Benefits of integration between heat pumps and food refrigeration systems for commercial applications.

An example of efficient energy recovery for Near Zero Energy Buildings

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16th of May 2017
Introduction

New solutions for HVAC/R market

Could water loop technology be a solution!?  

YES!

If each unit is also equipped with EEV and BLDC variable speed compressor water loop could be a better solution.
Introduction

Electronic expansion valve (EEV)
- Control of evaporation and condensation
- Keep the unit stable and increase efficiency
- Adapt the cabinet to water loop working condition

BLDC compressor
- Modulate power according to request
- Reduce number of ON-OFF cycles
- Optimize working conditions
Introduction

Compressor: ON-OFF vs BLDC

<table>
<thead>
<tr>
<th>Features</th>
<th>On-Off</th>
<th>BLDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal cooling capacity</td>
<td>2 kW</td>
<td>2 kW</td>
</tr>
<tr>
<td>Compressor maximum cooling capacity</td>
<td>2.4 kW</td>
<td>2.4 kW</td>
</tr>
<tr>
<td>Actual cooling capacity</td>
<td>1.5 kW</td>
<td>1.5 kW</td>
</tr>
<tr>
<td>Air set point</td>
<td>2 °C</td>
<td>2 °C</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>18 °C</td>
<td>18 °C</td>
</tr>
<tr>
<td>Evaporation temperature</td>
<td>-11.3 °C</td>
<td>-5.5 °C</td>
</tr>
<tr>
<td>Condensation temperature</td>
<td>28.9 °C</td>
<td>21.2 °C</td>
</tr>
</tbody>
</table>

Estimated energy saving rate: **35%**
Plant description

- Built in 2016, North of Germany
- Annual average temp.: 8.8 °C

<table>
<thead>
<tr>
<th>Type of Cabinet</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low temperature (LT)</td>
<td>17</td>
</tr>
<tr>
<td>Medium temperature (MT)</td>
<td>23</td>
</tr>
</tbody>
</table>

Condensation average temperature of cabinet: 25 °C
Plant description

R-744 Heat pump

Gas cooler

Heat recovery

CO₂ compressors

CO₂ accumulator

LT Cabinet
MT Cabinet

Bluebox

Water storage tank

Pumps
### Plant description

<table>
<thead>
<tr>
<th>Features</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Capacity (trans-critical)</td>
<td>90 kW</td>
</tr>
<tr>
<td>Cooling Capacity (sub-critical)</td>
<td>72 kW</td>
</tr>
<tr>
<td>Evaporation temperature</td>
<td>4 °C</td>
</tr>
<tr>
<td>Outlet water temperature (heating)</td>
<td>42 °C</td>
</tr>
<tr>
<td>Inlet water temperature (heating)</td>
<td>25 °C</td>
</tr>
<tr>
<td>Water tank with evaporator</td>
<td>700 liters</td>
</tr>
<tr>
<td>Compressors (Bitzer)</td>
<td>3 (1 V.S. + 2 On-Off)</td>
</tr>
<tr>
<td>COP (trans-critical)</td>
<td>2.6</td>
</tr>
<tr>
<td>COP (sub-critical)</td>
<td>7.8</td>
</tr>
</tbody>
</table>
Test and results

• First cycle of measurements: Jan.-Feb. 2016
• Second cycle of measurements: Mar. 2016
• Water loop for the cabinet is organized in 9 zones (topology, pipe length optimization)
• Test data from zone 6: here connected on the loop 5 cabinet dedicated to milky products
• Between the test sessions, the regulation parameters for R-744 heat pump has been refined and tuned in a more precise way
Test and results

Measurements have been acquired for **24 hours every day**, also during closing time on Sunday.

![Water inlet temperature](image1)

![Water outlet temperature](image2)

![Water inlet temperature](image3)

![Water outlet temperature](image4)
Test and results

Effect of PID tuning on water outlet temperature

Before PID tuning

After PID tuning
Test and results

Effect of PID tuning on evaporation temperature

- More precise regulation of EEV
- Reduced number of unnecessary switch on and off of the two On-Off compressors
Test and results

Effect of PID tuning on energy consumption

- Average reduction (2-3%)
- Reduction of peaks
## Test and results

### Cooling system failure test

<table>
<thead>
<tr>
<th>Time</th>
<th>Description</th>
<th>Water Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00</td>
<td>Test starts: the heat-pump chiller is switched off</td>
<td>17.5 °C</td>
</tr>
<tr>
<td>11:25</td>
<td>Water temperature reaches the peak value</td>
<td>41 °C</td>
</tr>
<tr>
<td>11:30</td>
<td>First cabinet stops for temperature control alarm</td>
<td>41 °C</td>
</tr>
<tr>
<td>11:30</td>
<td>The heat pump/chiller is switched on again</td>
<td>41 °C</td>
</tr>
<tr>
<td>11:50</td>
<td>Water temperature decrease to an efficient temperature level</td>
<td>24 °C</td>
</tr>
</tbody>
</table>

![Temperature Graph](chart.png)
Conclusions

• Integration of air conditioning and refrigeration is possible with benefits to both.

• The tuning phase assures a first level integration between the heat pump and the cabinet, thanks to the improvement of the stability of water loop working conditions.
Conclusions

• Opportunities to get further improvements:
  
  ➢ Integration of supervisory system to coordinate controls (Plant integration)

  ➢ Optimization of heat pump in partial conditions (System efficiency)

  ➢ Cabinet equipped with low GWP refrigerants (CO₂ emission reduction)