Low-Cost Gas Heat Pump for Building Space Heating

2015 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: **August 31, 2015**

Key Milestones:

1. **Cycle & System Design: 12/31/2014**
2. **Breadboard Test Results: 12/31/2014**
3. **Packaged Prototype Results: 04/01/2015**

Budget:

Total DOE $ to date: **$629,730**

Total future DOE $: **$273,140**

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.

Purpose and Objectives

What We Use For <u>Gas</u> Heating Has Not Changed Much

Furnaces | Boilers | Water Heaters

Non-Condensing Models Are 75 – 83% Efficient

Condensing Models Are 90 – 98% Efficient

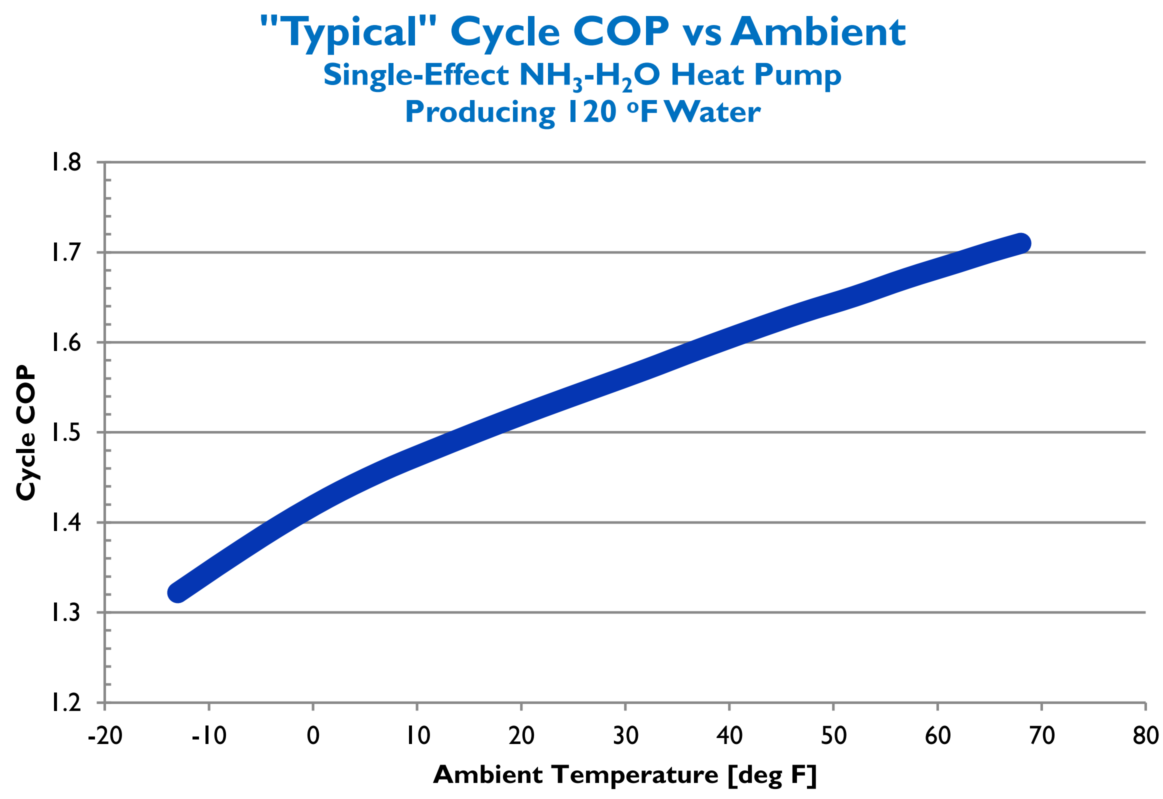
Direct Fired @ Maximum Efficiency
OEM Product Differentiation?
Efficiency Program Incentives?

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

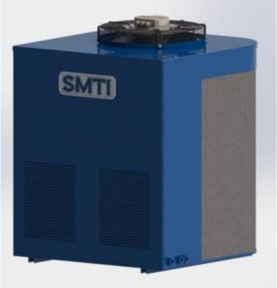


Problem: Historically Complex Cycles and High Cost

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

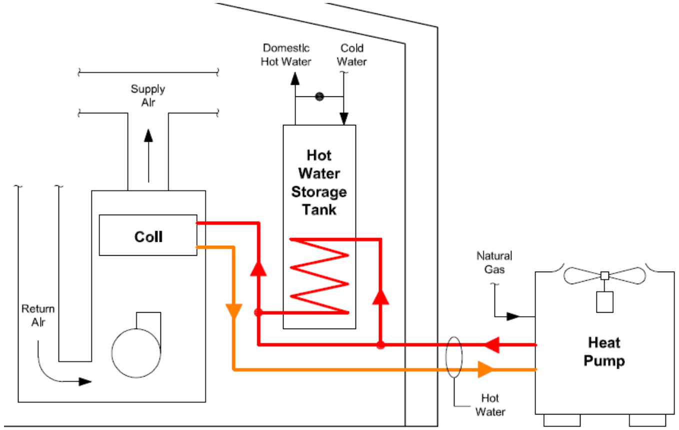
Purpose and Objectives

80,000 Btu/hr (23 kW) @ 47°F



COP = 1.40	47°F (8.3°C)
COP = 1.35	32°F (0°C)
COP = 1.30	17°F (-8.3°C)
COP = 1.20	-13°F (-25°C)

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



TARGET APPLICATIONS

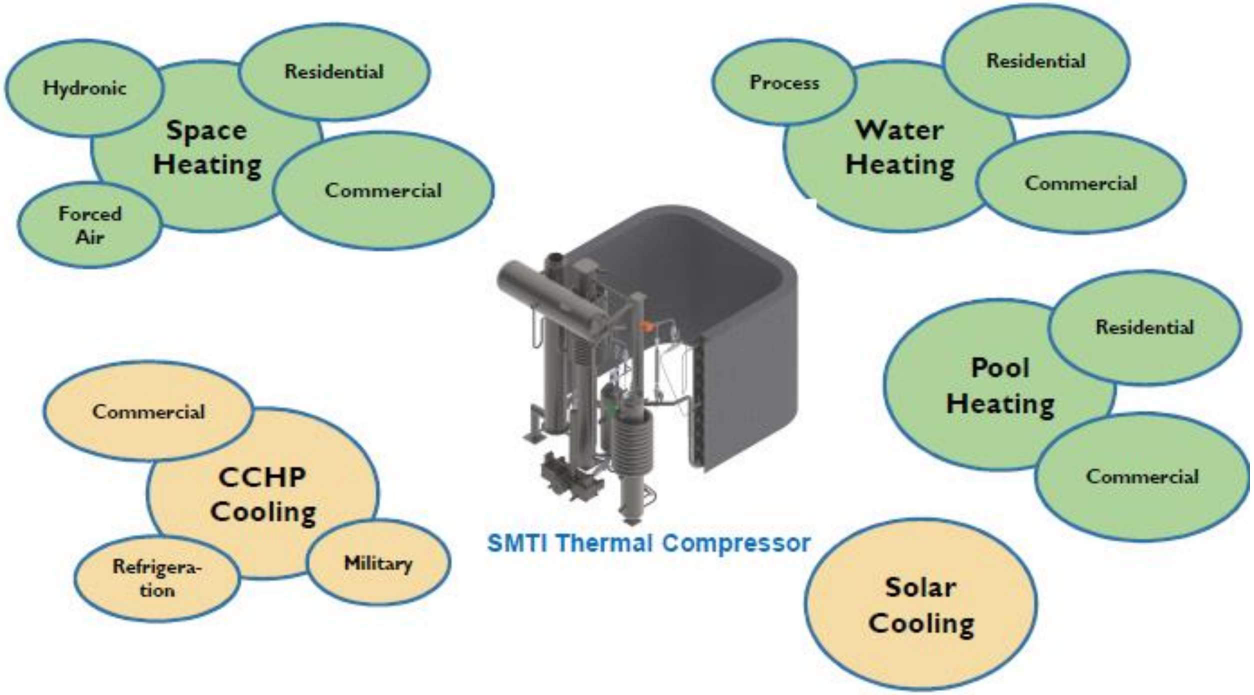
- Residential Space & Water Heating (cool/cold climates)
    - *3.5 Quads (185.5 Million Metric Ton CO_2) (65% Cool Climate Zones)*
- Commercial Space & Water Heating (all climates)
- Commercial Simultaneous Water Heating & Space Cooling (all climates)
- Pool Heating
- New Construction & Retrofit

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

Purpose and Objectives

Target Customers for SMTI Thermal Compressor:

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



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

Winter 2015:	**Controlled Field Testing, Reliability**
2016:	**Customer Agreement(s) in Place, Large Field Test, DFM, Vendor Qualifications**
2017:	**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:

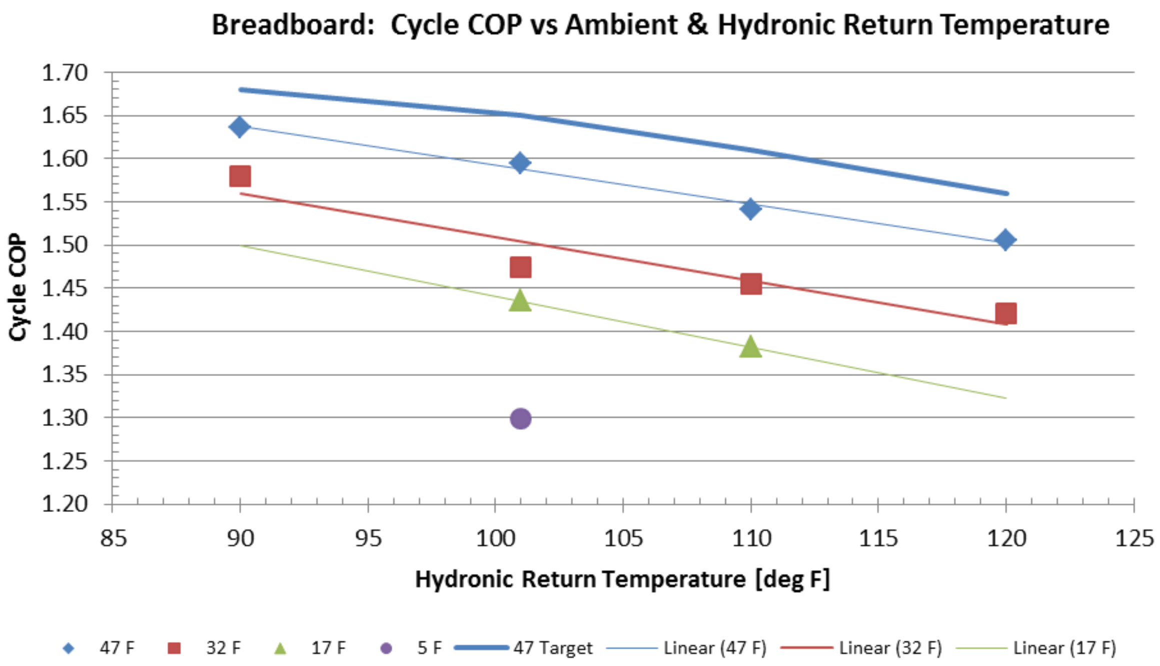
- **Evaporator Coil Design:** Validation of design model to ensure we arrive at optimized design for packaged prototype (achieve target cost and performance).
- **Rectifier Performance:** Achieving target ammonia purity using simple, low-cost design.
- **Scalability of Low-Cost Solution Pump**
- **System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

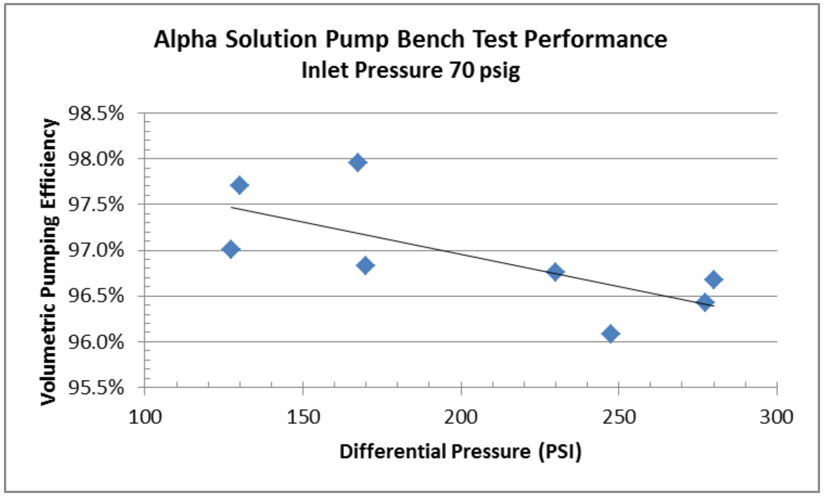
Progress and Accomplishments

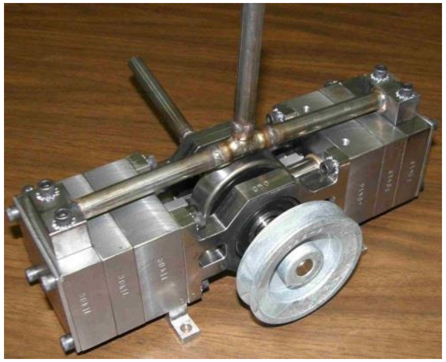
Accomplishments:

- ✓ Optimized Simple Single-Effect Cycle That Predicts Target Performance.
- ✓ Breadboard Testing Complete
  - ❖ 95% of Performance Target at design condition
  - ❖ 4:1 Modulation Achieved
- ✓ Evaporator Design Model Developed and Verified w/Experimental Data
  - ❖ 3 Coils Tested
  - ❖ Optimized coil ~25% cost reduction from original design
- ✓ Low-Cost Solution Pump Successfully Scaled Up Factor of 10.
- ✓ Alpha Packaged Prototype Fabricated & Lab Tested
- ✓ Preliminary manufacturing cost estimate is within our target range.

Progress and Accomplishments







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

Progress and Accomplishments

Alpha Prototype

Nominal Output : 80,000 Btu/hr (23.4 kW)

Gas Input: 54,000 Btu/hr (15.8 kW)

Max Supply: 145ºF (63ºC)

Size: 36 x 40 x 42" (91 x 112 x 117 cm)

Weight: ~500 lbm (227 kg)

As of end of March: 58 Steady-State Tests

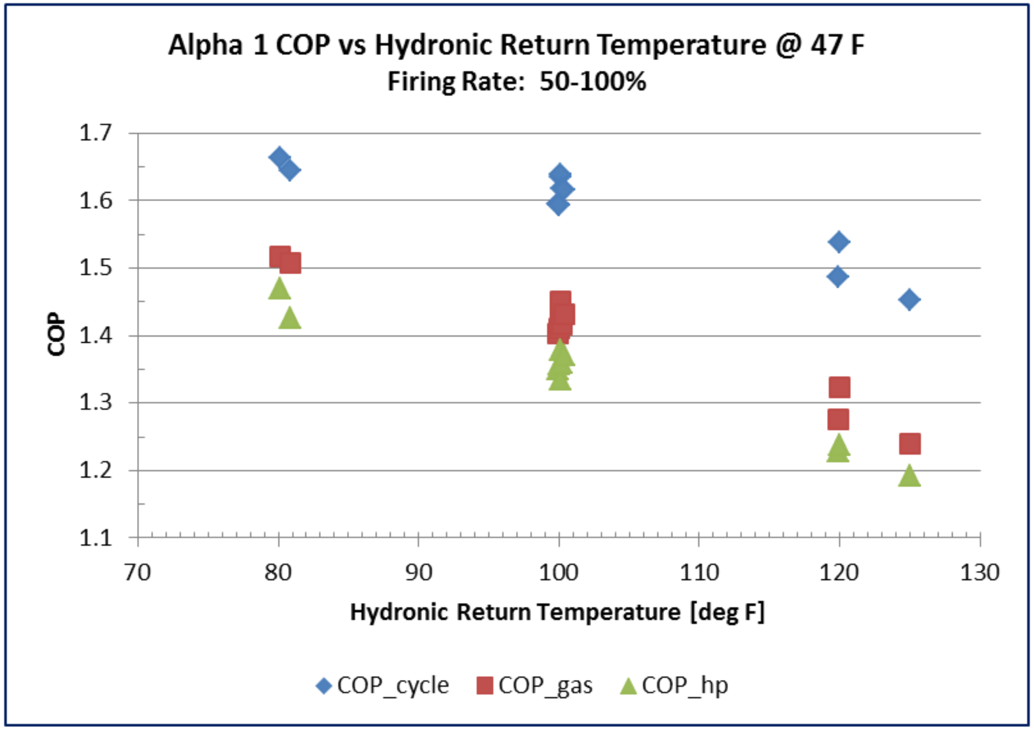
Ambient: -1 to 56ºF (-18.3 to 13.3ºC)

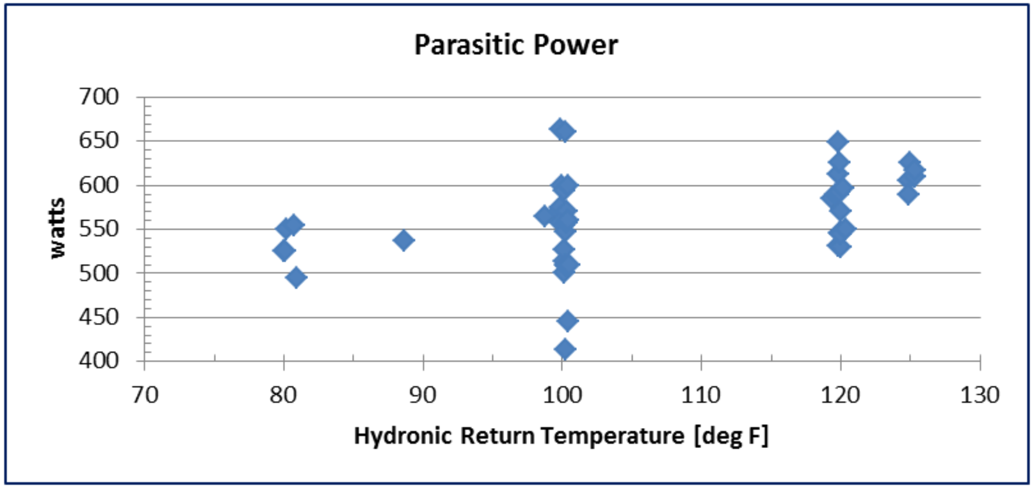
Hyd Return: 80 to 125ºF (26.7 to 51.7ºC)

Hyd Supply: 92 to 142ºF (33.3 to 61.1ºC)

Modulation: 4:1

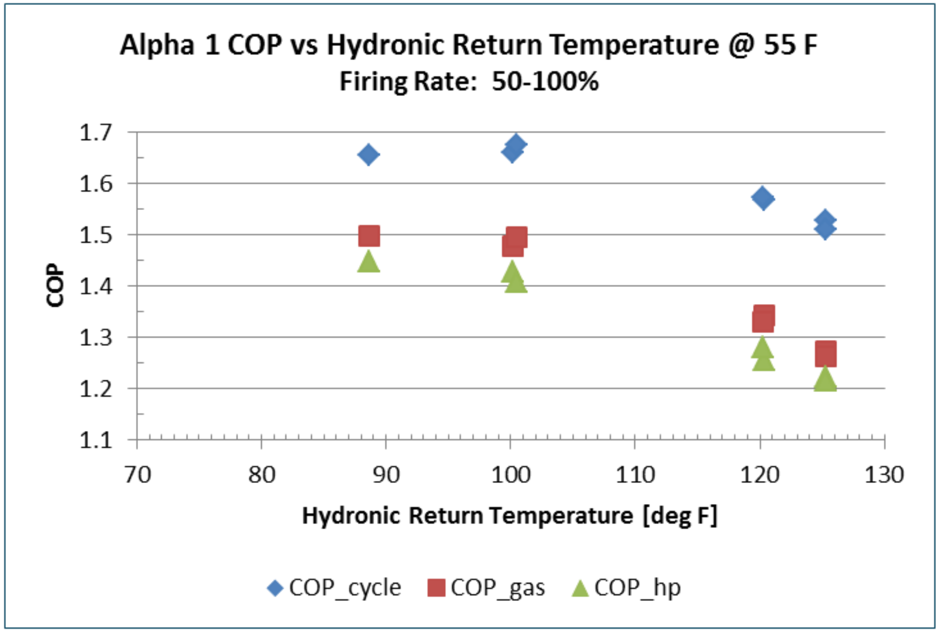
Progress and Accomplishments

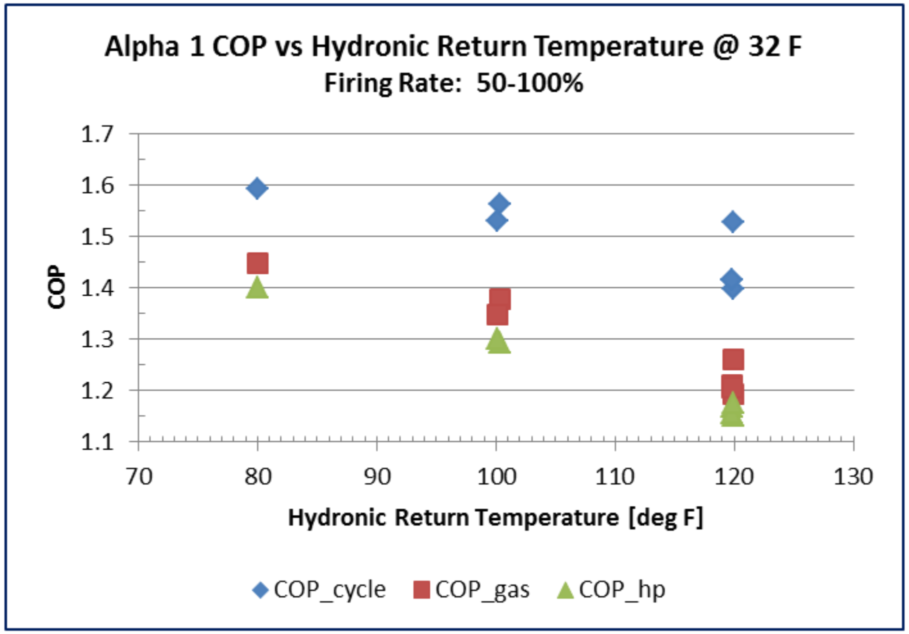


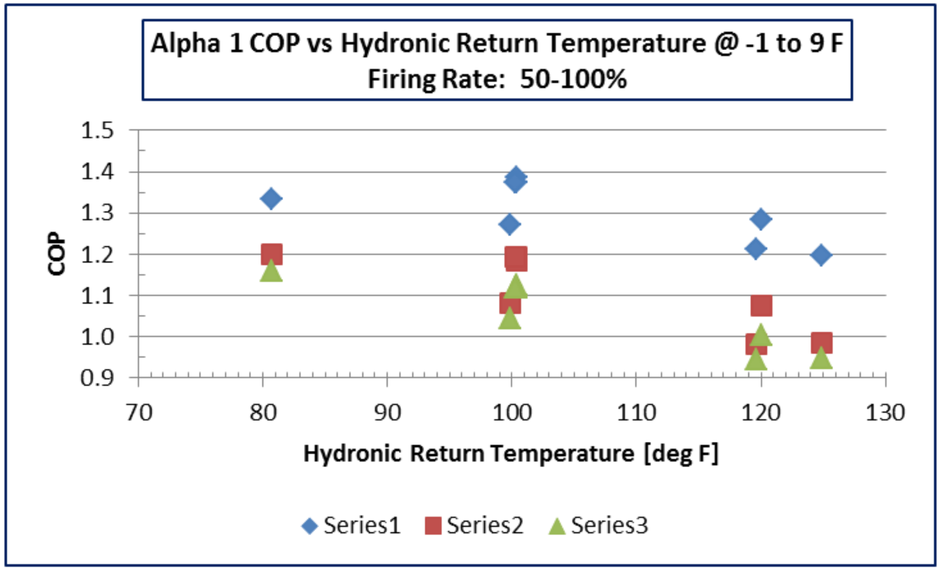


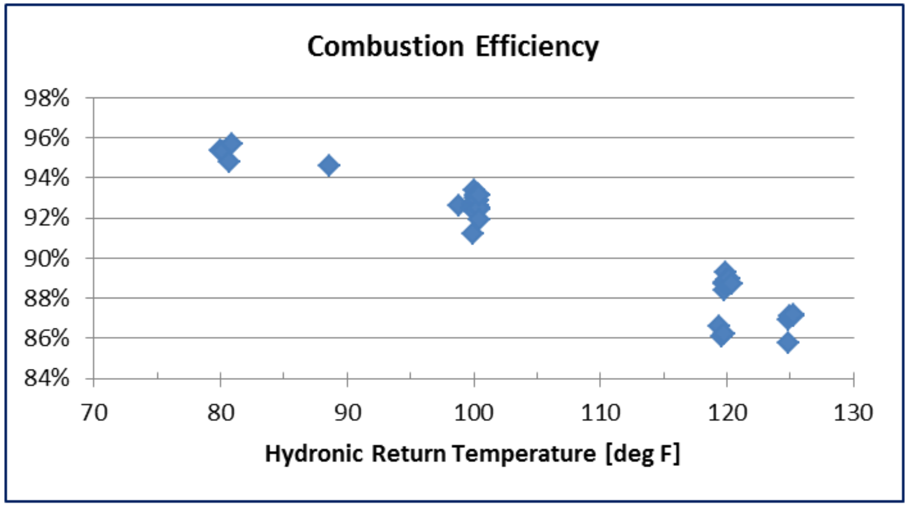
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Progress and Accomplishments



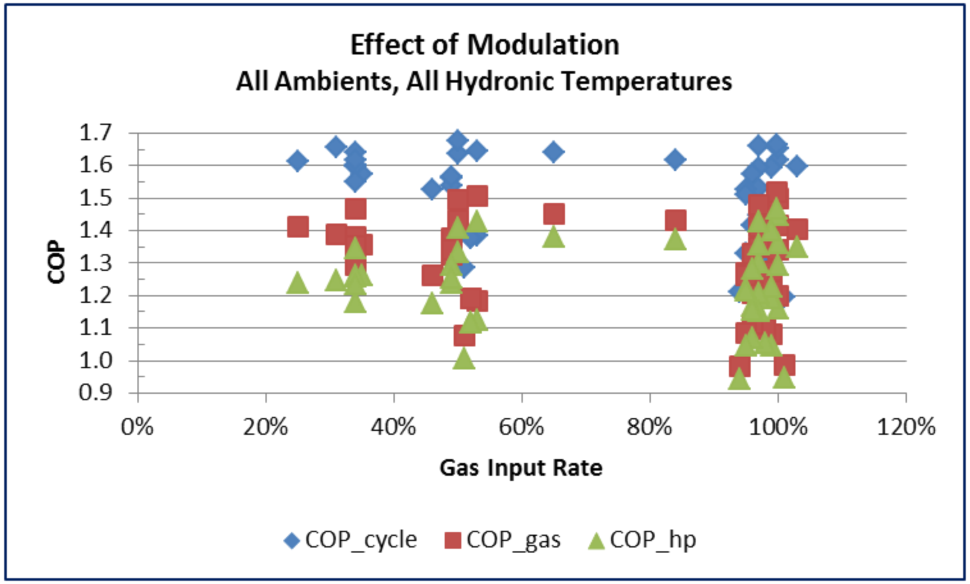






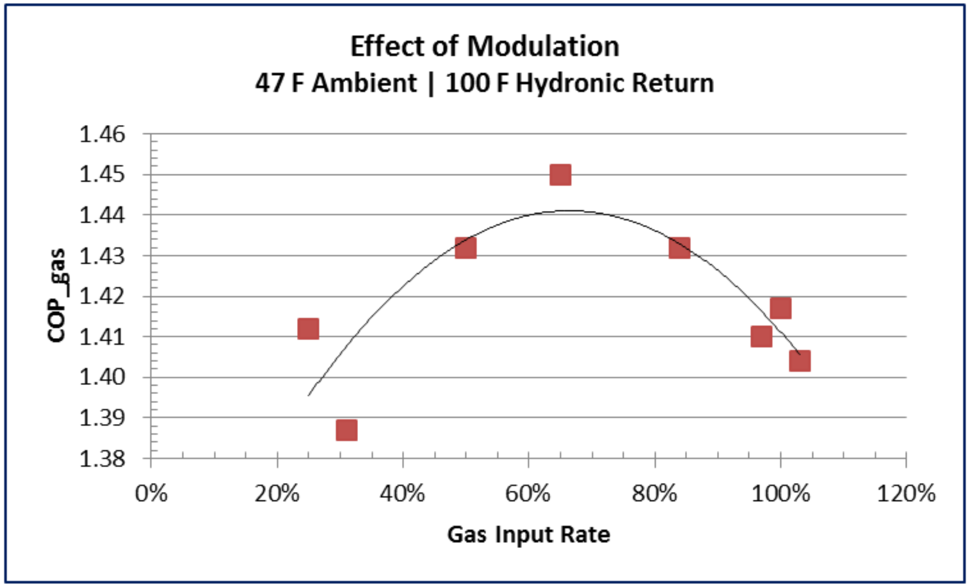
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Progress and Accomplishments



Considering all data, effect of modulation is minor.

Stability good all the way down to 4:1 modulation.



At single ambient and return hydronic temperature, performance maximized between 50 and 80% target gas input rate.

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

Progress and Accomplishments

Lessons, Issues & Opportunities:

- ❖ Performance 96% target at design conditions. 90% at cold ambients.
- ❖ Ammonia purity 99.2 – 99.4% at design conditions, down slightly from breadboard and less than 99.7% target. Primary cause of remaining performance gap and impact is greater at low ambients / high return temperatures.
- ❖ Solution Heat Exchanger effectiveness above target , but increases Rectifier load.
- ❖ Rectifier size to be increased 10% for Alpha 2 packaged prototype.

Market Impact:

- ❖ Field test and reliability units planned for 2015/2016 winter heating season.
- ❖ Business model to partner with leading OEMs for each market application. Leverages existing distribution/service channels, maximizes marketing efforts and consumer education, and minimizes time and money required by SMTI to launch product line.

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:

- **3rd Party Testing & Verification of Alpha 1 by GTI (April – June, 2015)**
  - **Steady-state and home/DHW simulation testing**
  - **Energy/Cost savings modeling for several regions**
- **Fabrication & Testing of Alpha 2 prototype at SMTI**
  - **Target incremental performance improvements**
  - **Controls optimization (modulation, combo systems, ambient set-back, etc).**
  - **Study coil defrost requirement and evaluate options**
  - **Test under commercial water heating conditions**
- **Installation of Alpha 1 on SMTI lab as primary heating system**
- **Sponsored field test/reliability units, Winter 2015/2016**
- **Expansion of Product Family (larger and smaller capacities)**

Project Budget

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

Variances: **Currently Under-Budget. Six month no-cost extension approved.**

Cost to Date: **Federal:** **$629,730 of $902,870 (70%)**
Cost Share: **$181,880 of $260,508 (70%)**

Budget History					
03/01/13 – FY2014 (past)		FY2015 (current)		FY2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$458,385	$142,586	$444,485	$117,922		

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												