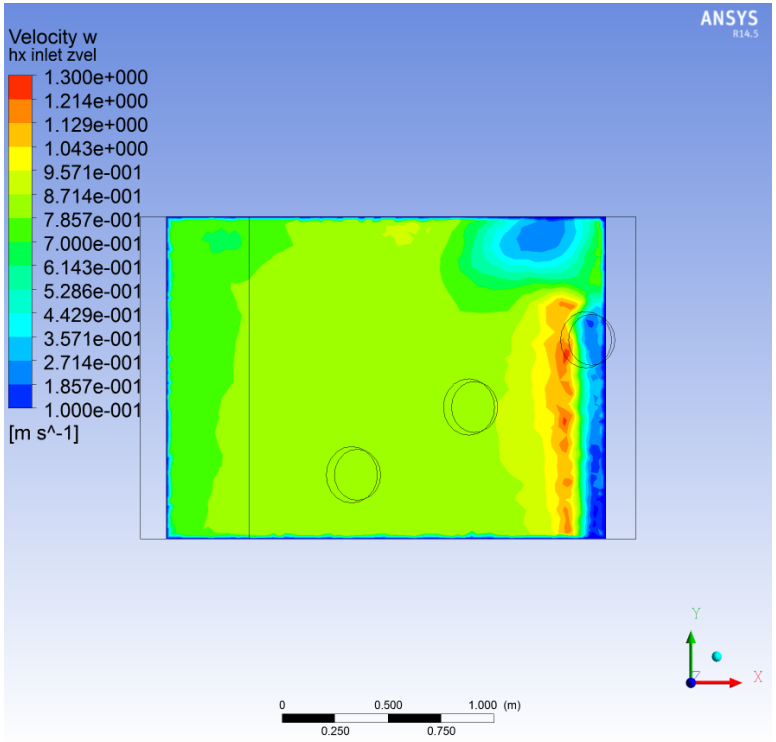
Indoor Blowers – Three Parallel Ebm-papst ECM, backward-curved blowers

Approach - Better indoor air flow distribution

Baseline, single blower

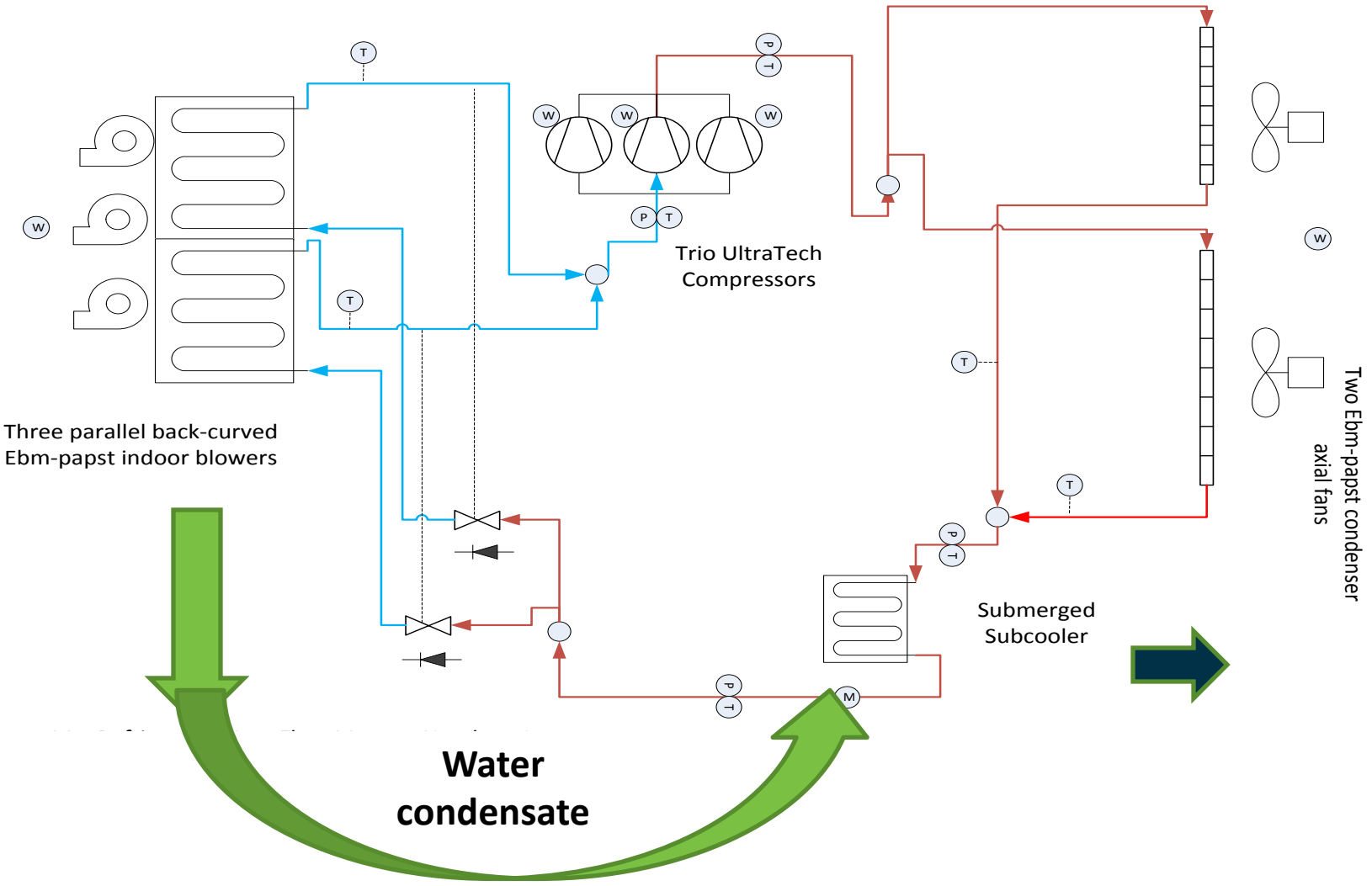


Improved, three blowers



- Improve the indoor air flow distribution and heat transfer noticeably.
- Reduce indoor blower power consumption by 30%.

Approach - Submerged subcooler to recover free cooling energy from indoor water condensate



- Recover free cooling energy, lead to 3% efficiency gain.

Progress and Accomplishments

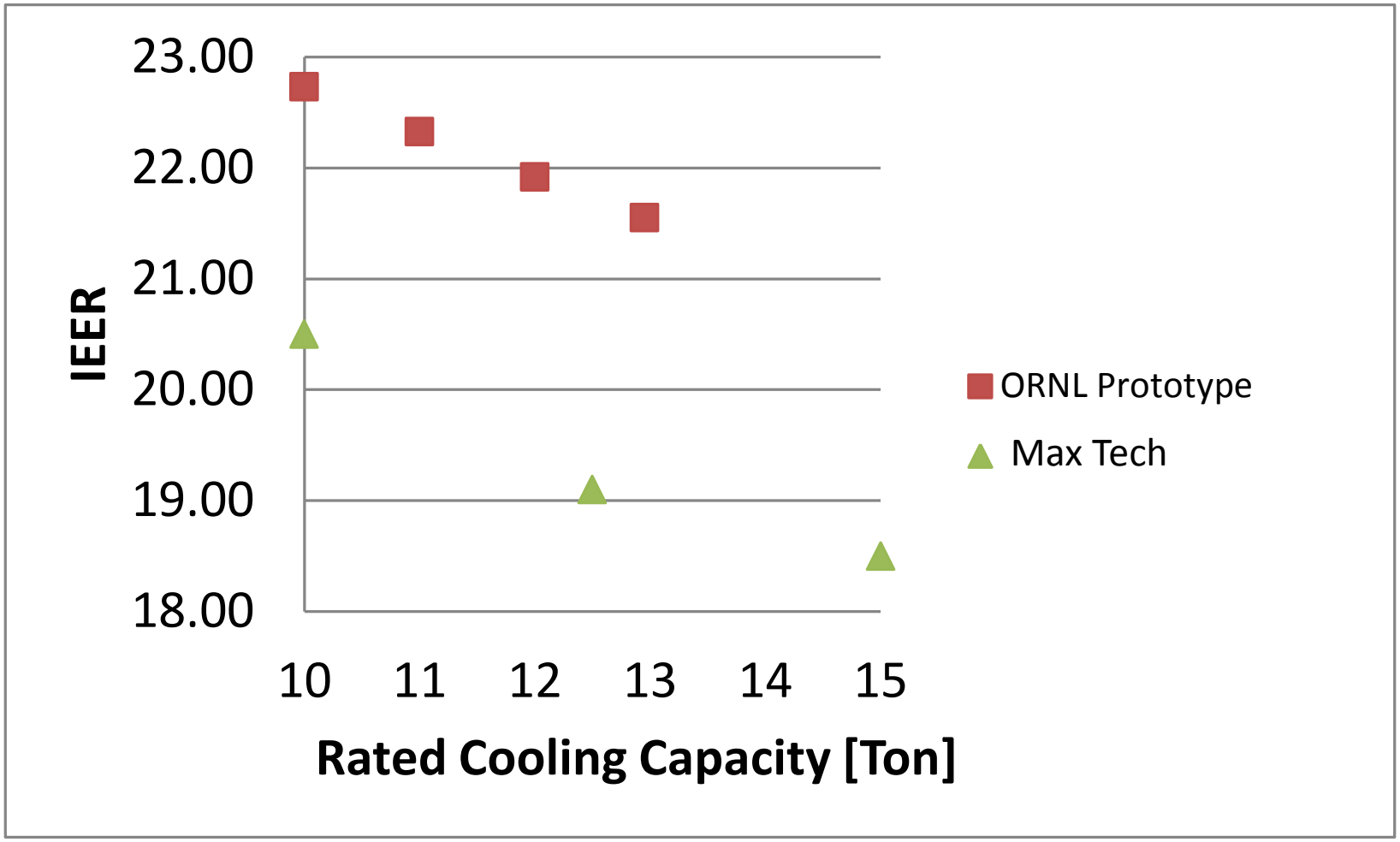
Market Assessment | Concept Design | Lab Prototyping | Optimization | Field Verification

Accomplishments:

Achieved the project goals

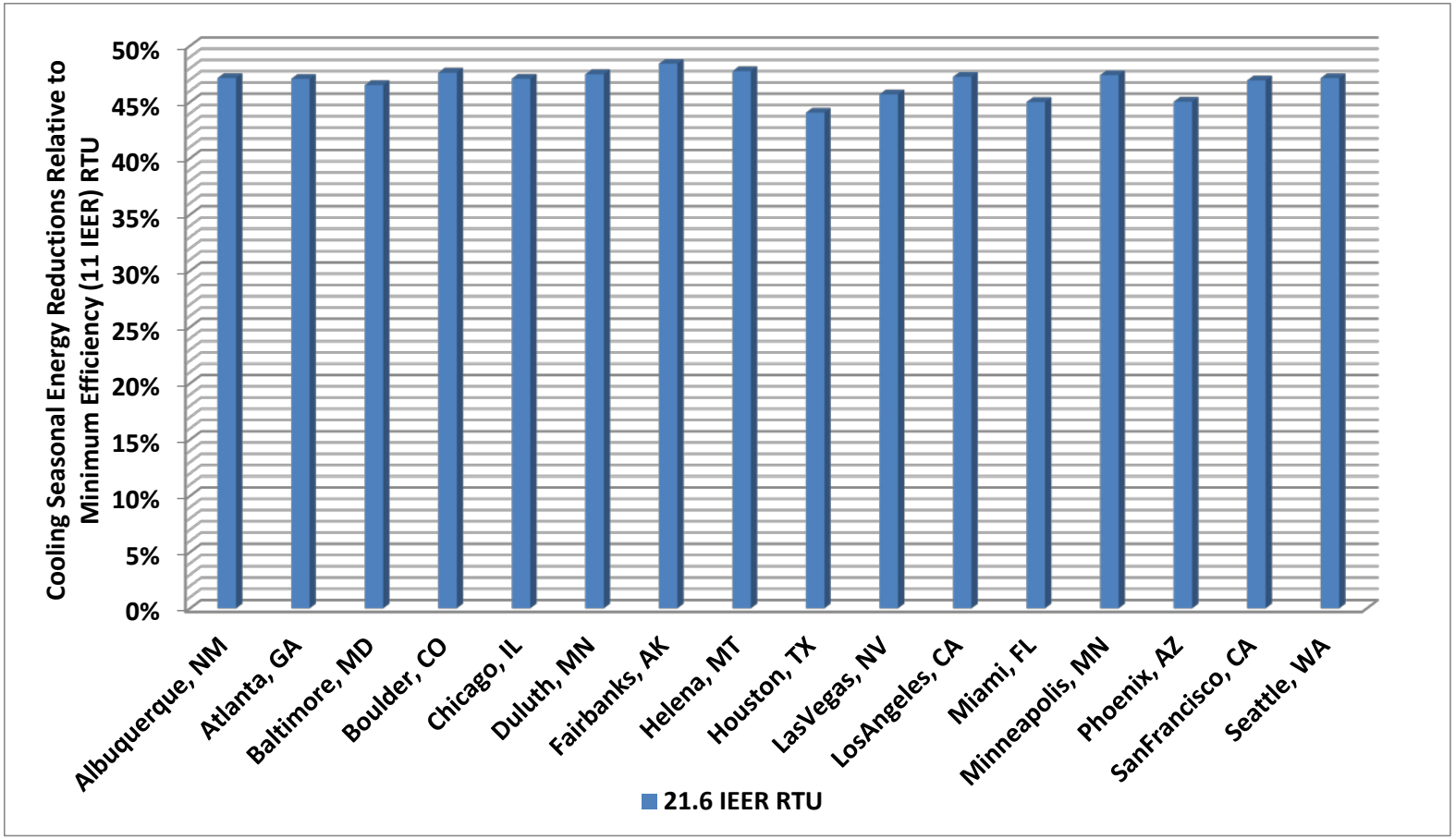
1. Lab prototype using R-410A reached 21.6 IEER.
2. Lab prototype using R-452B reached 22.6 IEER.
3. Field prototype in ORNL's flexible research platform passed field testing in 2016, reached 20.8 seasonal EER.
4. Project final report complete.

Exceed Max Tech on the market



- Max Tech data obtained in 2016.

Energy analyses completed to estimate energy saving potentials (EnergyPlus Simulations)



- Baseline single-speed RTU, IEER of 11.2, in commercial, small office buildings
- Only list the savings in vapor compression systems, not including savings by fans, economizer, etc.

Evaluate R-452B (DR-55) as drop-in replacement

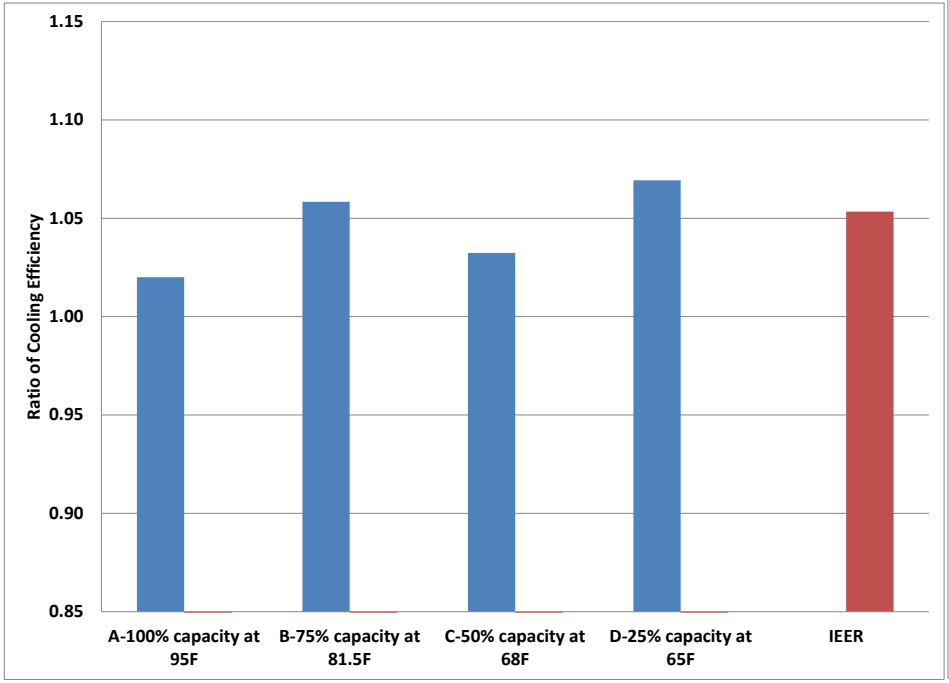
	GWP AR5	Safety Class	Glide in Condenser [K]	Glide in Evaporator [K]	Critical Temperature [C]
R-410A[a]	1924	A1	0.1	0.1	71.34
R-452B[b]	676	A2L	1.2	1.3	79.68

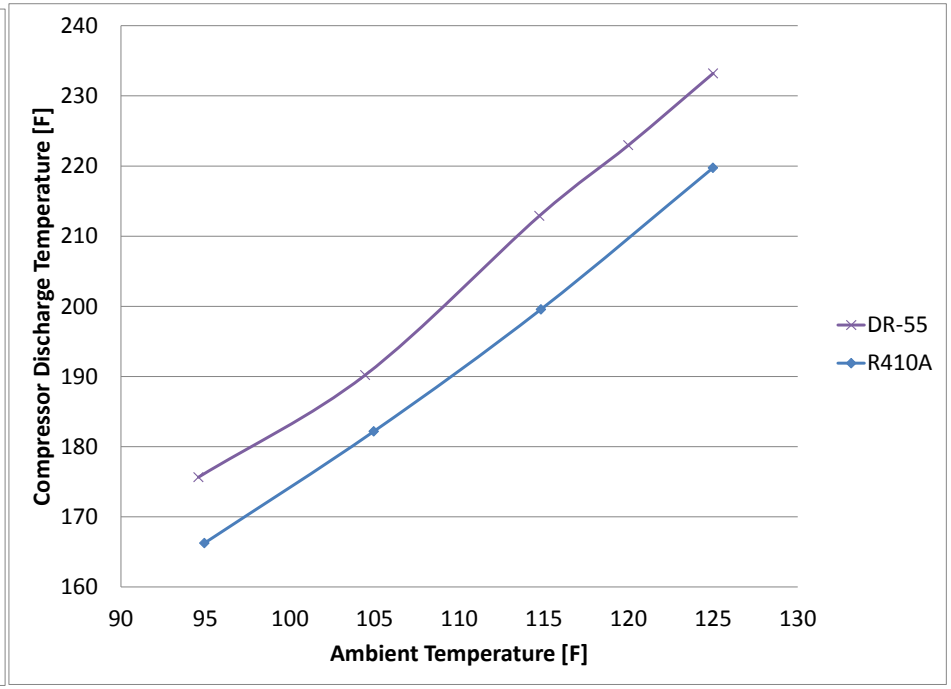
a. R-410A has mass-based compositions of R-32 (0.5)/R-125 (0.5)

b. R-452B (DR-55) has mass-based compositions of R-32 (0.67)/R-125 (0.07)/R-1234yf (0.26)

- 70% lower GWP
- Negligible glide
- Less flammable than R-32
- Comparable volumetric cooling capacity
- Better performance at high ambient temperatures

Evaluate R-452B (DR-55) as drop-in replacement





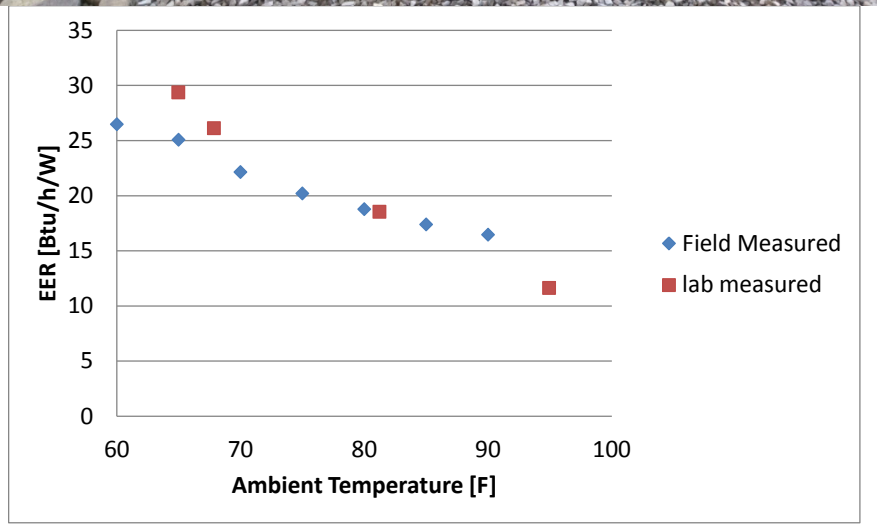
R-452B (DR-55) is 5% more efficient (IEER) than R-410A

R-452B (DR-55) has a moderate increase in discharge temperature (12 R)

Field Testing of High Efficiency RTU in ORNL's Flexible Research Platform

PV-panel powered fan to accelerate the evaporative cooling effect.

Condensate water pan containing a submerged subcooler.



- Field unit succeeded 2016 cooling season without any reliability issues.
- Field measured performance repeated lab measured performance.

Project Integration and Collaboration

Project Integration:

Component technologies:

- Collaborate with Emerson Climate Technologies to develop and use trio compressors in high efficiency RTUs.
- Collaborate with Ebm-papst Company and apply parallel backward-curved indoor blowers to improve indoor air flow and heat transfer.

Rooftop Unit Development: Provide design, analysis, laboratory and field testing support to Trane, Ingersoll Rand (CRADA).

Partners, Subcontractors, and Collaborators: CRADA partner, Trane, Ingersoll Rand.

Communications:

- Two conference papers and one journal paper.
- One ORNL invention disclosure (201603725).
- One final report.
- Project activity about R-452B reported by Japanese air conditioning, heating and refrigeration news (JARN, two issues of 08/2015, 09/2015).

Next Steps and Future Plans

Next Steps and Future Plans:

Continue field investigation in 2017

Market Impact:

1. Component technologies used on the market, e.g. trio compressors by Emerson, parallel indoor blowers in other Trane RTU products.
2. Trane working toward marketing a system.

Publications:

- Shen, B., Omar Abdelaziz, “Assessment of DR-55 as a Drop-In Replacement for R-410A”, International Refrigeration and Air Conditioning Conference at Purdue, July 11-14, 2016.
- Bo Shen, Keith Rice, 2015, “Next Generation Rooftop Unit (RTU) Development – Final Report”, ORNL Report, ORNL/TM-2015/625.
- Shen, B., Rice, C. K. and Vineyard, E. A., “Development of 20 integrated energy efficiency ratio rooftop units—system modeling and building energy simulations”. ASHRAE HVAC&R Research Journal, 19(7):836–846 (2013).
- Shen, B., Rice, C. K. and Vineyard, E. A., “Development of 20 IEER Rooftop Units – A Simulation Study”, International Refrigeration and Air Conditioning Conference at Purdue University, July 16-19, 2012.

REFERENCE SLIDES

Project Budget

Project Budget: DOE total $1,535K- FY11-17
Cost to Date: ~$1,535K through March 2017
Additional Funding: None expected

Budget History					
FY 2011 to FY 2016 (past)		FY 2017 (current)		FY 2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,435K	*	$100K	*	NA	NA

- In-kind contribution from CRADA partner–exceeds DOE funding level; exact total is confidential information.

Project Plan and Schedule

Original initiation date: 01-Oct-2010 -- Planned completion date: 30-May-2017

Go/no-go decision points

* Lab prototype reached 21.6 IEER using R-410A - Sept/2014 - passed
* Reached 22.6 IEER using R-452B – May/2015 - passed
* Field investigation of a prototype RTU– October/2016 - passed