Low-Cost Gas Heat Pump for Building Space Heating

2014 Building Technologies Office Peer Review

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

Michael Garrabrant
mgarrabrant@stonemtntechnologies.com
Stone Mountain Technologies, Inc.

Project Summary

Timeline:

Start date: **March 01, 2013**

Planned end date: **February 28, 2015**

Key Milestones:

1. **Cycle & System Design: 12/31/2014**
2. **Breadboard Test Results: 06/30/2014**
3. **Packaged Prototype Results: 02/28/2015**

Budget:

Total DOE $ to date: **$305,396**

Total future DOE $: **$597,474**

Target Market/Audience:

Residential & Light Commercial Space Heating

Light Commercial Potable Water Heating

Key Partners:

A.O. Smith
Gas Technology Institute

Project Goal:

Develop and demonstrate a gas-fired absorption heat pump, with heating COP's greater than 1.0 at low ambients. Design simplicity and volume manufacturing requirements emphasized from conception. Achieving a projected 2-5 year economic payback to drive market penetration is a higher priority than ultra-high efficiency.

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Purpose and Objectives

Problem Statement:

- Conventional gas-fired heating products at technical max, COP < 1.0.
- Heating capacity of electric vapor compression heat pumps fall below 50% of rated at low ambients. Not applicable for cooling dominated climate zones.
- Gas-fired absorption heat pumps can provide heating COP's well above 1.0, even at low ambients.
- Heating capacity of gas-fired absorption heat pumps remains above 80% of rated at low ambients.
- Current gas-fired absorption products are too large, too complex, and too expensive for residential and light-commercial heating markets.
- A right-sized, low-cost gas-fired absorption heat pump with an economic payback less than 5 years is needed reduce heating energy use in heating dominated climate zones.

Purpose and Objectives

Target Market and Audience:

- Owners of single and multi-family homes in heating dominated climate zones.
  - High-efficiency alternative to a furnace or boiler
  - Retrofitable to current building inventory

- Users of commercial hot water heaters with capacities less than 250,000 Bth
  - Small restaurants and office buildings

- Owners of residential swimming pools that are currently heated using gas boilers, electric resistance or electric heat pumps.

Residential Gas Space Heating: 3.5 Quads (185.5 Million Metric Ton CO_2) [1]
(65% Cool Climate Zones) [2]

1 http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.1.5
1 http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.4.3
2 http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.1.18

Purpose and Objectives

Impact of Project:

- Family of products for residential and light commercial space/DHW heating, distributed through existing HVAC channels by multiple OEMs.
- U.S. based manufacturing of gas heat pump sealed systems sold to multiple OEMs for integration into specific products for their specific customers and markets.

Proposed Development Schedule (after R&D project):

Year 1: Design refinements, 1-2 field test units installed, demonstration units provided to 1 or more OEM partners, reliability program initiated.

Year 2: OEM agreement(s) in place, product refinement, 4-5 field test units installed, reliability program continues, sealed system mfg investment in place.

Year 3: Product certification, sealed system production initiated, product(s) available in the market.

Approach

Approach:

- Cycle optimization for cost and reliability (not just performance).
- Component design focused on commonality of raw material, processes, scalability (up and down for future models). Scaling up (8X) low cost solution pump design.
- Focused modeling and optimization for evaporator coil (highest cost component).
- Breadboard testing prior to packaged prototype development to verify performance, allow quick evaluation of design options.
- Parallel development of controls and design for modulation.
- 3rd Party Validation of Packaged Prototype performance.

Key Issues:

- **Evaporator Testing:** Validation of design model to ensure we arrive at optimized design for packaged prototype (achieve target cost and performance).
- **Rectifier Performance:** Achieving target ammonia purity using simple, low-cost design.
- **System Behavior**: Understanding system behavior, especially at start-up and reduced load conditions (controls development for modulation, important for real-life seasonal energy efficiency and customer satisfaction).

Approach

Distinctive Characteristics:

- Design for manufacturing and cost from initiation of R&D. Ensure we do not design unnecessary costs “in” from the start.
- Commonality of component design to maximize raw material purchasing power and minimize capital equipment investment.
- Development in conjunction with current market-leading OEM so that required product features and voice-of-customer are incorporated from the start.
- Development in conjunction with natural gas industry so that product features and capabilities are communicated at early stage; streamline and speed-up market demonstration and education activities.

Progress and Accomplishments

Accomplishments:

- Cycle optimization and component design completed ahead of schedule, providing additional time for breadboard testing and evaluation of design alternatives.
- Significantly exceeded first performance-based (COP) milestone during very early stage of breadboard testing. Has provided time to focus on detailed component improvements and balance of system (i.e.. combustion) rather than macro problem resolution.
- Alpha evaporator coil confirmed to be over-sized (expected), with test data providing promise that very aggressive Beta coil (just received) will approach performance goals at a projected 50% cost reduction compared to Alpha.
- Preliminary manufacturing cost estimates, based on breadboard prototype designs, are within our target range.

Progress and Accomplishments

Market Impact:

- Based on early performance testing and preliminary manufacturing cost estimates, we are on-track to meet performance and cost goals.
- A product meeting these goals projects to 3-5 year economic payback, without incentives, for our target markets.
- SMTI is negotiating with OEM(s) to provide early prototypes for evaluation, in parallel with the fabrication of the packaged prototype under this project. This will speed up the post-project process of product design completion and commercialization.
- SMTI continues to keep the natural gas industry informed of our progress, product features, and target markets via communications and presentations to GTI, Energy Solutions Center (ESC), Consortium for Energy Efficiency (CEE), and ACEEE.

Project Integration and Collaboration

Project Integration:

- Market-leading OEM is a sub-contractor and providing cost-share.
- Gas Technology Institute is a sub-contractor and providing cost-share through contributions from gas utilities.
- Both are in constant communication with SMTI via conference calls, emails, and quarterly project reports (going both directions).
- GTI keeps gas utility sponsors updated via bi-annual meetings and informal communications.

Partners, Subcontractors, and Collaborators:

- **AO Smith (OEM):** Provides component design, fabrication, testing support, market research, and cost share to the project.

- **GTI:** Provides combustion system design and testing, system performance testing, cost share and gas utility communication.

Communications:

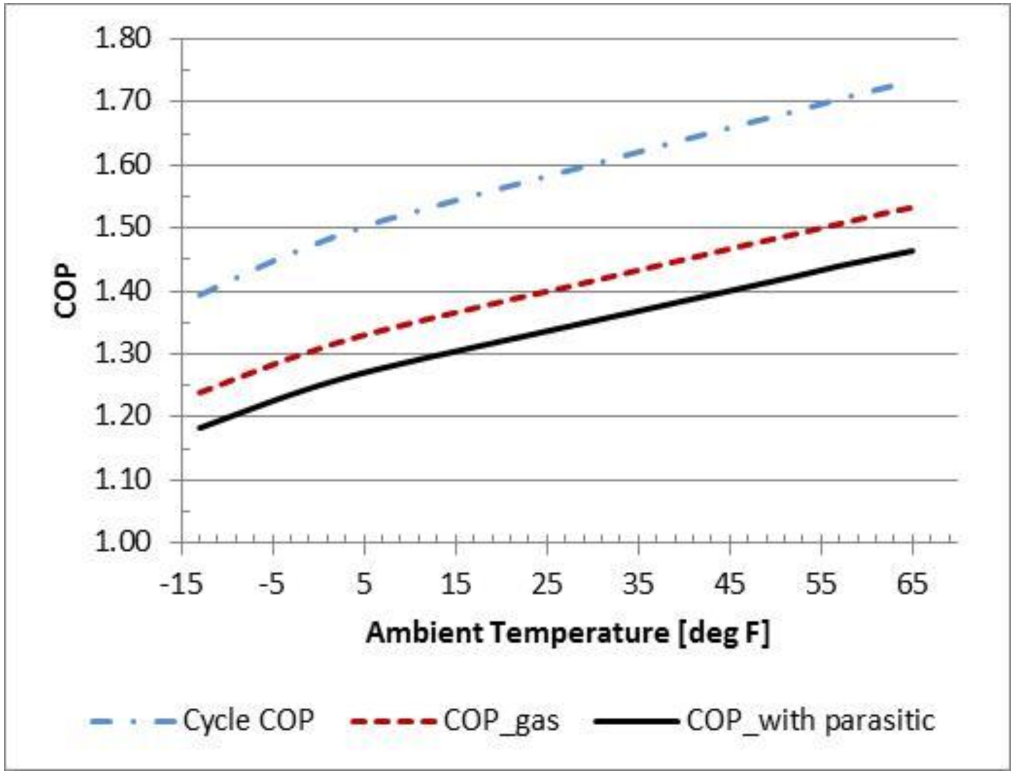
ACEEE Hot Water Forum, Energy Solutions Center Annual Meeting, CEE member conference call presentation, GTI bi-annual meetings with gas utility research sponsors, International Sorption Heat Pump Conference.

Next Steps and Future Plans

Next Steps and Future Plans:

- Fabrication of demonstration units for OEM in-house evaluation.
- Sponsored field test/field demonstrations through CEC and U.S. Air Force (with GTI program management and gas utility cost share).
- Expansion of Product Family via:
  - Development of a larger capacity model for commercial water heating in privately sponsored partnership with OEM.
  - Install additional field test units of our small residential heat pump water heater (potable water heating) via GTI and gas utility sponsorship.
- If we stay ahead of schedule and budget, fabrication of a 2nd packaged prototype for additional SMTI testing and industry demonstration.

Modeled and Target Performance



Ambient [F]	COP [gas HHV]	Capacity [Btu/hr]	Hyd Return [F]	Hyd Supply [F]
47	1.40	80000	100	120.0
32	1.36	77300	100	119.4
17	1.31	74700	100	118.7
-13	1.20	68500	100	117.1

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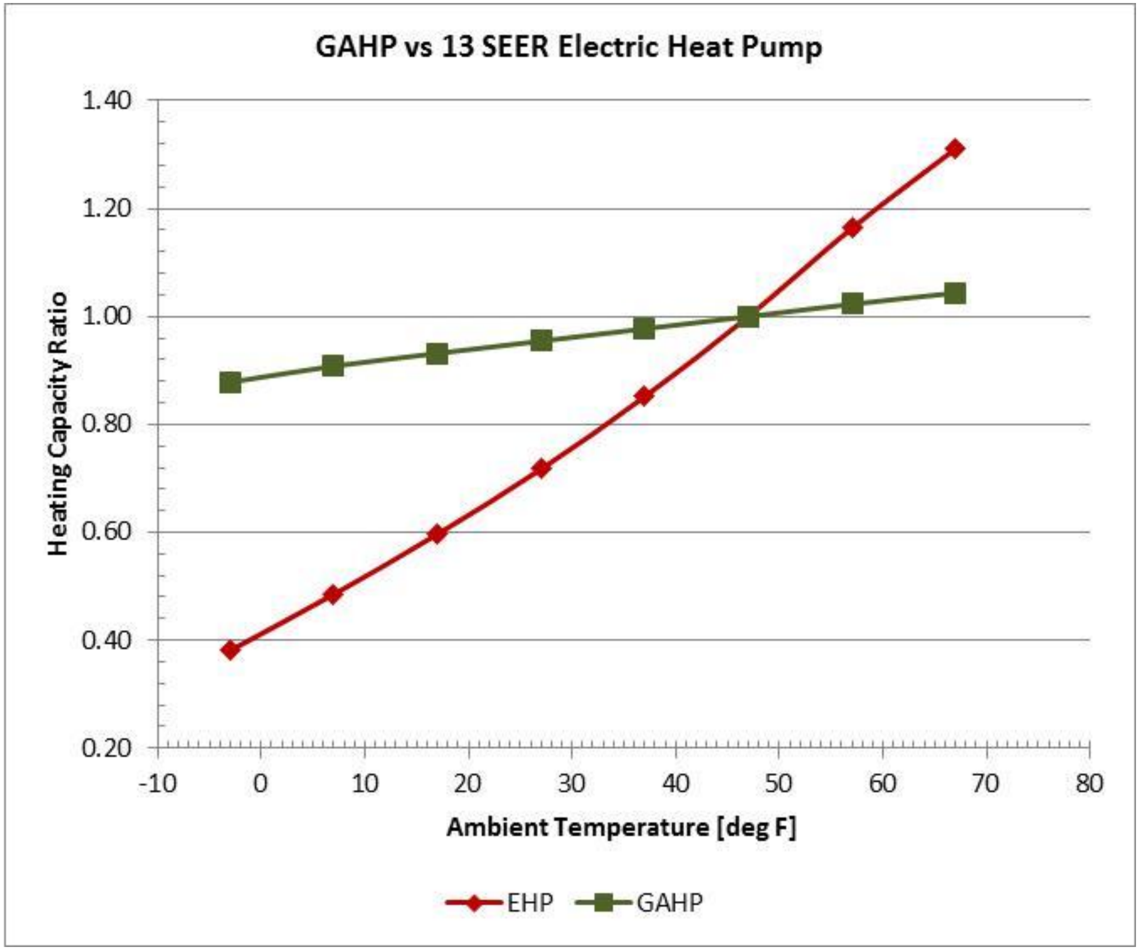
Comparison to Electric Heat Pumps



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Project Budget

Project Budget: $902,870 (Fed) + $232,294 (CS) = $1,135,164

Variances: Currently Under-Budget. No Schedule Impact.

Cost to Date: Federal: $305,396 of $902,870 (33.8%)
Cost Share: $90,631 of $232,294 (39%)

Budget History					
03/01/13 – FY2013 (past)		FY2014 (current)		FY2015 – 02/28/15 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$243,694	$72,449	$514,999	$108,245	$144,177	$51,294

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Project Plan and Schedule

Project Schedule		
Project Start: 03/01/2013		Completed Work
Projected End: 02/28/2015		Active Task (in progress work)
	◆	Milestone/Deliverable (Originally Planned) use for missed
	◆	Milestone/Deliverable (Actual) use when met on time

	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
M1: Cycle Modeling			◆									
M2: Cycle Heat HX and Combustion Design				◆								
M3: Solution Pump Design and Testing					◆							
M4: Breadboard Fabrication					◆							
Current/Future Work												
M5: Breadboard Testing							◆					
M6: Condensing HX Prototype Testing							◆					
M7: Packaged Prototype Fab & Assy									◆			
M8: Packaged Prototype Preliminary Testing									◆			
M9: Packaged Prototype Final Testing										◆		