Forced Air Cooling

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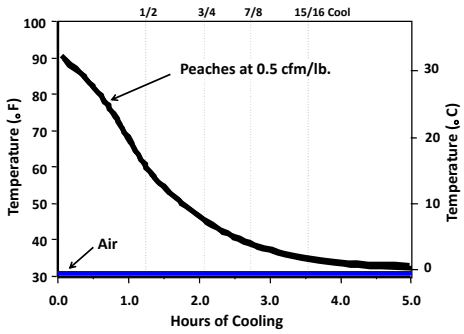
Forced Air Cooling

Product Temperature during Forced Air Cooling



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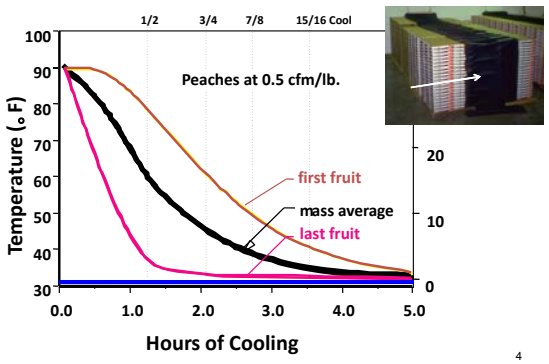

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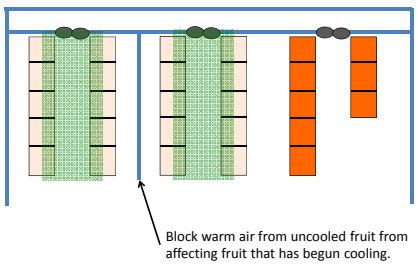
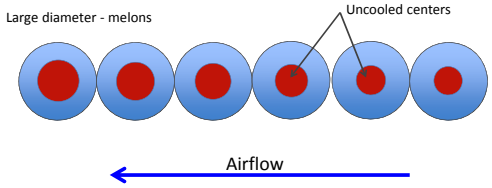
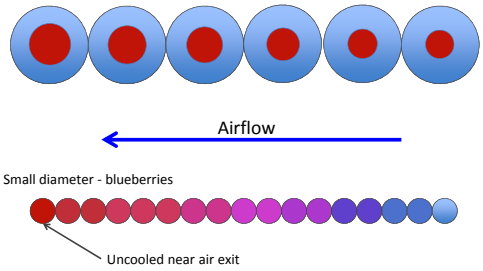
Divide Airspace Between Coolers



Temperature Variation During Forced Air Cooling



Temperature Variation During Forced Air Cooling



Temperature Measurement

Reversing Airflow Direction

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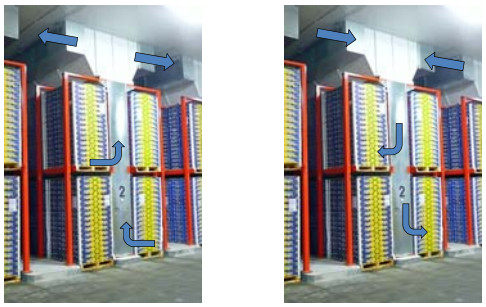
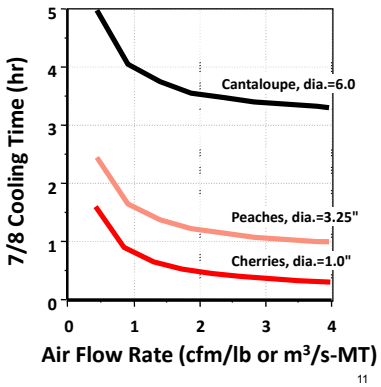
Vertical Cooler with Flow Reversal



Effect of Product Diameter



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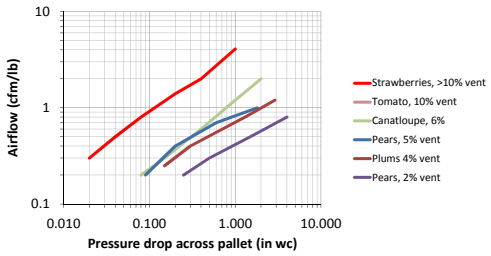
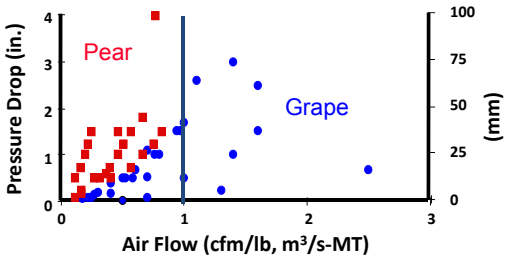
Pressure Drop vs. Airflow



- Vent area should be greater than 5% for airflow > 1 CFM/lb (m^3/s-MT)

Pressure Drop vs. Airflow



- Interior packaging has a big effect omn pressure drop.

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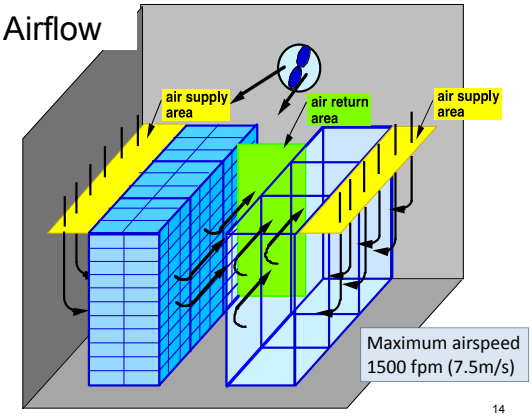
Airflow



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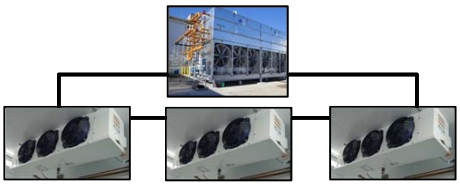
Refrigeration Capacity Calculations

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



Evaporator Capacity

Refrigeration capacity limit	Refrigeration capacity (tons/1000 lb of product (kW/MT))	Capacity (% of maximum)	7/8ths cooling time (min)
Unlimited	2.43 (19)	100	150
Average for first 1/2 cooling period	1.80 (14)	74	155
Average for 7/8 cooling	1.45 (11)	60	165

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

Cooler	Season Average EC
Strawberry A	0.68
Strawberry E	0.40
Strawberry C	0.33
Strawberry D	0.33
Strawberry B	0.23
Grape C	0.49
Grape B	0.49
Grape A	0.34

Oldest facility

Electricity Use in Forced Air Cooling

	Electricity Use (%)
Product	36
Fans	30
Lights	16
Walls	14
Lifts	4

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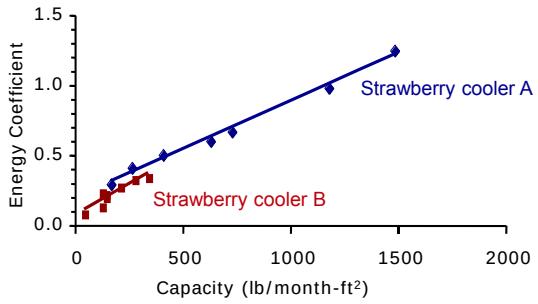
Reduce Electricity Use in Cold Storage and Forced-Air Coolers

- 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

Location	Unit cost ($)	Use (hr/da)	Payback (days)
Outside	293	6	1360
Cold Storage	293	16	280
Cold Storage w/ motion sensor	373	4	210

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.

Refrigeration System Efficiency

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 exterior refrigeration piping.

Reduce Electricity Use in Cold Storage and Forced-Air Coolers

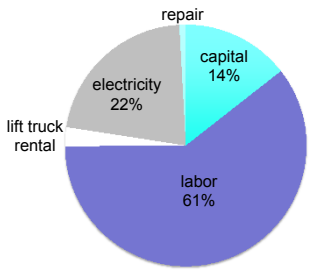
- Maximize use of refrigerated volume.
- Install efficient lighting.
- Improve refrigeration system efficiency.
- Minimize exterior heat gain.
- Minimize fan electricity use.

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)