Control strategies of CO$_2$ refrigeration / heat pump system for supermarkets

Liang Shi, Carlos Infante Ferreira, Jan Gerritsen,

Hendrine Kalkman
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Introduction

CO$_2$ : no ozone depletion potential and insignificant global warming potential compared to HFCs but low thermodynamic efficiency.

CO$_2$ thermodynamic characteristics make heat recovery an interesting option.

Combining cooling and heating demands may compensate the low thermodynamic efficiency.

How much do we need to sacrifice the COP to fully satisfy the heating needs of supermarkets by heat recovery?
CO$_2$ booster systems in supermarkets
Heat Recovery from the System
Supermarket characteristics

Location: The Netherlands
Floor area: 1300 m²
Opening hours: 8:00 to 20:00; 6 days per week
Cooling demand delivered by cooling cabinets
Max. heating demand: 91.0 kW (day) / 71.5 kW (night)
Max. cooling demand: 119.1 kW
Max. freezing demand: 17.1 kW
Model specifications

Gas cooler: condensation temperature $\geq 10 \, ^{\circ}\text{C}$ (oil return requirement); minimum temperature approach: 5 to 2 K; subcooling at outlet condenser: 2 to 0 K.

Receiver: controlled at -0.9 $^{\circ}\text{C}$

$$\frac{\dot{m}_g}{\dot{m}_t + \dot{m}_m} = \frac{h_7 - h_8}{h_{12} - h_7}$$

Cabinets: controlled at -33 $^{\circ}\text{C}$ and -8 $^{\circ}\text{C}$ evaporating temperature; superheating 8 K. Additional superheating in lines.
Isentropic efficiency of low pressure compressors
Experimental vs model results

- Cooling capacity
- Freezing capacity
- Heating capacity
- Desuperheater outlet temp.
Operating conditions

Operating hours

Heating power requirement

Cooling & freezing power requirement
Control with floating condensation temperature

Blue: recoverable heat; Red: required heating.

Blue: system COP; Red: mid pressure COP.
Control for continuous heat recovery

Blue: recoverable heat; Red: required heating.

Blue: system COP; Red: mid pressure COP.
# Comparison of the control methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Gas [kWh]</th>
<th>Electricity [kWh]</th>
<th>Primary energy [kWh]</th>
<th>Savings [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floating condensation + boiler</td>
<td>126,970</td>
<td>175,060</td>
<td>550,462</td>
<td></td>
</tr>
<tr>
<td>Continuous heat recovery</td>
<td>201,342</td>
<td>479,386</td>
<td></td>
<td>12.9</td>
</tr>
</tbody>
</table>
Conclusions

Heating requirement can be fulfilled by heat recovery in CO$_2$ based supermarkets (by sacrificing the COP).

Primary energy savings are around 13%
Thanks