Forced Air Cooling

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Product Temperature during Forced Air Cooling

Forced Air Cooling

Peaches at 0.5 cfm/lb.

Temperature (°F) vs. Hours of Cooling

Peaches at 0.5 cfm/lb.

Temperature (°C) vs. Hours of Cooling

first fruit

mass average

last fruit
Divide Airspace Between Coolers

Block warm air from uncooled fruit from affecting fruit that has begun cooling.

Temperature Variation During Forced Air Cooling

Large diameter - melons

Uncooled centers

Airflow
Temperature Variation During Forced Air Cooling

Airflow

Small diameter - blueberries

Uncooled near air exit

Temperature Measurement
Reversing Airflow Direction

Vertical Cooler with Flow Reversal
Effect of Product Diameter

- Cantaloupe, dia.=6.0
- Peaches, dia.=3.25"
- Cherries, dia.=1.0"

Pressure Drop vs. Airflow

- Grape
- Pear
Pressure Drop vs. Airflow

- Bagged grapes in liner
- Chilean grapes
- Strawberries
- Plums, 4% vent
- Bagged grapes EPS
- Tomato, 10% vent
- Pears, 2% vent

Airflow

Maximum airspeed 1500 fpm (7.5 m/s)
Refrigeration Capacity Calculations

- **Evaporator**
  - Capacity for product cooled by each unit
- **Compressor/condenser**
  - Capacity for sum of all evaporators

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Evaporator Capacity

<table>
<thead>
<tr>
<th>Refrigeration capacity limit</th>
<th>Refrigeration capacity (tons/1000 lb of product (kW/MT))</th>
<th>Capacity (% of maximum)</th>
<th>7/8ths cooling time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2.43 (19)</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Average for first 1/2 cooling period</td>
<td>1.80 (14)</td>
<td>74</td>
<td>155</td>
</tr>
<tr>
<td>Average for 7/8 cooling</td>
<td>1.45 (11)</td>
<td>60</td>
<td>165</td>
</tr>
</tbody>
</table>

Based on cooling 24 pallets of broccoli with 32°F (0°C) air and 68°F (20°C) initial temperature. Refrigeration load for product only.
Energy Coefficient

Energy Coefficient = Cooling Work / Electricity Use

- Product cooled per billing period (lbs)
- Temperature drop in cooling (°F)
- Electricity use (kWh)

High EC = more cooling for less electricity

Forced-Air Cooler Efficiency

<table>
<thead>
<tr>
<th>Cooler</th>
<th>Season Average EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry A</td>
<td>0.68</td>
</tr>
<tr>
<td>Strawberry E</td>
<td>0.40</td>
</tr>
<tr>
<td>Strawberry C</td>
<td>0.33</td>
</tr>
<tr>
<td>Strawberry D</td>
<td>0.33</td>
</tr>
<tr>
<td>Strawberry B</td>
<td>0.23</td>
</tr>
<tr>
<td>Grape C</td>
<td>0.49</td>
</tr>
<tr>
<td>Grape B</td>
<td>0.49</td>
</tr>
<tr>
<td>Grape A</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Oldest facility
## Electricity Use in Forced Air Cooling

<table>
<thead>
<tr>
<th>Electricity Use (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>36</td>
</tr>
<tr>
<td>Fans</td>
<td>30</td>
</tr>
<tr>
<td>Lights</td>
<td>16</td>
</tr>
<tr>
<td>Walls</td>
<td>14</td>
</tr>
<tr>
<td>Lifts</td>
<td>4</td>
</tr>
</tbody>
</table>

Reduce Electricity Use in Cold Storage and Forced-Air Coolers

- Maximize use of refrigerated volume.
FA coolers are inefficient at low product throughput rates

Maximize Use of Refrigerated Volume

- Use racks or stack pallets - **Consolidate**
- Divide storage and refrigerate only space needed - **Shut down**
Reduce Electricity Use in Cold Storage and Forced-Air Coolers

- Maximize use of refrigerated volume.
- Install efficient lighting.

Lighting Options

HID

High Bay Fluorescent
Replace 400 W HID lamps with High Bay Fluorescent

<table>
<thead>
<tr>
<th>Location</th>
<th>Unit cost ($)</th>
<th>Use (hr/da)</th>
<th>Payback (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside</td>
<td>293</td>
<td>6</td>
<td>1360</td>
</tr>
<tr>
<td>Cold Storage</td>
<td>293</td>
<td>16</td>
<td>280</td>
</tr>
<tr>
<td>Cold Storage w/ motion sensor</td>
<td>373</td>
<td>4</td>
<td>210</td>
</tr>
</tbody>
</table>

Cold Storages are Hard to Light
Task Lighting

Reduce Electricity Use in Cold Storage and Forced-Air Coolers

- Maximize use of refrigerated volume.
- Install efficient lighting.
- Improve refrigeration system efficiency.
Refrigeration System Efficiency

- Increase suction pressure.
  - Floating suction pressure control
- Decrease discharge pressure.
  - Install more condenser capacity
- Speed control for screw compressors.
- Proper compressor sequencing.
- Optimum control of system.

25 to 40% Reduction in electricity use
Reduce Electricity Use in Cold Storage and Forced-Air Coolers

- Maximize use of refrigerated volume.
- Install efficient lighting.
- Improve refrigeration system efficiency.
- Minimize exterior heat gain.

Minimize Heat Gain

- Install rapid acting doors.
- Use high reflectivity exterior surfaces.
- Add wall or roof insulation.
- Insulate refrigeration piping.
Reduce Electricity Use in Cold Storage and Forced-Air Coolers

- Maximize use of refrigerated volume.
- Install efficient lighting.
- Improve refrigeration system efficiency.
- Minimize exterior heat gain.
- Minimize fan electricity use.

Fan Electricity Use

- Reduce fan speed near the end of cooling?
- In storage, reduce airflow when evaporators operate a partial capacity.
  - Fan cycling
  - Slow motor speed.
Forced-Air Cooler Cost
(Tunnel cooler in an existing cold room, no high side)

- New designs
- < energy use
- << lower labor cost
- ≥ capital cost

Approximate Forced Air Cooler Cost (2012 data)

$/pallet
(10 hr/day, 100 day/yr)

- Standard tunnel
- Vertical, double channel
- Flow through