High-Efficiency Low-GWP Compressor

2017 Building Technologies Office Peer Review

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

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Project Summary

Timeline:

Start date: September, 2015

Planned end date: August, 2017

Key Milestones

- ✓Phase1: Design complete for Go/No-go review. Metrics: 5TR capacity; 76% $\eta_{compression,}$ (Aug. 2016)
- Phase 2: Prototype testing and data analysis complete; 5TR capacity; 73% $\eta_{flange\text{-}to\text{-}flange}$; 2.1 primary COP (Aug. 2017)

Budget:

Total Project $ to Date: (through Jan 2017)

- DOE: $702,472
- Cost Share: $301,059

Total Project $:

- DOE: $974,054
- Cost Share: $417,452

Key Partners: (none)

Project Outcome:

United Technologies Research Center will demonstrate a high efficiency compressor design that is critical to enabling low direct-GWP high-efficiency small-commercial rooftop systems

Two compressor prototypes designed, fabricated and tested for a 5 TR rooftop advancing the TRL from 2 to 5.

Purpose and Objectives

Problem Statement:

- Current small commercial building HVAC systems use R410A with GWP=2088*.
- Potential regulations and market drivers are pushing the HVAC&R industry to lower direct GWP and higher efficiency systems (indirect GWP).
- New low-GWP refrigerants require new approaches for compressor and system design in order to achieve high efficiency and safe/reliable operation.

Target Market and Audience:

- Mid-term - light commercial rooftop cooling (3 to 20TR)
- Long-term - Residential systems (1.5 to 5 TR)

Impact of Project:

- 30% primary annual energy savings and with low GWP enabled through:
  - 2 prototype compressors advancing TRL from 2 to 5 ($\eta_{compression,total} \geq 73\%$**)
  - 5 TR rooftop design (< 25$/kbtu; SEER > 20)
  - Potential plan for system demonstration (2019); field trial (2021)

* IPCC AR4 (2007)

** Drive and compression.

Approach

Approach:

- Leverage proprietary UTC HVAC and aerospace compressor design experience & tools.
- Carrier proprietary software to design rooftop system
- Maximize optimal seasonal efficiency (SEER) through modeling
- Use Carrier supply chain to determine cost impact of new components.
- Demonstrate compressor performance on calorimeter over required operating envelope. Two prototype iterations.

Key Issues:

- Maximizing compressor efficiency over a wide range of operating conditions including low-capacity for SEER rating. Minimize system cost.

Distinctive Characteristics:

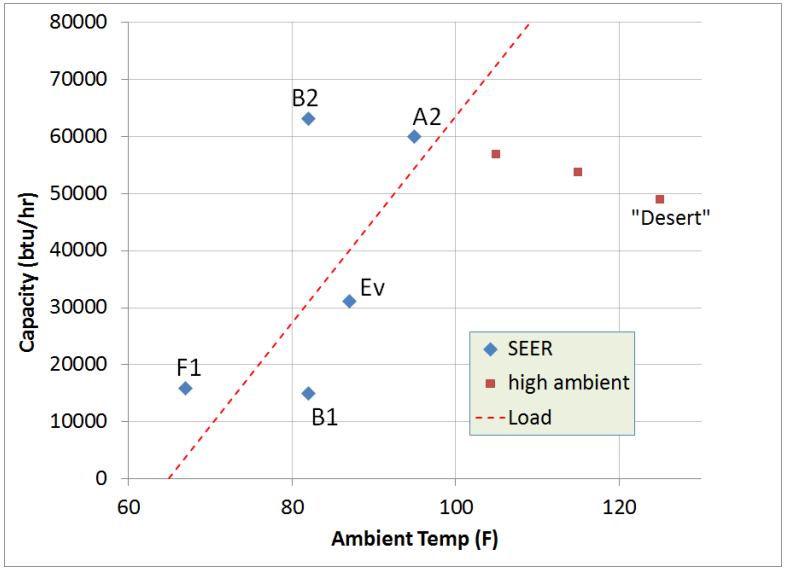
Combination of novel compression with low GWP refrigerant, high efficiency and system-level design optimization that is scalable for residential and light commercial HVAC systems

Progress and Accomplishments

Accomplishments:

- Phase 1 approval secured (Aug. 2016) based on compressor design & analysis
- Prototype 1 compressor testing metrics met (Jan. 2017)
- System analysis show >20SEER achievable and cost premium <$25/1000btuh

Capacity Requirements
(ARI 210/240 + High-Ambient)



SEER analysis conditions

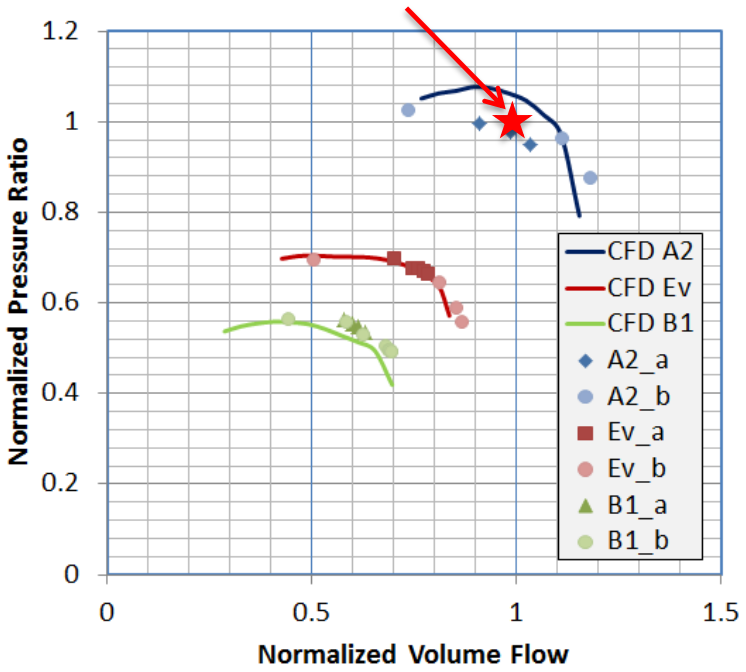
Compressor Calorimeter Test Rig (Phase 1 approved)

Progress and Accomplishments

- Prototype 1 testing metrics met (aero-performance, compression flow and eff.)

Pressure-Flow Curve

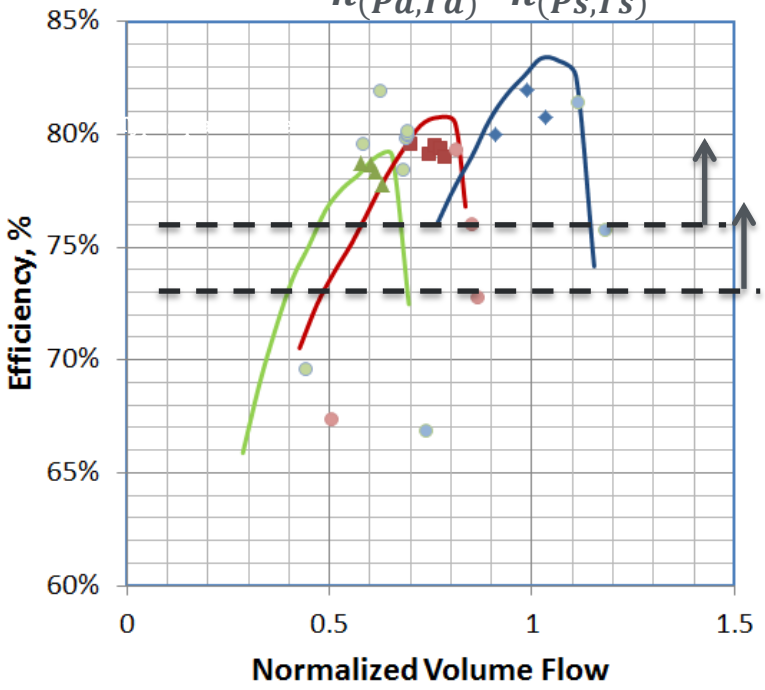
Normalized Design requirements (ARI-A)



- Required flow and pressure rise achieved for design point (ARI-A)
- Lower speed for off-design (SEER Ev and B1), achieve predicted pressure-flow curves.

Efficiency-Flow Curve

$$eff = \frac{h_{(Pd,ss)} - h_{(Ps,Ts)}}{h_{(Pd,Td)} - h_{(Ps,Ts)}}$$

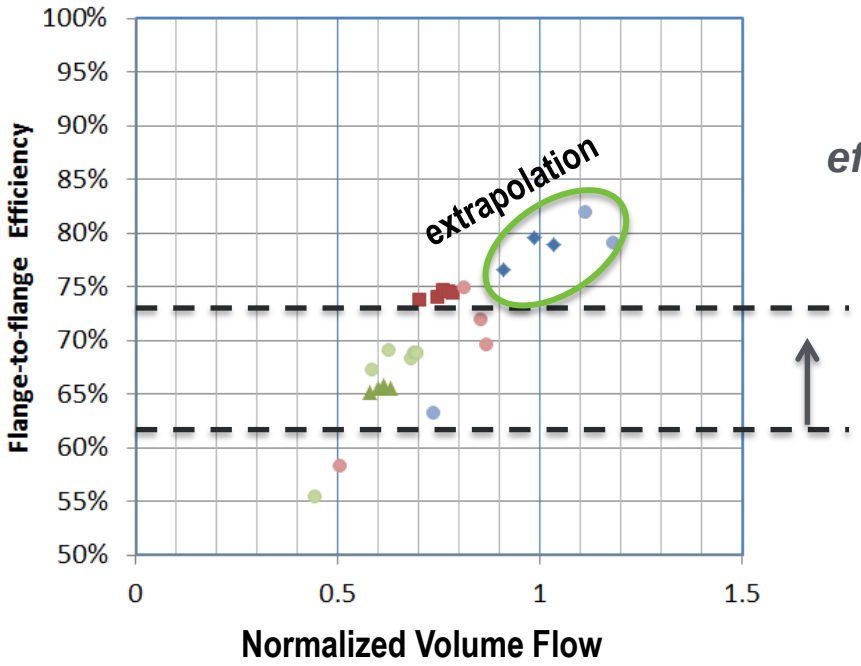


- Exceed required compression efficiency at all required conditions

(lines: CFD predictions; points: data)

Progress and Accomplishments

- Prototype 1 testing metrics met: flange-to-flange efficiency including motor.
- Currently running smoothly, >50hrs of operation



$$eff = \frac{\dot{m}\left(h_{(Pd,ss)} - h_{(Ps,Ts)}\right)}{\dot{P}ow}$$

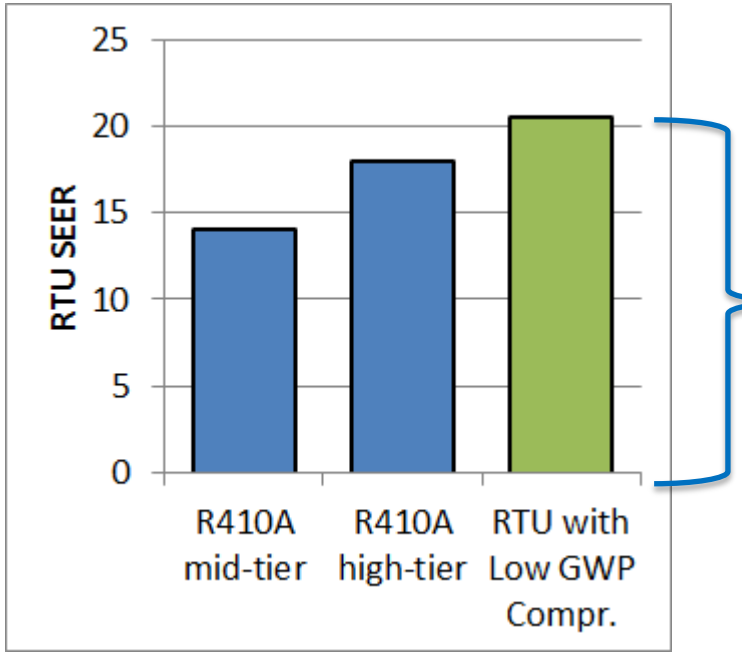
Prototype 2 testing target (project end)

Prototype 1 testing target

- Flange-to-flange exceeds Prototype 1 testing target at all required conditions

Progress and Accomplishments

- SEER analysis shows >20SEER possible
  - Heat Exchanger and RTU system optimization study completed.



- Variable Speed Compressor
- High-Tier Fans
- Higher efficiency refrigerant

Progress and Accomplishments

Market Impact:
The UTRC team is heavily engaged with the Commercial North American HVAC division of Carrier Corporation. This engagement ensures that metrics are met during development to accelerate future transition. Carrier Corporation proprietary tools and other standard work are being used throughout the execution of the project which helps transition the developed system.

Awards/Recognition: none.

Lessons Learned:
Maximize extension of compressor envelope operability
Need to further optimize design (compression, motor etc.) to meet all compressor power metrics for phase 2

Project Integration and Collaboration

Project Integration:

- Carrier Corporation is the commercialization path for HVAC technologies and concepts developed at UTRC.
- Carrier is the world's largest manufacturer and distributor of HVAC&R equipment and has a long history of developing successfully commercialized products.
- UTRC project team is closely engaged with product and engineering teams to ensure metrics are met during conceptualization and testing phases
- Carrier is providing partial cost share for this project and significant in-kind contribution

Partners, Subcontractors, and Collaborators: None.

Communications: Presented at UTC CTO and CEO reviews

Next Steps and Future Plans

Next Steps and Future Plans:

- Prototype 2 Design, modifications suggested from Prototype 1 data.
  - Motor, compression and test rig
- Plan for system and field demonstrations
- Revisit value proposition
- Support Carrier evaluation of compressor and system

REFERENCE SLIDES

Project Budget

Project Budget: $1,391.5K
Variances: none
Cost to Date: $1,002.5K
Additional Funding: Cost Share 25% UTRC, 5% Carrier.

Budget History					
Sept. 4, 2015 – FY 2016 (past)		FY 2017 (current)		FY 2018 (NA, to be completed FY2017)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$537,284	$230,265	$165,187	$70,795	0	0

Project Plan and Schedule