Working Fluids: Low Global Warming Potential Refrigerants

2014 Building Technologies Office Peer Review

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Project Summary

Timeline:
Start date: 01-Oct-2010
Planned end date: 30-Sep-2016

Key Milestones
1. Data analysis and reporting of supermarket system: baseline and alternative refrigerants; 12/31/2014
2. Perform initial field testing of alternative refrigerant in 3rd party installation; 9/30/2014
3. Deliver enhanced Life Cycle Climate Performance (LCCP) Design Tool; 9/30/2014

Budget:
Total DOE $ to date: $2,650K
Total future DOE $: $1,000K ($500K for FY15 and $500K for FY16)

Target Market/Audience:
Residential and Commercial Heating, Air Conditioning, and Refrigeration with a Primary focus on Commercial Refrigeration due to the large leak potential

Key Partners:

<table>
<thead>
<tr>
<th>Honeywell</th>
<th>CRADA Partner and Key Contributor</th>
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<tbody>
<tr>
<td></td>
<td>Subcontractor and LCCP Design Tool Developer</td>
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Project Goal:
To develop low Global Warming Potential (GWP) refrigerant solutions for the Heating, Air Conditioning and Refrigeration (HVAC&R) market through leadership in Life Cycle Climate Performance (LCCP) modeling, experimental evaluation, and field testing.
Purpose and Objectives

Problem Statement:

- HCFC phase out resulted in the use of high GWP HFC
- Newly developed low GWP refrigerants are blends that require more studies: flammability, glide, heat transfer, efficiency/GWP trade-off

Target Market and Audience:

- Residential and Commercial HVAC&R: emphasis supermarket refrigeration
- Using the BTO Market Definition; these sectors are responsible for ~11.4 Quads in 2030 (1.59 Quads for supermarket refrigeration)

Impact of Project:

1. Development of a validated Open Source LCCP Design Tool
2. Development of best practices for low GWP refrigerant switch-over with a documented field study results
3. The project impact
   a. Number of software downloads and web-traffic, field test performance
   b. Successful pilot low GWP supermarket refrigeration installation
   c. Market share of low GWP supermarket refrigeration
Approach

• Characterize performance of alternative low GWP refrigerants developed by Honeywell, our CRADA partner in HVAC&R equipment
  – Heat exchangers testing
  – Compressor calorimeter testing
  – Supermarket refrigeration system

• Develop an Open Source Life Cycle Climate Performance (LCCP) Design tool to allow the next generation of HVAC&R engineers to design equipment with life cycle emissions as an important decision factor
Approach: Key Issues

• Large quantity of high GWP refrigerants currently in use in existing HVAC&R equipment
  – R-404A has a GWP$_{100}$ of 3700, typical Supermarket Refrigeration-Centralized DX charge is 3000 lbs

• Identify low GWP refrigerant replacements which are drop-in replacements

http://www.littletonair.com/refrigerants_and_your_air_condit.html
Approach: Distinctive Characteristics

• Develop an open-source LCCP Design tool
  – Anticipated to be the internationally recognized “go-to” tool to assess environmental impacts of HVAC&R equipment
  – Involve the industry: ASHRAE MTG.Low GWP, AHRI
  – Involve the international community: participation through IIR working party and IEA Heat Pump Center

• Determine low GWP refrigerant performance:
  – Supermarket refrigeration system, under controlled lab conditions using N-40 (GWP = 1273)
  – Compressor calorimeter evaluations
  – Heat exchanger evaluation
Progress and Accomplishments

Lessons Learned:
- Need for adequate moisture management
- Reduce number of quick coupling (leak potential)
- Need to properly size the expansion valves to achieve adequate superheat controls; especially with alternative refrigerants

Accomplishments:
- Developed an Open Source LCCP Design Tool (http://lccp.umd.edu/) with a web-based interface for air source heat pumps and supermarket refrigeration (FY2013 Q4 Milestone)
- Tested baseline R-404A and alternative low GWP N-40 refrigerants in a supermarket refrigeration system under a controlled environment in an experimental test bed (FY2014 Q1 Milestone)
- Analyzed the LCCP of several supermarket refrigeration systems with various refrigerants
- Evaluated a heat exchanger with baseline and 2 alternative refrigerants (FY2014 Q2 Milestone)
Life Cycle Climate Performance (LCCP) – DOE Links
ORNL-LCCP Desktop Application Download
ORNL-LCCP Web Application
Progress and Accomplishments

Full-Scale Supermarket Refrigeration Experimental Evaluation under Controlled Laboratory Conditions

- N40 performance over R-404A over the ambient temperature range
  - Reduced compressor power by 3.7%
  - Increased refrigeration capacity by 7.5%
  - Increased system COP by 11.6%
The actual superheat of 407A and 407F is usually higher than R404A. This results in matched capacities at lower refrigerant flow rates.
Progress and Accomplishments

Market Impact:
• Based on the favorable results of N-40 and its low GWP (1273); it is expected that it will become the optimal solution for supermarket refrigeration systems
  – The CRADA partner expects to launch it this year (pending some approvals)
  – “Relevant” end users have shown strong support for using N-40 already

• Web-based LCCP tool is highly used: 661 unique users to-date

• 2012 Purdue Conference Paper on LCCP of Commercial Refrigeration:
  – 167 downloads in the last year only

• ASHRAE MTG Alternative Global Warming Refrigerant
  – Growing membership
  – Expanding Program

• AHRI AREP
  – Successful participation in the program

Awards/Recognition:
None
Project Integration and Collaboration

Project Integration:

- ASHRAE MTG on low GWP refrigerant research
- AHRI AREP testing
- International Institute of Refrigeration (IIR) working party on LCCP
- Attending conferences (regional, national, and international)

Partners, Subcontractors, and Collaborators:

- Honeywell: CRADA Partner; low GWP refrigerant developer and global supplier
  - Mark Spatz: Director of Refrigerants Technology/Sponsor
  - Samuel Yana-Motta: Refrigerants R&D Leader/Project manager
  - Gustavo Pottker: Experimental Engineer/Scientist
  - Ankit Sethi: Modeling/Simulation Engineer/Scientist
  - Paul Sullivan: Application support
- University of Maryland: Subcontractor; development of Open Source LCCP Design Tool
  - Reinhard Radermacher: Center Director
  - Vikrant Aute: Principal Investigator
Communications: Last 12 Months

SEMINAR PRESENTATIONS (1)

CONFERENCE PAPERS (5)

JOURNAL ARTICLES (1)

WEBINARS (1)
Next Steps and Future Plans:

- Develop field test plan and identify field test site for evaluation of alternative refrigerant in 3rd party installation (6/30/2014)
- Perform initial field testing of alternative refrigerant in 3rd party installation (9/30/2014)
- Complete 3rd party field evaluation and report results (6/30/2015)
- Perform testing of low GWP refrigerants in equipment that has been modified or designed specifically for the alternative refrigerant (9/30/2015)

Planned and Submitted Publications:

- Beshr et al. 2014. 15th Int. Ref. & Air Cond. Conf., West Lafayette, IN.
  - Impact of Charge Degradation on the Life Cycle Climate Performance of a Residential Air-Conditioning System
REFERENCE SLIDES
Project Budget: DOE Total $3,650K, FY11-16.

Variances: Budget cut by $850k due to program prioritization, timeline relaxed for 2 years to accommodate the budget cut.

Cost to Date: ~ $2,461K through February 2014

Additional Funding: None expected.

### Budget History

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<tr>
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<th>FY2011 – FY2013 (past)</th>
<th>FY2014 (current)</th>
<th>FY2015 – FY2016 (planned)</th>
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<tr>
<td>DOE</td>
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<tr>
<td>Cost-share</td>
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<tr>
<td></td>
<td>$2,200K</td>
<td>$450K</td>
<td>$1,000K</td>
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* In-kind contribution from CRADA partner – matches or exceeds DOE funding level; exact total is confidential information
# Project Plan and Schedule

## Project Schedule

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<tr>
<th>Task</th>
<th>FY2013</th>
<th>FY2014</th>
<th>FY2015</th>
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<tr>
<td></td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
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<td>Past Work</td>
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<tr>
<td>Q2 Milestone: LCCP Analysis, Refrig. System</td>
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<td>Diamond</td>
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<td>Q3 Milestone: LCCP Tool Expansion (ASHP)</td>
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<td>Q4 Milestone: LCCP Analysis, ASHP</td>
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<td>Diamond</td>
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<tr>
<td>Q4 Milestone: Sensitivity/Validation of LCCP Tool</td>
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<td>Diamond</td>
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<tr>
<td>Current/Future Work</td>
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<tr>
<td>Q1 Milestone: Refrigeration System Evaluation</td>
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<tr>
<td>Q2 Milestone: Heat Exchanger Evaluation</td>
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<td>Q3 Milestone: Field Site Test Plan</td>
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<td>Q4 Milestone: Initiate Field Testing</td>
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<td>Q3 Milestone: Complete Field Testing</td>
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<td>Q4 Milestone: Testing of Advanced Equipment</td>
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**Legend:**
- **Completed Work:** Blue
- **Active Task (in progress work):** Black
- **Milestone/Deliverable (Originally Planned):** Use for missed
- **Milestone/Deliverable (Actual):** Use when met on time

**Project Start:** 1 October 2011

**Projected End:** 30 September 2016