Commercial Water Heating with Gas Absorption Heat Pumps:

Development Update and Impact of Storage Tank Design

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Topics of Discussion

- GAHP Technology Background
- Current State of Commercial GAHP Water Heater
- Modelling/Savings
- Impact of Storage tank on GAHP Performance
How Does It Work?

\[
\text{COP}_h = \frac{Q_{\text{cond}}}{E_{\text{in}}} = 3.0 - 4.0
\]
\[
Q_{\text{heat}} = \sim 1.1 \times Q_{\text{cooling}}
\]

\[
\text{COP}_h = \frac{(Q_{\text{cond}} + Q_{\text{abs}})}{Q_{\text{in}}} = 1.4 - 2.0
\]
\[
Q_{\text{heat}} = (Q_{\text{cond}} + Q_{\text{abs}}) \sim 2.5 \times Q_{\text{evap}}
\]

*Capacity & COP Remain High at Low Ambient Temperatures*
Renewable Energy Content: ~35%

Solar Energy
(via the atmosphere)

Fuel Source **

** Natural Gas, Propane, Fuel Oil, BioDiesel, Renewable Gas, etc.
SMTI GAHP Target Performance
Nominal 20F Rise

System COP vs Ambient and Return Temperature

HHV including Electrical Power

Confidential © SMTI 2015
GAHP Commercial Water Heating
SMTI Gas Absorption Heat Pumps

\[ \text{COP}_{\text{HHV}} = 1.45 \text{ at } 47/120^\circ\text{F} \]

- Gas-Fired, Air to Water Heat Pump
- Condensing
- 4:1 Modulation
- 10,000 to 140,000 Bth Heating Output Models
- 20° F Hydronic Differential
- Outdoor Installation (no venting)
- SCAQMD NOx Compliant
GAHP Commercial Water Heater Development

**Beta Prototype**

Nominal Output:
140,000 btu/hr (41.0 kW)

Gas Input:
97,000 btu/hr (28.4 kW)

Max Supply:
160°F (71°C)

Size:
50” x 40” x 60”

Weight:
~850 pounds

Modulation:
4:1

30% reduction in size from Alpha to Beta Prototype
GAHP Commercial Water Heater Development

- COP of 1.41 at 47/100°F design (97% of 1.45 target)
- Reliability testing underway
Energy Plus Modeling
Commercial Water Heater Modeling: EnergyPlus

140K GAHP Configuration

Conventional High Efficiency Configuration

Full Service Restaurant - Daily draw pattern
Daily use: 2080 Gallons of Hot Water

15 Minute Draw Volumes

6 cities in the Southern and South Central climate zones investigated
- Full service restaurant (FSR) using 2080 gallons per day
- On average, the 140K GAHP configuration offered an annual gas savings of 35%

10 cities in the European Union (EU) investigated
FSR using 2080 gallons per day
The 140K GAHP configuration offered an average annual gas savings of 31.1%

**Yearly Average Ambient Temperature, °F**

<table>
<thead>
<tr>
<th>City</th>
<th>London</th>
<th>Athens</th>
<th>Oslo</th>
<th>Moscow</th>
<th>Madrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>53</td>
<td>64</td>
<td>42</td>
<td>41</td>
<td>58</td>
</tr>
</tbody>
</table>

(Reykjavik, Paris, Vienna, Rome, Helsinki)

(Portland, OR yearly average is 55°F)

6 U.S. cities studied by Geoghegan et al. (2016) at 2080 gpd
4160 gpd SMTI modeling

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<tr>
<td>140K GAHP System</td>
<td>$16,500</td>
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![Graph showing payback period vs. natural gas cost](image)
Commercial Water Heater Modeling

- 10 Year total cost for avg of 6 U.S. cities studied by Geoghegan et al. (2016)
- Savings of $12,000 for 2080 gpd
- Savings of $19,600 for 4160 gpd

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Natural gas cost of $1.00/therm assumed
Impact of Indirect Storage Tank
Impact of Indirect Storage Tanks on GAHPs

- Indirect heat exchangers are undersized
  - Heat exchangers are sized for hydronic supply temperatures of 160-180°F (increased LMTD to limit UA)
  - GAHPs need to operate at lower supply temperatures to take advantage of higher COPs

For same coil and conditions:
- 80K btu/hr at 180°F hyd in
- 40K btu/hr at 140°F hyd in
Impact of Indirect Storage Tanks on GAHPs

- Thermostat Location
  - T-stats located at the mid internal coil location result in frequent cycling of the heating system
  - GAHPs should be operated for longer cycles to limit the impact of reduced performance during the start-up period
GAHP Tank Heating Investigation

- Tank 1 (45 Gallon) coil is 28.3 feet long, surface area of 11.1 ft$^2$
- Tank 2 (113 Gallon) coil is 67.3 feet long, surface area of 22 ft$^2$
GAHP Tank Heating Investigation

- Supply Water Temperature Set-point of 140°F
- Once SP achieved, GAHP firing rate starts to reduce
- Larger HX Coil Allows Operation at Lower Supply Temperatures
GAHP Tank Heating Investigation

- Tank 1 Average COP of 1.25
- Tank 2 Average COP of 1.50
GAHP Storage Tank Design

- 80K GAHP matched coil – surface area of ~50 ft\(^2\)
- 140K GAHP matched coil – surface area of ~85 ft\(^2\)

- Heat exchange and surface area enhancement must be balanced with pressure loss

- Potential for scaling reduced with lower driving temperatures
Guidelines for tank design coupled to GAHP

- Thermostat location above the hydronic coil to limit cycling (ideally close to the mid-point of the tank)

- Tank/coil size selected relative to GAHP capacity so that minimum acceptable runtimes are achieved

- Maximum GAHP firing rate is a function of the internal heat exchanger size (needs to be considered when sizing the coil)
Summary

- Commercial GAHP water heaters have the potential to significantly reduce energy use and operating cost.
- Reasonable paybacks expected compared to condensing storage (<4 years).
- Success tied to indirect hot water storage tank design.
- Appropriately sized tanks/internal coils not readily available.
Next Steps in 2017

- Commercial water heating field test in Tennessee
- Two full service restaurant field tests in Los Angeles, California (Water heating and kitchen cooling)
Next Steps in 2017

- 3-6 Residential combi field tests (pending)
- Six residential water heater field tests in Los Angeles, California
- 5 kW Residential Combi Prototype
- Beta engine waste heat driven chiller for military and disaster relief applications
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Thank You!

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