Residential and Commercial Capacity Absorption Heat Pumps for Space and Domestic Water Heating Applications

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Outline

- Introduction
- Modeling and Analysis
- 23.5 kW GAHP Residential Combi (Space and Water Heater)
- 41 kW GAHP Commercial Water Heater
- 3 kW GAHP Residential Water Heater
- Energy and Economic Savings
- Conclusions
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

Need COP >> 1.0

Must Work at Low Ambients
Must be Economically Viable

Gas Heat Pumps (GAHP) offer next step in COP & significant opportunity to decarb heating w/o impact on grid
Family of Absorption Heat Pumps, 3-40 kW
Development Goals

- Reduce Cost By 50%
- Scalable Capacity
- Simple, Reliable
- Application / Fuel Flexible
  - Space, Water, Pool
  - Gas, LP, Oil, Biodiesel
Gas-fired Absorption Heat Pumps (GAHP)

- **Offer COP values >> 1**
- **Maintain heating performance at low ambients**

- **Single-effect** ammonia-water absorption heat pump
  - SHX & RHX effectiveness of 0.97 & 0.93
  - Evap-Amb pinch of 3°C
  - CHX-Hyd pinch of 3°C
  - HCA pinch of 3°C
  - Condenser pinch of 10°C

- **SE versus GAX**
  - Lower desorber temps than GAX
  - Better reliability
  - More options for NC control
  - Fewer heat exchangers
  - Easier to control
Cycle Modeling and Analysis

- GAHP cycle models for the 23.5, 41 and 3 kW systems that were developed in Engineering Equation Solver (EES) were used to evaluate experimental results.

\[
Q_{Hydronic} = \dot{m} \times c_p \times (T_{Hydronic\ Out} - T_{Hydronic\ In}) \quad COP_{GAS,HHV} = \frac{Q_{Hydronic}}{Q_{Gas}}
\]

COP_gas based on Higher Heating Value (HHV)
GAHP Test Facility

- Allowed for testing at ambient temperatures of -17.8 to 12.8°C
- Hydronic return temperatures of 27 to 52°C
23.5 kW of heat at hydronic return/ambient conditions of 37.7/8.3°C
Target COP\_gas, HHV of 1.45 at above conditions
Size: Approximately 1 square meter
Air-coupled evaporator occupies 64% of total footprint
Stand alone units designed to maintain set hydronic supply or return temperature when call for heat is present
23.5 GAHP Residential Combi

- Steady state testing performed with 2nd Generation (Beta) Units
- Units performed near design for the range of operating conditions investigated
- Maximum Supply Temperature: 71°C
ANSI Z21.40.4 test method used to estimate the Annualized Fuel Utilization Efficiency (AFUE)

Performance analyzed for climate region IV (-15°C design ambient, 5643 bin hours)

Predicted AFUE of 141% achieved (HHV)

4:1 Modulation

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<th>Rating Point</th>
<th>Ambient Temp, °C</th>
<th>Hydronic Supply, °C</th>
<th>Hydronic Return, °C</th>
<th>Firing Rate, kW</th>
<th>Heating load, kW</th>
<th>COP_{GAS,HHV}</th>
<th>Total Electric Usage, kW</th>
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23.5 GAHP Residential Combi

- Active defrost investigated on Beta units
- Control strategy for defrost period optimized
- Allows unit to continue to run and provide heating
Space Heating Combi Demonstration

- 23.5 kW GAHP
  - 4:1 Modulating

- Hydronic Air-Handler
  - 3-Speed

- Indirect DHW Storage Tank

- Home Owner Feedback Very Positive

- 200 m²
  - Single Family Home
  - Built 1947
41 kW of heat at hydronic return/ambient conditions of 37.7/8.3°C

Target COP_gas,HHV of 1.45 at above conditions

Unit W × D × H of 1.4 × 1.0 × 1.5 meters

Evaporator occupies 64% of total footprint

4:1 Modulation
Steady state testing performed with second prototype
Unit performed within 4% of at hydronic return/ambient conditions of 37.7/8.3°C
Performance reduced at off-design conditions to within 12% of model
Maximum Supply Temperature: 71°C
3 kW GAHP Residential Water Heater

- GAHP system is designed to mount on top of domestic hot water storage tank (similar of EHPWHs)
- GAHP is hydronically coupled to the storage tank with an internal coil
- Flue gas passes through a separate internal coil to allow for condensation of water in the flue gas

Steady state testing performed with 3rd Generation Units

Range of water inlet (29-57°C) and ambient (5-20°C) temperatures investigated

Units performed within 15% of design for the range of operating conditions investigated

* Heat input from the condensing flue gas heat exchanger is not included
Energy and Economic Savings

- **Residential Water Heating (3 kW)**
  - Demonstrated 50% energy savings compared to non-condensing gas storage
  - Save $123 per year for average family in U.S.

- **Residential Space Heating (23.5 kW)**
  - For U.S. Climate Region IV (aka Chicago)
  - GAHP = 141% AFUE / 28,597 kWh natural gas
  - Gas Furnace = AFUE 90% / 45,136 kWh natural gas
  - Save $994 (assuming $0.62 per m$^3$)

- **Commercial Water Heating (41 kW)**
  - GAHP modeled to reduce energy usage by 35% for a Full Service Restaurant, (8000 L/day), compared to condensing, for 6 warm climate cities in U.S.
  - Annual energy and operating cost savings range from 48,600 to 55,600 kWh and $2900 to $3400 (US)
Conclusions

- **The 23.5 kW system is in its 2\textsuperscript{nd} Generation of development**
  - AFUE of 141\% was achieved (HHV) for -15°C design temperature climate zone
  - 4:1 modulation was achieved
  - 2\textsuperscript{nd} Round of Field Testing: 2017/2018

- **The 41 kW system is in its 1\textsuperscript{st} Generation of development**
  - The unit performed within 4\% of design at standard conditions
  - Initial Field Testing: 2017/2018

- **The 3 kW system is in its 3\textsuperscript{rd} Generation development**
  - Demonstrated energy savings of 50\% in initial field tests
  - 4\textsuperscript{th} Round of Field Testing: 2017/2018

- **Scalable, Simple, Cost Effective Design Established**

- **Significant Potential to DeCarb Heating w/o Impacting Grid**
Next Steps

23.5 kW GAHP
Field test of four units (2017-2018)

41 kW GAHP
Filed test of one unit (2017-2018)

3 kW GAHP Residential Water Heater
Field test of one unit (2016-2017)
Field test of six units (2017-18)

Fuel-Oil / Biodiesel Model
5kW Combi Model
CHP Model (cooling)
Acknowledgements
Thank You

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