Heat Pumps for Low-Temperature Industrial Process Heat

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“Widening the Lens on Innovation for Clean Manufacturing”

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Question: How can we leverage the extensive and ongoing innovation in buildings-related heat-pump technology for industrial application?

Many practical challenges exist for higher temperatures:

- Refrigerant properties, pressure
- Compressor redesign
- Large air-side heat exchangers
- Limited innovation to date because of low-cost gas

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Chemical formula</th>
<th>GWP</th>
<th>Flammability</th>
<th>$T_c$ °C</th>
<th>$p_c$ MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-290</td>
<td>CH$_3$CH$_2$CH$_3$</td>
<td>~20</td>
<td>yes</td>
<td>96.7</td>
<td>4.25</td>
</tr>
<tr>
<td>R-601</td>
<td>CH$_3$-CH$_2$-CH$_2$-CH$_3$</td>
<td>~20</td>
<td>yes</td>
<td>196.6</td>
<td>3.37</td>
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<td>R-717</td>
<td>NH$_3$</td>
<td>0</td>
<td>yes</td>
<td>132.25</td>
<td>11.33</td>
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<tr>
<td>R-744</td>
<td>CO$_2$</td>
<td>1</td>
<td>none</td>
<td>30.98</td>
<td>7.3773</td>
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<tr>
<td>R-1234yf</td>
<td>CF$_3$CF=CH$_2$</td>
<td>&lt;1</td>
<td>weak</td>
<td>94.7</td>
<td>3.382</td>
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<td>R-134a</td>
<td>CF$_3$CH$_2$F</td>
<td>1,430</td>
<td>none</td>
<td>101.06</td>
<td>4.0593</td>
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<td>R-1234ze(E)</td>
<td>CFH=CHCF$_3$</td>
<td>6</td>
<td>weak</td>
<td>109.37</td>
<td>3.636</td>
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<td>R-1243ze(E)</td>
<td>CFH=CHCF$_3$</td>
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<td>weak</td>
<td>153.7</td>
<td>3.97</td>
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<td>R-245fa</td>
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<td>3.5709</td>
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<td>R-1336mzz</td>
<td>9</td>
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<td>171.1</td>
<td>n.a.</td>
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<td>R-365mfc</td>
<td>CF$_3$CH$_2$CF$_2$CH$_3$</td>
<td>794</td>
<td>weak</td>
<td>186.85</td>
<td>3.266</td>
</tr>
</tbody>
</table>

Example: Mayekawa CO$_2$ Industrial Heat pump

- Co-generates 120°C air + 25°C chilled water
  - Chilled water inlet = 30°C
- COP$_{\text{heat}}$ = 3.1, COP$_{\text{cool}}$ = 2.1 ($T_{\text{amb}}$ = 20°C)
- Capacity = 89kW (~300 kBtu/h)
- Target applications:
  - Drying / Dehumidifying
  - Laminator, Coater, Gravure printing

Sources: Mayekawa (2021).
Potential Opportunities:

- New refrigerants
- Non-Vapor Compression cycles
- “Waste” heat upgrade
- Process re-engineering for lower temperatures
- “Tricks” from high-lift buildings applications
  - Cascading systems
  - Refrigerant economizer
  - Multi-stage systems

Your answers here!
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