Applying a Microturbine/Desiccant CHP System to a Supermarket

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Richard S. Sweetser  Exergy Partners

OAK RIDGE NATIONAL LABORATORY
CHP in Supermarkets

- Peak is 400-600 kW for typical store
- Significant space heating loads due to refrigerated display cases
- Desiccant dehumidification is widely used in supermarkets
  - more than 1,000 desiccant units in US stores
- Good balance between thermal and electrical loads
The CHP System

- 60 kW Microturbine
- Nat. Gas Compressor (scroll)
- Heat Exchanger
- Hot Water Coils Installed in HVAC Unit
Installed CHP System
Heat Recovery System

Hot water coils installed in HVAC Unit

Des Unit

Supply Air

Hot Water Coils

glycol piping

approx. 35 ft

Regeneration

Hot Water Coil

Supply Air

Hot Water Coil

Unifin HX (w/ pump)

Inlet

(drain plug inside)

Outlet

(vent inside)

Expansion Tank

“Charging Port”

Coil Inlet/Outlet

2" NPT female

3-way valve

2" Victraulic Pipe or Copper

HX Inlet/Outlet

2” - Style 75 Victraulic

Tee and 1.5” Ball Valve for Flow Meter

(supplied by CDH)

Coil Inlet/Outlet

1.5” NPT female

C

HX

turbine

Regeneration

Hot Water Coil
Main HVAC Unit

*Provides Heating, Cooling & Dehumidification*

- Compressors
- Regen HR Coil
- Gas Burner
- Des Wheel
- DX Coil
- Heating HR Coil
- Supply Fan
- Gas Furnace
- Supply Air
- Return Air

New Coils Added

- 60 tons of cooling
- 1.2 MMBtuh heating
- 263 lb/h dehumid
CHP System Summary

• CHP System sized for thermal loads
  – provide 60 kW of baseload power
  – grid-parallel operation only
  – may consider scheduling turbine operation for periods when heat recovery loads are low

• System can use heat recovery when available or Standard burner systems: fully redundant
Field Monitoring

- Installed data logging equipment to quantify thermal and electric performance
  - electrical turbine output (kW, amps, volts)
  - thermal output of
    - HX (flow, ΔT)
    - turbine exhaust
      (T, static P, flow)
    - desiccant/HVAC unit
      performance (T, RH, kW)
  - 56 points total
Turbine Impact on Store

Peak Total Demand: 395.5 kW @ 12:15 PM
Peak Utility Import Demand: 342.5 kW @ 12:15 PM
# Daily Summer-Time CHP Performance

<table>
<thead>
<tr>
<th>Date</th>
<th>Power Output (kWh)</th>
<th>Gas Input (MBTU)</th>
<th>Gas Compressor (kWh)</th>
<th>Heat Recovery (kWh)</th>
<th>Space Heating (MBTU)</th>
<th>Desiccant Regen (MBTU)</th>
<th>&quot;Net&quot; Turbine Generation Efficiency (%)</th>
<th>&quot;Net&quot; CHP Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 1, 2003</td>
<td>1,265.9</td>
<td>18,428</td>
<td>92.9</td>
<td>20.6</td>
<td>0</td>
<td>4,868</td>
<td>21.7%</td>
<td>47.8%</td>
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<tr>
<td>Aug 2, 2003</td>
<td>1,221.1</td>
<td>18,025</td>
<td>93.1</td>
<td>20.6</td>
<td>0</td>
<td>5,310</td>
<td>21.4%</td>
<td>50.4%</td>
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<tr>
<td>Aug 3, 2003</td>
<td>1,223.8</td>
<td>18,025</td>
<td>93.2</td>
<td>20.6</td>
<td>0</td>
<td>5,308</td>
<td>21.4%</td>
<td>50.5%</td>
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<tr>
<td>Aug 4, 2003</td>
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<td>17,925</td>
<td>93.0</td>
<td>20.5</td>
<td>0</td>
<td>5,358</td>
<td>21.5%</td>
<td>51.0%</td>
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<td>Aug 5, 2003</td>
<td>1,222.1</td>
<td>17,937</td>
<td>92.7</td>
<td>20.6</td>
<td>0</td>
<td>5,434</td>
<td>21.5%</td>
<td>51.4%</td>
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<tr>
<td>Aug 6, 2003</td>
<td>1,210.8</td>
<td>17,836</td>
<td>92.8</td>
<td>20.6</td>
<td>0</td>
<td>4,791</td>
<td>21.4%</td>
<td>47.9%</td>
</tr>
<tr>
<td>Aug 7, 2003</td>
<td>1,205.5</td>
<td>17,735</td>
<td>92.8</td>
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<td>47.2%</td>
</tr>
<tr>
<td>Aug 8, 2003</td>
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<td>17,936</td>
<td>92.8</td>
<td>20.6</td>
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<td>5,193</td>
<td>21.3%</td>
<td>49.9%</td>
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<tr>
<td>Aug 9, 2003</td>
<td>1,222.1</td>
<td>17,936</td>
<td>93.0</td>
<td>20.5</td>
<td>0</td>
<td>5,083</td>
<td>21.5%</td>
<td>49.4%</td>
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<td>Aug 10, 2003</td>
<td>22.5</td>
<td>100</td>
<td>1.8</td>
<td>0.4</td>
<td>0</td>
<td>39</td>
<td>21.1%</td>
<td>49.2%</td>
</tr>
</tbody>
</table>

*Note: Actual natural gas HHV is used.*
Microturbine Efficiency Trend

EFF = 30.0 - 0.0843 * TAO

Efficiency Based on Higher Heating Value (HHV)
Typical Performance of Heat Recovery System
HR Rate in Different Modes

Heat Recovery (MBtu/h)

- Space Heating
- Desiccant Regeneration
- Passive Heat Loss

May 2003
Desiccant Module Performance
Impact of Heat Recovery

Desiccant - Regeneration Operation - Regen Fan ON

- Regeneration (TR)
- Regeneration Leaving (TRL)
- Entering Burner (TRE)

Heat Recovery Operation Increases TRE and Decreases Gas Use
Desiccant Gas Use Varies with Ambient

\[ \text{TRE} > 74.7 \text{ F} \quad \text{FGE (therm/h)} = 5.47 \]

\[ \text{TRE} < 74.7 \text{ F} \quad \text{FGE (therm/h)} = -0.093 \times \text{TRE} + 12.43 \]
Regeneration
Burner Modulation

<table>
<thead>
<tr>
<th>Ambient Temperature (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 60 70 80 90 100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Regeneration Leaving Temperature (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115 120 125 130 135</td>
</tr>
</tbody>
</table>

RED = Heat Recovery ON

Minor loss of burner control on hot days:
~ 5-7 F too high
Confirmed Airflows with various measurements

Process Airflow Measurements

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design/Nominal Process Airflow (from drawings)</td>
<td>9,000 scfm</td>
</tr>
<tr>
<td>Pitot Tube Measurement</td>
<td>8,117 scfm (-10%)</td>
</tr>
<tr>
<td>TSI Multi-Pt Velocity Traverse (Process Outlet)</td>
<td></td>
</tr>
<tr>
<td>October-02</td>
<td>10,242 scfm (+14%)</td>
</tr>
<tr>
<td>July-03</td>
<td>9,380 scfm (+4%)</td>
</tr>
<tr>
<td>September-03</td>
<td>9,447 scfm (+5%)</td>
</tr>
<tr>
<td>TSI Multi-Pt Velocity Traverse (Process Inlet)</td>
<td>9,628 scfm (+7%)</td>
</tr>
</tbody>
</table>
Impact of Heat Recovery on Desiccant Gas Use

[Graph showing the impact of heat recovery on desiccant gas use with ambient absolute humidity (gr/lb) on the x-axis and desiccant gas use (therm/day) on the y-axis. The graph compares data with and without microturbine heat recovery.]
HR Impact on Space Heating

Have some data confirming space heating benefit
Summary

• Supermarket desiccant is a good match for available heat in summer
  – HR with glycol loop meets about ½ regen gas use
  – Direct use of turbine exhaust would meet 100%

• Space heating still provides bulk of HR savings
  – At least in Northern climate
  – In Southern climate direct exhaust might be better

• Standard modulating controls on regeneration burner were adequate with HR operation