Exploring Industrial Refrigeration Systems and Energy Efficiency Opportunities

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Director, Industrial Refrigeration Consortium
Regional Electric Consumption (SIC 20)

<table>
<thead>
<tr>
<th>Census Region</th>
<th>2006 Electricity Consumed [million kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>5,441</td>
</tr>
<tr>
<td>Midwest</td>
<td>30,774</td>
</tr>
<tr>
<td>South</td>
<td>24,169</td>
</tr>
<tr>
<td>West</td>
<td>13,057</td>
</tr>
<tr>
<td>Total</td>
<td>73,441</td>
</tr>
</tbody>
</table>

Source: EIA, 2009
Food Industry Energy Costs Increase
Projected

![Graph showing projected electricity purchases and expenditures.](image)

Electricity expenditures ($US) vs. Purchased Electricity.

Source: EIA “Energy Outlook”, 2010
Single Stage Compression System

- Evaporative Condenser
- High Pressure Receiver
- King valve (automatic)
- High pressure gas
- DX evaporator
- Suction Trap
- Refrigerant Transfer System
- Compressor(s)
- Pumped recirculator
- Overfed evaporator(s)
- Equalizer line
- Wet return
- To HPR
- Dry suction
- High pressure liquid
- Overfed evaporator(s)
- Evaporative Condenser
Two-Stage Compression System

Evaporative Condenser(s)

Equalizer

King valve

High pressure liquid

Low temperature evaporator(s)

Low temp recirculator

High Pressure Receiver

Medium pressure liquid

Booster discharge

Booster suction

Booster Compressor(s)

Intercooler

High-stage suction

High-stage discharge

High-Stage Compressor(s)
Let’s Explore Some Energy Efficiency Improvement Opportunities
## 10 Efficiency Improvement Opportunities

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Energy efficiency opportunity</th>
<th>Capital cost</th>
<th>Operational risk</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>New</td>
<td>Retrofit</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Floating head pressure control</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>2</td>
<td>Raise suction pressure</td>
<td>n/a</td>
<td>L-M</td>
<td>M</td>
</tr>
<tr>
<td>3</td>
<td>VFD for evaporator fans</td>
<td>L</td>
<td>L-M</td>
<td>L</td>
</tr>
<tr>
<td>4</td>
<td>VFD for compressors</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>5</td>
<td>VFD for evaporative condenser fans</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>6</td>
<td>Heat recovery (oil cooling)</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>7</td>
<td>Improved compressor sequencing and capacity control</td>
<td>L</td>
<td>L-M</td>
<td>L</td>
</tr>
<tr>
<td>8</td>
<td>Improve hot gas defrost dwell period</td>
<td>L</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>9</td>
<td>Convert liquid injection oil cooling to external oil cooling</td>
<td>M</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>10</td>
<td>Reduce parasitic loads</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
</tbody>
</table>

L = low, M = medium and H = high.

2 Cold Front is the IRC’s quarterly newsletter available at www.lrc.wisc.edu/?/newsletter.
## Lowering Head Pressure

### Rules-of-thumb

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Efficiency Gain [%/°F]$^1$</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>R22</td>
<td>1.2</td>
<td>Refrigeration</td>
</tr>
<tr>
<td>R410a</td>
<td>1.4</td>
<td>[High stage]</td>
</tr>
<tr>
<td>R717</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>R22</td>
<td>1.6</td>
<td>Air conditioning</td>
</tr>
<tr>
<td>R410a</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>

$^1$ Percent efficiency gain per °F decrease in saturated condensing temperature
Raising Suction Pressure

<table>
<thead>
<tr>
<th>Refrigeration Duty</th>
<th>Efficiency Gain [%/°F]&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>High stage</td>
<td>1.7</td>
<td>Relatively insensitive to refrigerant type</td>
</tr>
<tr>
<td>Low stage</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Percent efficiency gain per °F increase in saturated suction temperature
Applying VFDs

• Condenser fans
  o All or none – expect 2 to 3% savings

• Evaporator fans
  o 2 to 4% savings range
  o Simple paybacks range from 1 to 5 years

• Compressor
  o At most, one VFD comp per suction level
  o Simple paybacks range from 1 to 4 years
Case Studies
Madison Ice Arena

- New system (one year old)
- City-owned and operated
- Rink operated year round
- 103 tons capacity
- Six compressors – max power = 240 kW
- R22 with ethylene glycol to rink
- Evaporatively condensed
- Annual electrical operating cost: $45,600
Madison Ice Arena

- As-installed – head pressure controlled 220-235 psig
- Proposed – condenser pressure allowed to ‘float’ down to 150 psig
- Required change – fan controller set point
- Advantages
  - Fewer machines running = lower maintenance
  - 21% operating cost savings = $9,600/yr
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Pumps Total [HP]</td>
<td>300</td>
<td>450</td>
</tr>
<tr>
<td>Fan Total [HP]</td>
<td>480</td>
<td>900</td>
</tr>
<tr>
<td>Compressor [HP]</td>
<td>9,100</td>
<td>14,000</td>
</tr>
<tr>
<td>System NH$_3$ Charge [kg]</td>
<td>88,400</td>
<td>83,900</td>
</tr>
</tbody>
</table>
Condenser VFD Retrofit

System #1 retrofit project

- Installed 12-15HP, 12-25HP VFDs for 6 evaporative condensers
- Set 15 Hz minimum condenser fan speed
- Did not upgrade to inverter duty motors
- Did not have motor failures due to VFDs
Condenser VFD Retrofit (continued)

Energy & economics
- 51% reduction in fan kWh
- 4% reduction in system kWh
- 1.5 year simple payback

Other benefits
- Soft-start with no more fan squealing
- Better head pressure control
- Quiet
Dairy Plant (Ice Cream)
Plant Energy Efficiency Opportunities

- Major addition 3 years prior
- New industrial ammonia refrigeration system installed
- State-of-the-art design, controls
- No industry energy benchmarks to compare:
  - Annual energy use = 29,179,000 kWh
  - Peak demand = 13 MW
  - Annual energy cost = ~$8,000,000
Significant Savings Opportunities Identified

Non capital

($411,121) savings
Immediate payback

+Capital

($732,900) savings
<2 year payback

That’s a LOT of ice cream!
Keys To Success

• Identify energy efficiency improvement opportunities
• Evaluate cost/benefit
• Assess operational risk/constraints
• Methodically implement/verify
• Don’t let low hanging fruit grow back
Questions?

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Thank you!