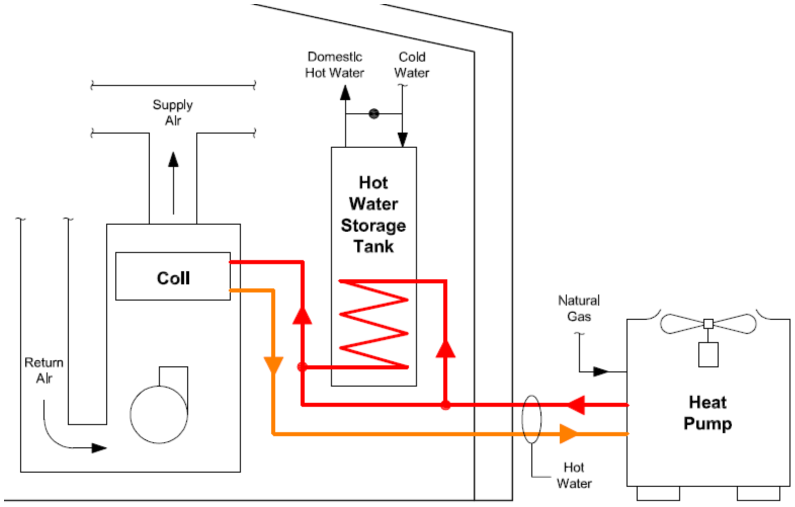
Low-Cost Gas Heat Pump for Building Space Heating

2016 Building Technologies Office Peer Review



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

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Project Summary

Timeline:

Start date: **March 01, 2013**

End date: **August 31, 2015**

Key Milestones:

1. **Cycle & System Design: 12/31/2014**
2. **Breadboard Test Results: 12/31/2014**
3. **Alpha Packaged Proto Results: 04/01/2015**
4. **Beta Packaged Proto Results: 08/31/2015**

Budget:

Total DOE $ to date: **$901,842**

Total future DOE $: **$0**

($1,028 under budget)

Target Market/Audience:

Residential & Light Commercial Space Heating

Light Commercial Potable Water Heating

Simultaneous Water Heating/Space Cooling

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.

What We Use For Gas Heating Has Not Changed Much

Furnaces | Boilers | Water Heaters

Non-Condensing Models Are 75 – 83% Efficient

Condensing Models Are 90 – 98% Efficient

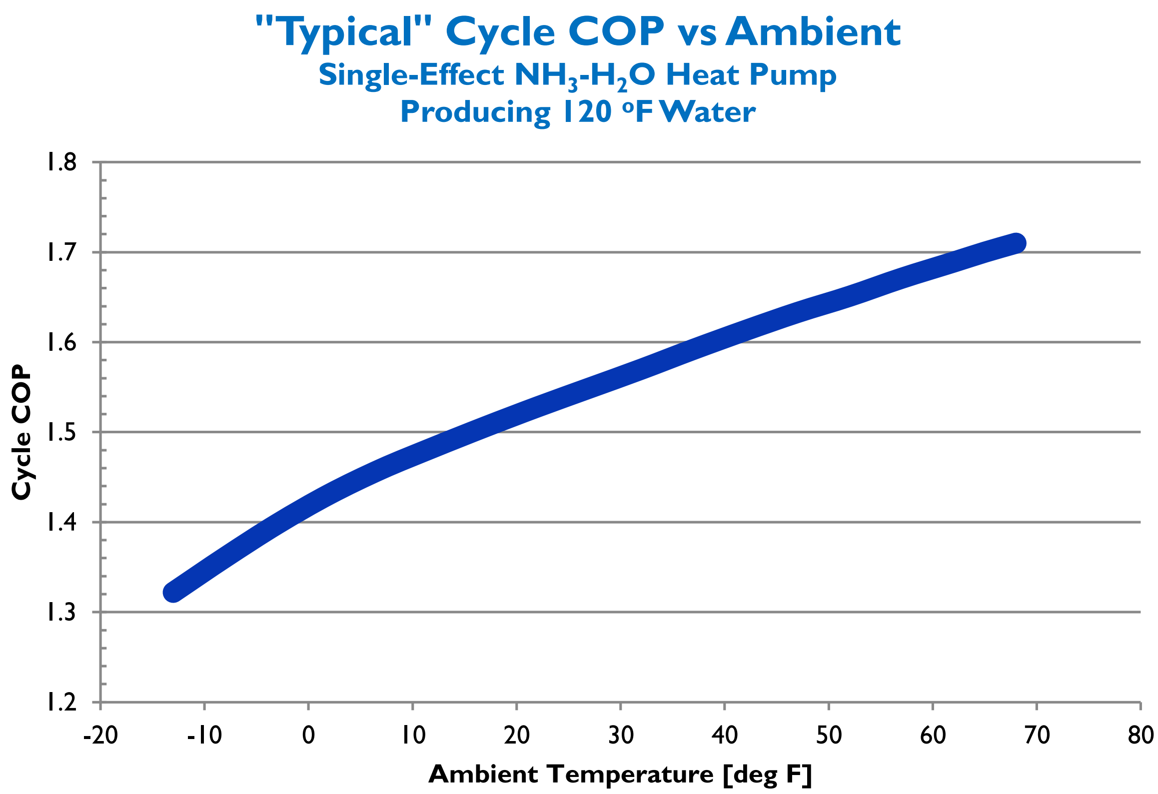
Direct Fired @ Maximum Efficiency
OEM Product Differentiation?
Efficiency Program Incentives?

Need COP >> 1.0
Must Work at Low Ambients
Must be Economically Viable

Purpose and Objectives

Gas Absorption Heat Pumps

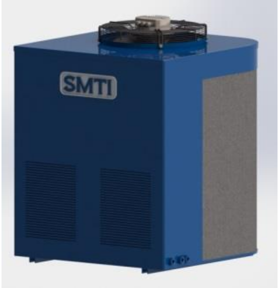
Excellent Heating Efficiencies Even at Low Ambients



Problem: Historically Complex Cycles and High Cost

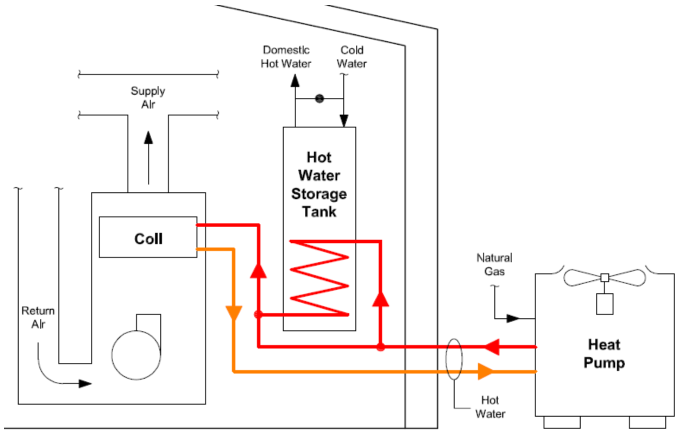
Purpose and Objectives

80,000 Btu/hr (23 kW) @ 47ºF



COP = 1.40	47ºF (8.3ºC)
COP = 1.35	32ºF (0ºC)
COP = 1.30	17ºF (-8.3ºC)
COP = 1.20	-13ºF (-25ºC)

- *COP @ HHV of gas*
- *Parasitic Power < 750 watts*
- *Condensing Combustion Efficiencies*
- *At least 3:1 Modulation*
- *20ºF (11.1ºC) Hydronic Differential*
- *Consumer Price ~$4,500*



TARGET APPLICATIONS

- Residential Space & Water Heating (cool/cold climates)
  - *3.5 Quads (185.5 Million Metric Ton CO_2) (65% Cool Climate Zones)*
- Commercial Space & Water Heating (all climates)
- Commercial Simultaneous Water Heating & Space Cooling (all climates)
- Pool Heating
- New Construction & Retrofit

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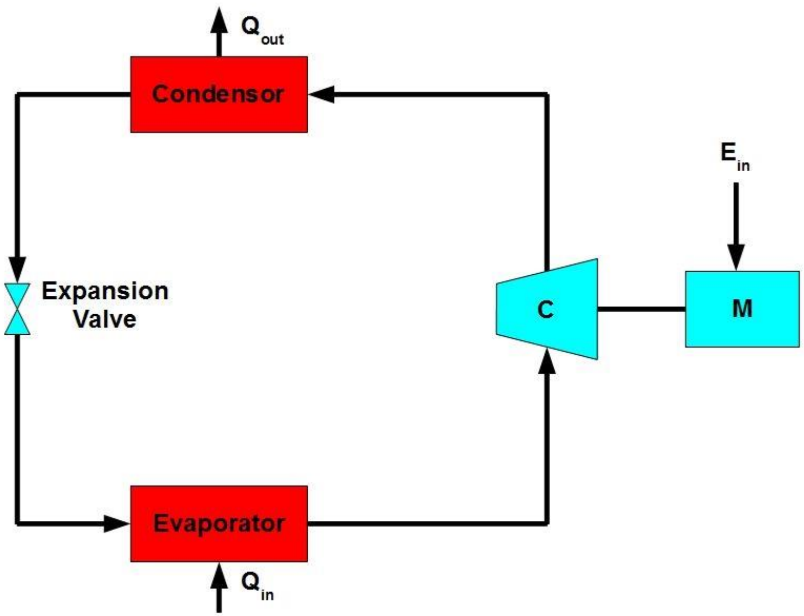
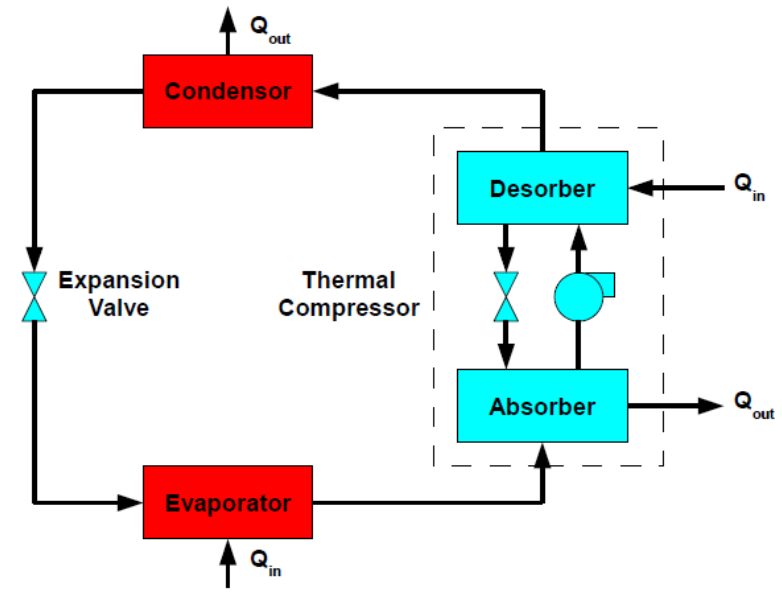
How Does It Work?





COP_h = Qcond/E_{in} = 3.0-4.0

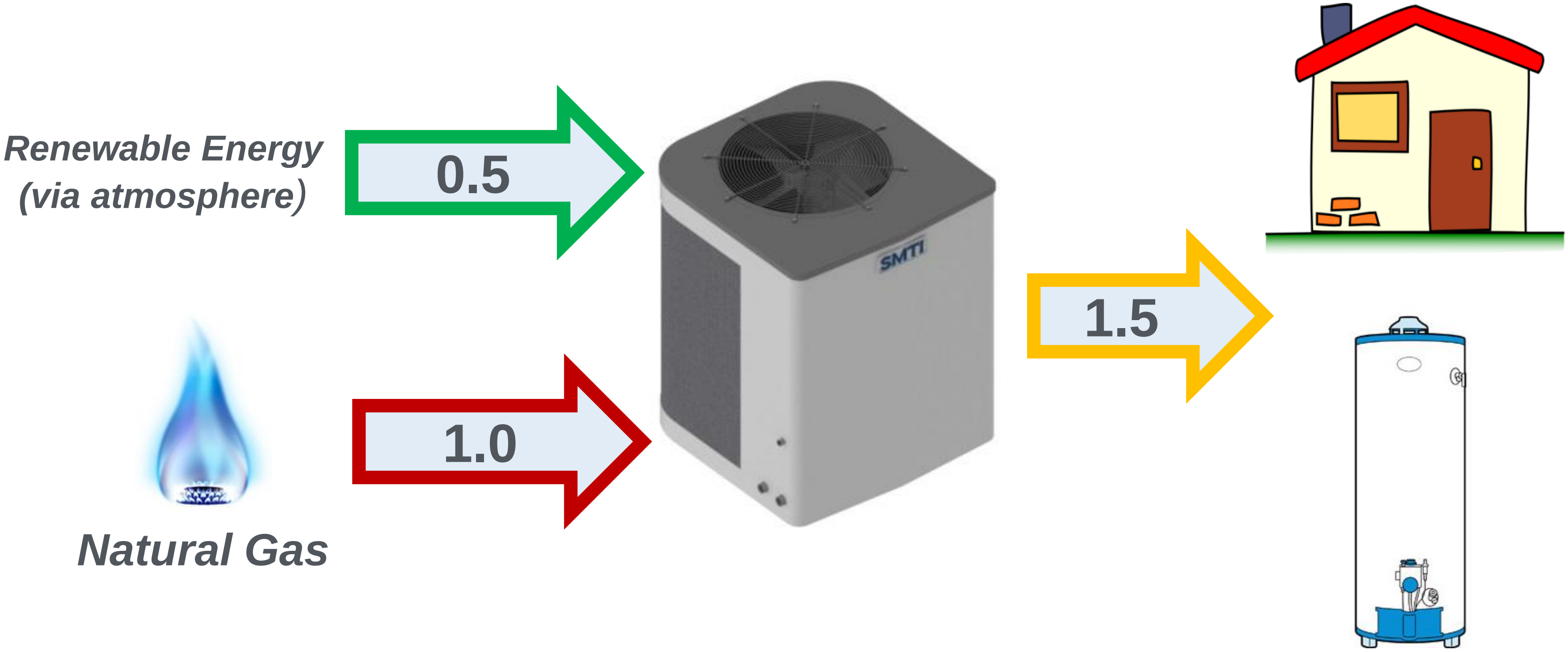
Qheat = ~1.2 x Qevap

COP_h = (Qcond + Qabs)/Q_{in} = 1.4-2.0

Qheat = (Qcond + Qabs) ~ 2.5 times Qevap

Capacity & COP Remain High at Low Ambient Temperatures

Gas Absorption's Renewable Energy Content: 35%



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Purpose and Objectives

Target Customers for SMTI Thermal Compressor:

HVAC & Water Heating OEMs That Want to Offer Gas Heat Pump Products

OEM

Anchor Partners

Partners, Not Competitors
Speed to Market
Reduced R&D and Capital Investment
Quicker Access to Export Markets

U.S. based manufacturing, family of Thermal Compressor products

Winter 2015/2016:	**Controlled Field Testing, Reliability**
Winter 2016/2017:	**Customer Agreement(s) in Place, Large Field Test, DFM, Vendor Qualifications**
FY2018:	**Certification and Production Start**

Approach

- **Simple Cycle, optimized for cost and reliability.**
- **Commonality of raw material, processes, and scalability.**
- **Total Cost Focus from beginning.**
- **Optimization of evaporator coil (highest cost component).**
- **Breadboard development, then packaged prototype.**
- **Parallel development of controls and design for modulation.**
- **3rd Party validation of Packaged Prototype performance.**
- **OEM and Natural Gas Industry Partners to Ensure Market Acceptance & Education**

Key Issues:

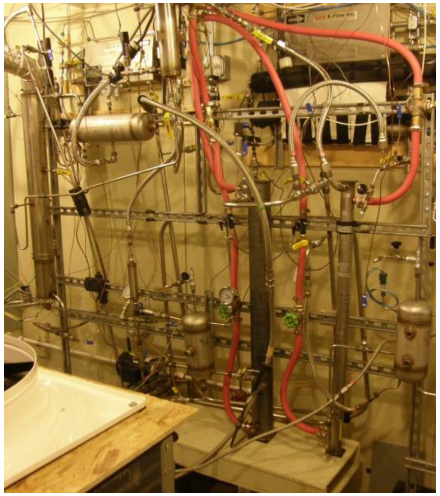
- **Evaporator Coil Design:** Validation of design model to ensure we arrive at optimized design for packaged prototype (achieve target cost and performance).
- **Rectifier Performance:** Achieving target ammonia purity using simple, low-cost design.
- **Scalability of Low-Cost Solution Pump**
- **System 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).

Progress and Accomplishments

Accomplishments:

- ✓ **Optimized Simple Single-Effect Cycle That Predicts Target Performance.**
- ✓ **Breadboard Testing: 95% Performance Target and 4:1 Modulation Achieved**
- ✓ **Evaporator Design Model Developed and Verified w/Experimental Data**
  - ❖ **Optimized coil ~25% cost reduction from original design**
- ✓ **Low-Cost Solution Pump Successfully Scaled Up Factor of 10.**
- ✓ **Alpha 1 Packaged Prototype Fabricated & Lab Tested: 97% Target**
  - ❖ **Performance Verified By Gas Technology Institute (GTI), 4:1 Modulation**
- ✓ **Alpha 2 Packaged Prototype Fabricated & Lab Tested: 97% Target**
  - ❖ **Reduced Parasitic Power ~15%**
  - ❖ **Modulating Evaporator Fan**
  - ❖ **Achieved 160º F Supply Water Temperature**
  - ❖ **Trialed ECM Solution Pump Motor for Additional Parasitic Power Reduction**
- ✓ **Manufacturing cost estimate is within our target range.**

Progress and Accomplishments



Breadboard

Alpha 1

GTI Testing
Alpha 1

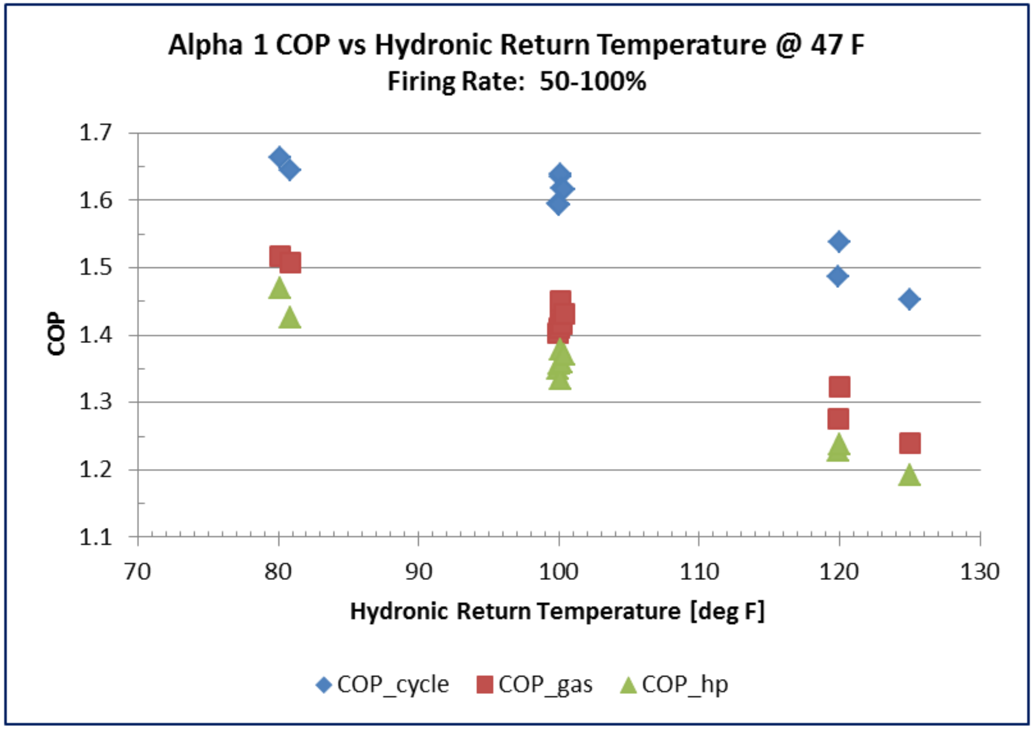
Alpha 2

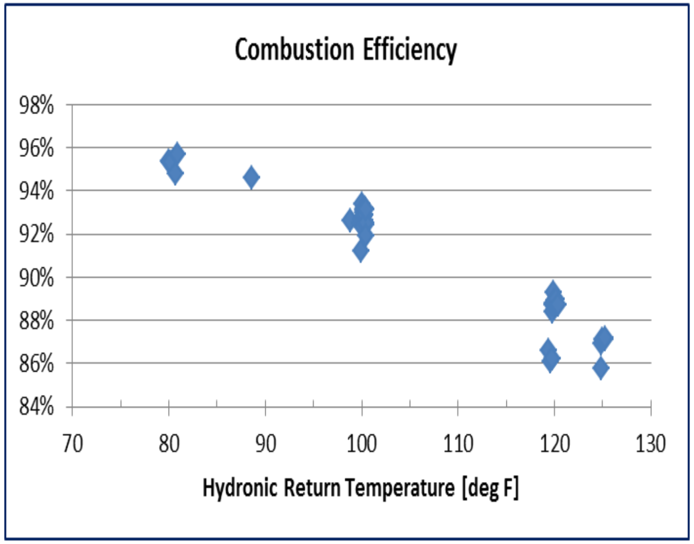
Progress and Accomplishments: Alpha 1

GTI

Ambient Temperature (°F)	COP_gas	Capacity (Btu/hr)	Hydronic ΔT (°F)
47	1.50	79,584	22.5
35	1.44	79,703	19.7
17	1.37	71,919	17.9
-13	1.17	55,746	14.7

SMTI





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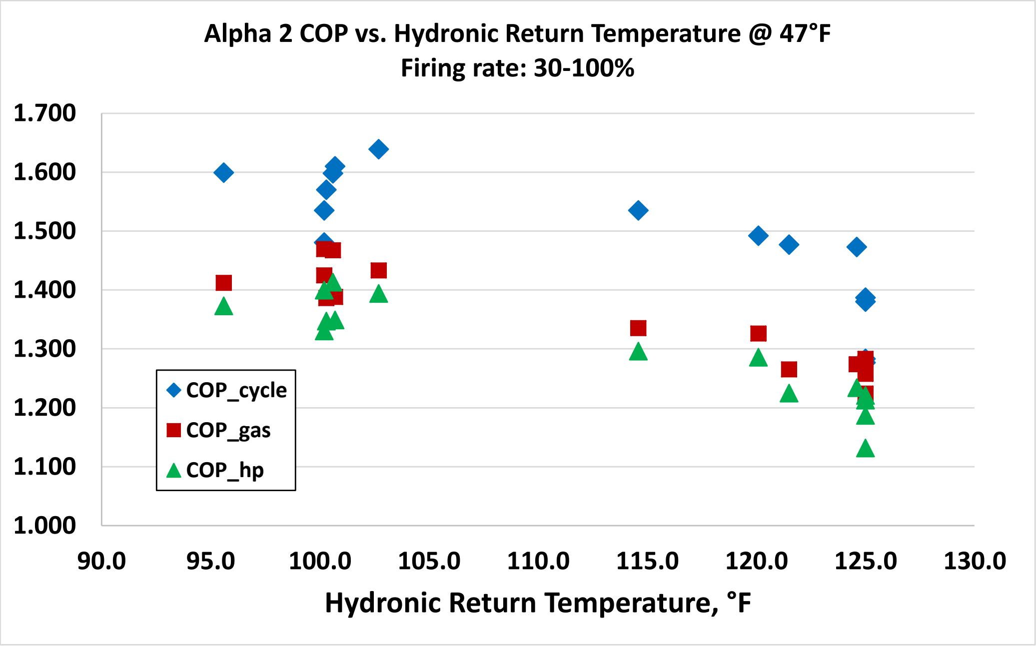
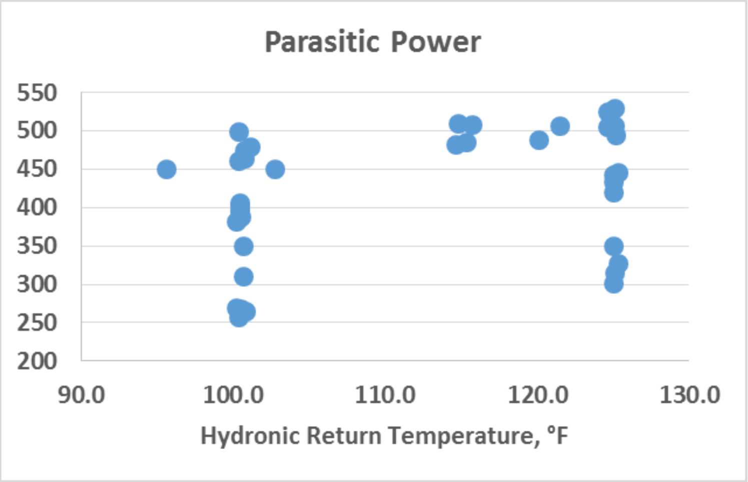
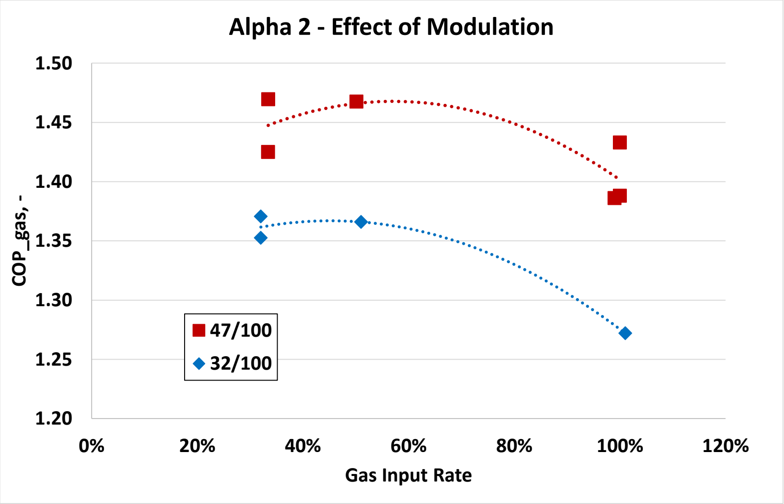
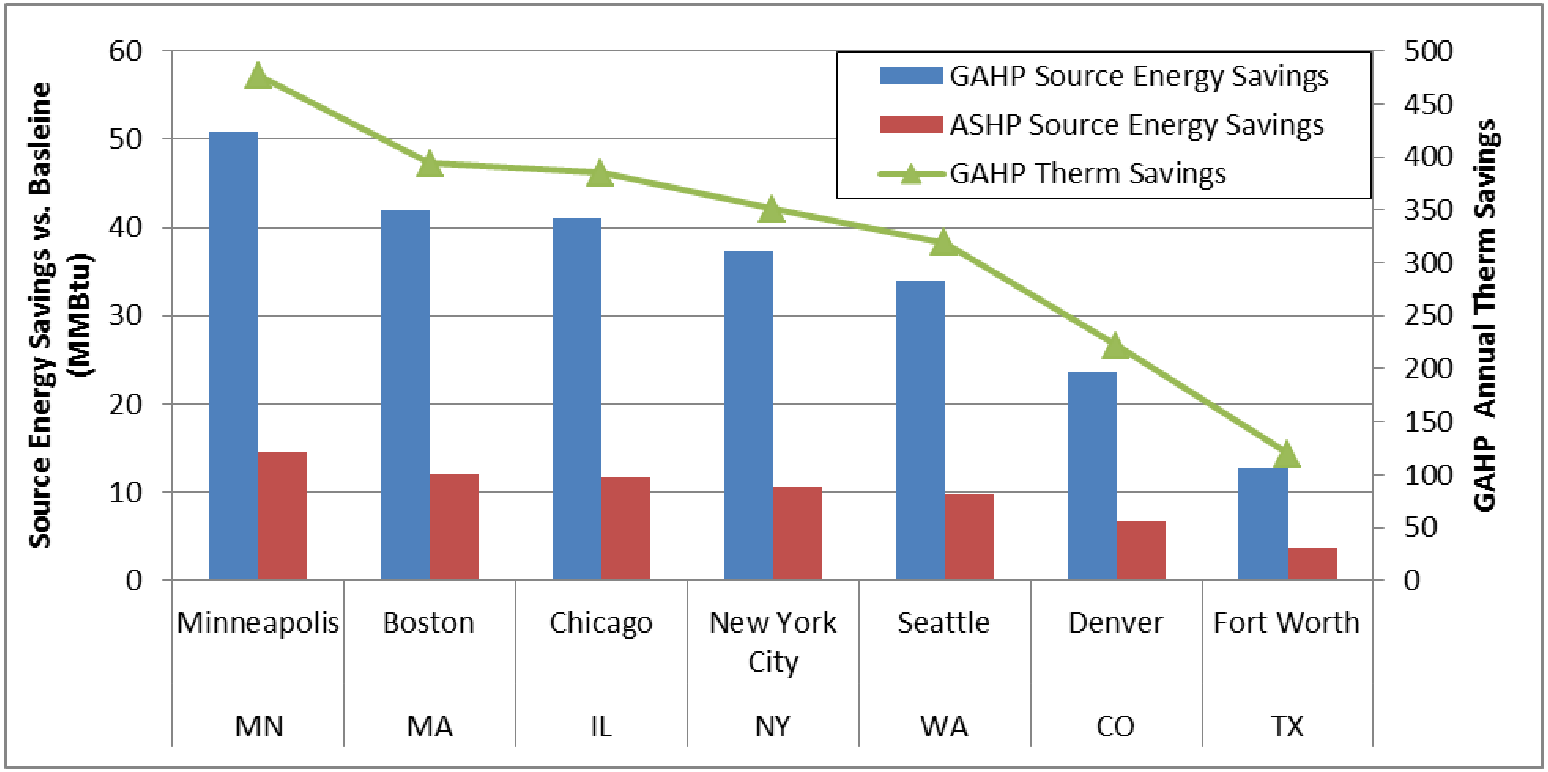
Progress and Accomplishments: Alpha 2







Progress and Accomplishments



GTI Building Energy Simulation: Comparison to 80% Furnace Baseline

Project Integration and Collaboration

Project Integration:

- Market-leading OEM was a sub-contractor and providing cost-share.
- Gas Technology Institute was a sub-contractor and providing cost-share through contributions from gas utilities.
- GTI kept 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 Forums, Energy Solutions Center Annual Meetings, CEE conference call presentation, GTI bi-annual meetings with gas utility research sponsors, International Sorption Heat Pump Conference. Planned: Purdue Conference & ASHRAE.

Next Steps and Future Plans

Alpha 1 Field Test @ SMTI
(GTI Monitoring)

Alpha 2 Field Test (combi)
(GTI Monitoring)

Beta 1-2 are being fabricated: Advanced testing & reliability

Ready for larger scale field test, Winter of 2016/2017.

Project Budget

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

Variances: **Six month no-cost extension.**

Cost to Date: **Federal:** **$901,842 of $902,870 (99.9 %)**
Cost Share: **$303,240 of $260,508 (116 %)**

Budget History					
03/01/13 – FY2015 (past)		FY2016 (current)		FY2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$901,842	$303,240				

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Project Plan and Schedule

Project Schedule												
Project Start: 03/01/2013		Completed Work										
Projected End: 08/31/2015		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												
M5: Breadboard Testing												
M6: Condensing HX Prototype Testing												
M7: Packaged Prototype Fab & Assy												
Current/Future Work												
M8: Packaged Prototype Preliminary Testing												
M9: Packaged Prototype 1 Final Testing												
M9: Packaged Prototype 2 Final Testing												
M10: Packaged Prototype 3rd Party Testing												