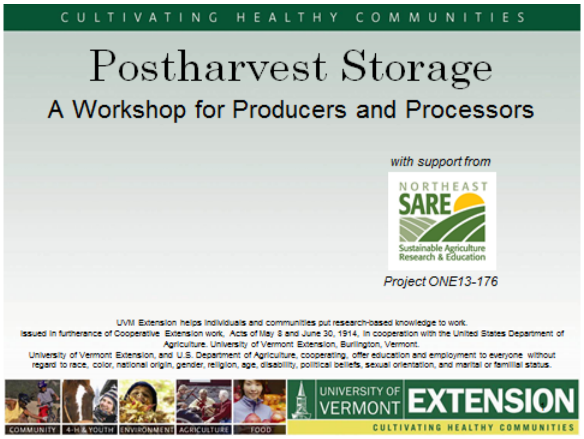


Chris Callahan – chris.callahan@uvm.edu

802-773-3349 x277

http://blog.uvm.edu/cwcallah

Outline

- Importance of Food Storage
- Energy and Heat Transfer
- Components of a Storage System
- {Lunch}
- Storage Characteristics of Food
- Sizing and Design
- Practice Session

Importance of Food Storage

- Product quality preservation
- Harvesting & season flexibility
- Food safety
- Food security
- Sunk costs
- Market extension

Energy in Food Storage

Food storage and quality preservation depend on maintaining

Temperature

Humidity

Against ambient conditions that differ from the target conditions and which change

Generally cooling, but may be heating as well.

- **Energy**: The ability to do work.

Can be stored

Cannot be created or destroyed

Units: kWhr, BTU, Joules, Calories

- **Power**: Energy converted over time.

Instantaneous measure

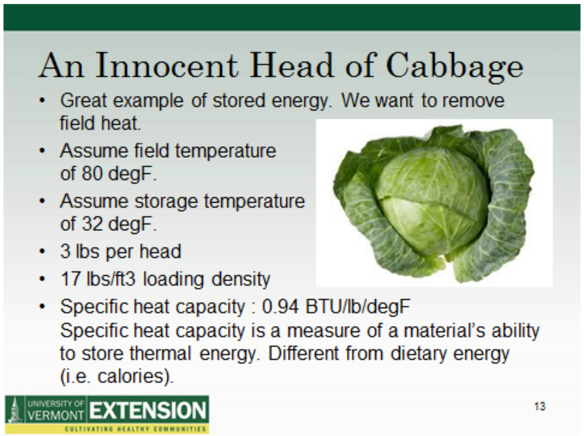
Never 100% efficient

Units: kW, BTU/hr, Joules/second, Calories/day

The Rules

- **0th Law** – There is such a thing as **thermal equilibrium**. "All heat is of the same kind."
- **1st Law** – **Energy is conserved**, you can't create or destroy it.
- **2nd Law** – **Systems seek equilibrium** and will do so on their own. Also, there is no free lunch, **no such thing as 100% efficiency**.
- **3rd Law** – We can't reach absolute zero temperature.

Precooling



1. What is the temperature change?
   80-32 degF = **48 degF**

2. How much are we cooling?
   Let's assume a pallet bin 4'x4'x4' = 64 ft3. Multiply by the loading density of 17 lbs/ft3… 64 ft3 x 17 lb/ft3 = **1088 lbs**

3. Cooling energy =
   mass cooled x specific heat x temperature change
   1088 lb x 0.94 BTU/lb/degF x 48 degF = **49,090 BTU**

4. How quickly are we cooling?
   Let's say **2 hours**.

5. Cooling power =
   Cooling energy / time
   49,090 BTU / 2 hour = **24,545 BTU/hr**

What does 49,090 BTU and 24,545 BTU/hr tell us?

What is the rating of the evaporator? Will it do the job? Needs to be at least 24,545 BTU/hr and if it is keeping other things cool you need to account for that as well.

If you're considering a hydrocooler or ice machine will you have the capacity?

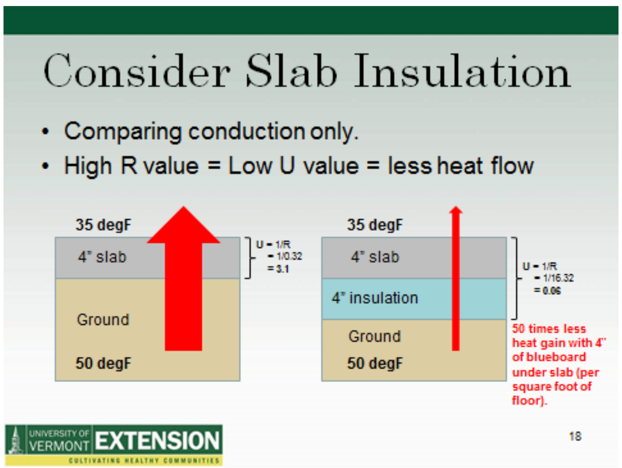
49,090 BTU is about 340 lbs of ice melting

144 BTU/lb of melted ice

Heat Transfer and Insulation

- The rate of heat transfer is proportional to the temperature difference and the *overall heat transfer coefficient*.
- Overall heat transfer coefficient (“U”) captures how easily heat moves from one body or fluid to another.

Conduction – through solids
Convection – through fluids
Radiation – body to body



A very common question is, “**How much insulation should I put in my cooler?**”

- Let’s take a look at a 10’x20’x8’ cooler.
- Assume 90 degF air and 50 degF ground
- Assume 34 degF cooler temp (6 months of use)
- Framed and insulated by grower
- Walls have 4” blueboard insulation.

R16 walls, 4 (hr-ft2-F)/BTU per inch

- **Compare 4” slab insulation to no insulation**

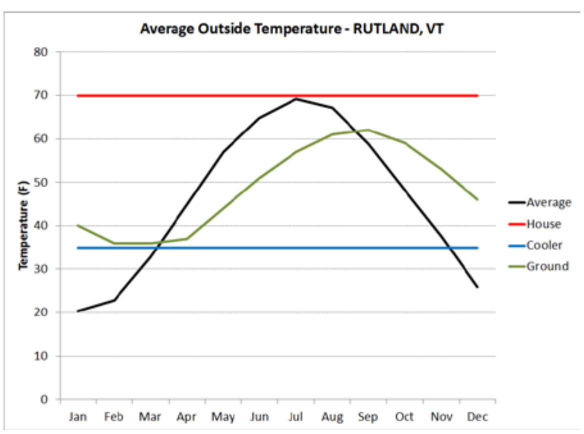
	With Slab Insulation	**Without** Slab Insulation	
Peak Loss / Evaporator Sizing	2,580	12,380	BTU/hr
Peak Loss / Compressor Sizing	0.3	1.7	HP
Electricity Use (6 months)	288	4,522	kWhr/yr
Operating Costs (6 months)	43	678	$/yr

- Insulation costs about $0.70 per inch thickness per square foot.
- 4” slab insulation would cost $560 for this cooler
- Our annual savings would be $635.
- Payback <1 year of operation.
- You can insulate above a slab as well, so retrofit is possible.
- What if everything was the same except wall & ceiling insulation thickness?

	With 2 inch wall insulation R8	With 4 inch wall insulation R16	With 6 inch wall Insulation R24	
Peak Loss / Evaporator Sizing	4,960	2,580	1,787	BTU/hr
Peak Loss / Compressor Sizing	0.7	0.3	0.2	HP
Electricity Use (6 months)	1,041	564	405	kWhr/yr
Operating Costs (6 months)	156	85	61	$/yr

Why Are Slabs So Important?

- Ground temperature lags air temperature seasonally.
- It is highest right when most growers are seeking long-term storage.
- And stays higher than desired storage temperature.
- Always a load.



List of R-values

Used with permission of R. L. Martin & Associates, Inc.

http://www.coloradoenergy.org/procorner/stuff/r-values.htm

Material	R/ Inch hr·ft2·°F/Btu	R/ Thickness hr·ft2·°F/Btu
Insulation Materials		
Fiberglass Batts	3.14-4.30	
3 1/2" Fiberglass Batt		11.00
3 5/8" Fiberglass Batt		13.00
3 1/2" Fiberglass Batt (high density)		15.00
6 1/2" Fiberglass Batt		19.00
5 1/4" Fiberglass Batt (high density)		21.00
8" Fiberglass Batt		25.00
8" Fiberglass Batt (high density)		30.00
9 1/2" Fiberglass Batt		30.00
12" Fiberglass Batt		38.00
Fiberglass Blown (attic)	2.20-4.30	
Fiberglass Blown (wall)	3.70-4.30	
Rock Wool Batt	3.14-4.00	
Rock Wool Blown (attic)	3.10-4.00	
Rock Wool Blown (wall)	3.10-4.00	
Cellulose Blown (attic)	3.60-3.70[1]	
Cellulose Blown (wall)	3.80-3.90[1]	
Vermiculite	2.13	
Autoclaved Aerated Concrete	1.05	
Urea Terpolymer Foam	4.48	
Rigid Fiberglass (> 4lb/ft3)	4.00	
Expanded Polystyrene (beadboard)	4.00	
Extruded Polystyrene	5.00	
Polyurethane (foamed-in-place)	6.25	
Polyisocyanurate (foil-faced)	7.20	
Construction Materials		
Concrete Block 4"		0.80
Concrete Block 8"		1.11
Concrete Block 12"		1.28
Brick 4" common		0.80
Brick 4" face		0.44
Poured Concrete	0.08	
Soft Wood Lumber	1.25	
2" nominal (1 1/2")		1.88
2x4 (3 1/2")		4.38
2x6 (5 1/2")		6.88
Cedar Logs and Lumber	1.33	
Sheathing Materials		
Plywood	1.25	
1/4"		0.31
3/8"		0.47
1/2"		0.63
5/8"		0.77
3/4"		0.94
Fiberboard	2.64	
1/2"		1.32
25/32"		2.06
Fiberglass (3/4")		3.00
(1")		4.00
(1 1/2")		6.00
Extruded Polystyrene (3/4")		3.75
(1")		5.00
(1 1/2")		7.50
Foil-faced Polyisocyanurate (3/4")		5.40
(1")		7.20
(1 1/2")		10.80
Siding Materials		
Hardboard (1/2")		0.34
Plywood (5/8")		0.77
(3/4")		0.93
Wood Bevel Lapped		0.80
Aluminum, Steel, Vinyl (hollow backed)		0.61
(w/ 1/2" Insulating board)		1.80
Brick 4"		0.44
Interior Finish Materials		
Gypsum Board (drywall 1/2")		0.45
(5/8")		0.56
Paneling (3/8")		0.47
Flooring Materials		
Plywood	1.25	
(3/4")		0.93
Particle Board (underlayment)	1.31	
(5/8")		0.82
Hardwood Flooring	0.91	
(3/4")		0.68
Tile, Linoleum		0.05

Carpet (fibrous pad)		2.08
(rubber pad)		1.23
Roofing Materials		
Asphalt Shingles		0.44
Wood Shingles		0.97
Windows		
Single Glass		0.91
w/storm		2.00
Double insulating glass (3/16") air space		1.61
(1/4" air space)		1.69
(1/2" air space)		2.04
(3/4" air space)		2.38
(1/2" w/ Low-E 0.20)		3.13
(w/ suspended film)		2.77
(w/ 2 suspended films)		3.85
(w/ suspended film and low-E)		4.05
Triple insulating glass (1/4" air spaces)		2.56
(1/2" air spaces)		3.23
Addition for tight fitting drapes or shades, or closed blinds		0.29
Doors		
Wood Hollow Core Flush (1 3/4")		2.17
Solid Core Flush (1 3/4")		3.03
Solid Core Flush (2 1/4")		3.70
Panel Door w/ 7/16" Panels (1 3/4")		1.85
Storm Door (wood 50% glass)		1.25
(metal)		1.00
Metal Insulating (2" w/ urethane)		15.00
Air Films		
Interior Ceiling		0.61
Interior Wall		0.68
Exterior		0.17
Air Spaces		
1/2" to 4" approximately		1.00

Intro to Psychrometrics—Humidifying & Drying

- What is actually happening?
- Depends on water changing "phase"

Liquid

Vapor

- That requires air, energy flow, and temperature

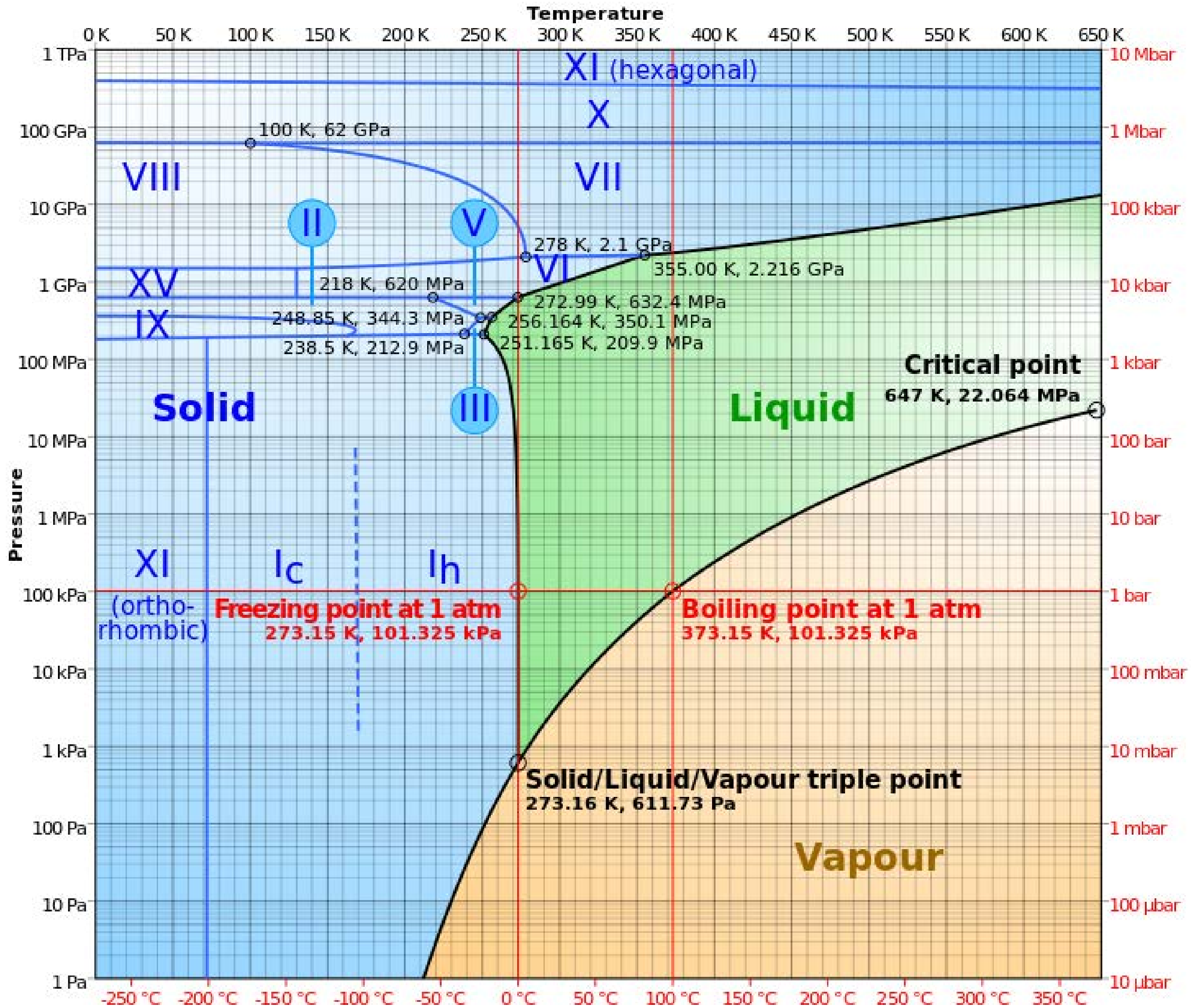
Water's Phase Change – Boiling or Evaporating

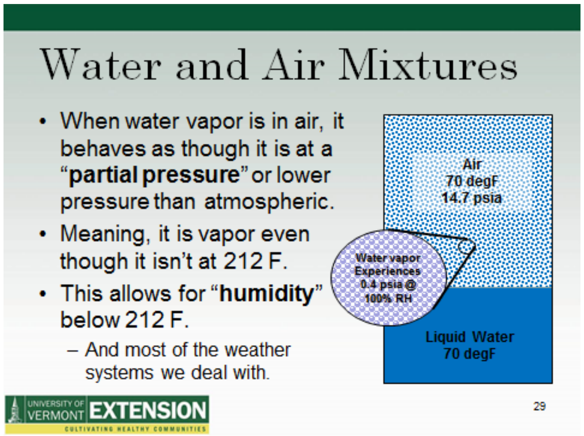
- What we think we know…

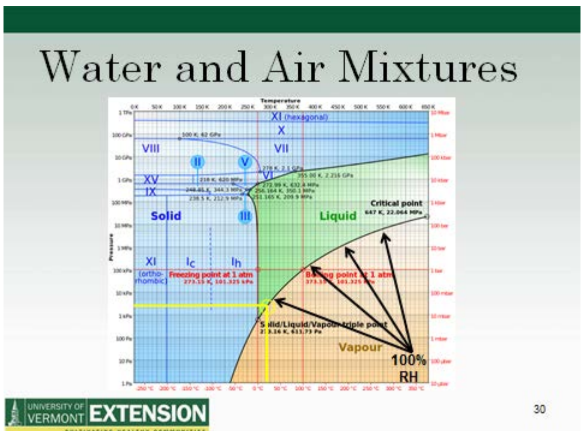
Water freezes at 32 F and 0 C

Water boils at 212 F and 100 C

- It is true….but…
- Only at standard atmospheric pressure!
- How is there water vapor in air when it is less than 212 F?


Temperature
0 K
50 K
100 K
150 K
200 K
250 K
300 K
350 K
400 K
450 K
500 K
550 K
600 K
650 K
Pressure
1 TPa
100 GPa
10 GPa
1 GPa
100 MPa
10 MPa
1 MPa
100 kPa
10 kPa
1 kPa
100 Pa
10 Pa
1 Pa
10 Mbar
1 Mbar
100 kbar
10 kbar
1 kbar
100 bar
10 bar
1 bar
100 mbar
10 mbar
1 mbar
100 µbar
10 µbar
-250 °C
-200 °C
-150 °C
-100 °C
-50 °C
0 °C
50 °C
100 °C
150 °C
200 °C
250 °C
300 °C
350 °C
XI (hexagonal)
X
VII
VIII
100 K, 62 GPa
II
V
278 K, 2.1 GPa
VI
355.00 K, 2.216 GPa
XV
218 K, 620 MPa
272.99 K, 632.4 MPa
IX
248.85 K, 344.3 MPa
256.164 K, 350.1 MPa
238.5 K, 212.9 MPa
251.165 K, 209.9 MPa
Critical point
647 K, 22.064 MPa
Solid
III
Liquid
XI
(ortho-
rhombic)
Ic
Ih
Freezing point at 1 atm
273.15 K, 101.325 kPa
Boiling point at 1 atm
373.15 K, 101.325 kPa
Solid/Liquid/Vapour triple point
273.16 K, 611.73 Pa
Vapour





Relative Humidity

- The degree to which air is "saturated" with water vapor at a certain temperature and barometric pressure.
- Since barometric pressure is relatively constant, RH is really a function of temperature.

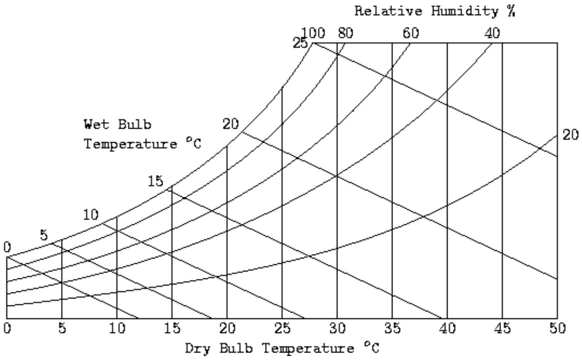
For *most* agricultural applications

Pressure's influence is the basis of vacuum cooling, however…

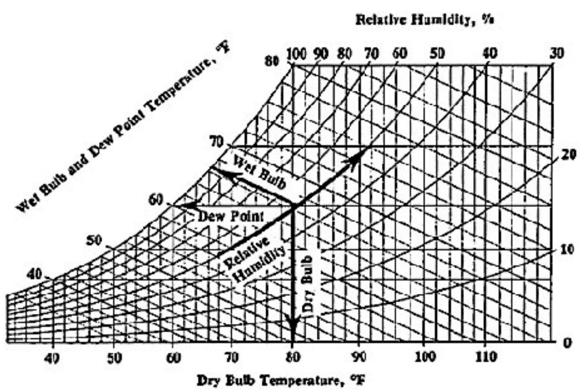
Psychrometric Charts

Relating Temperature and RH

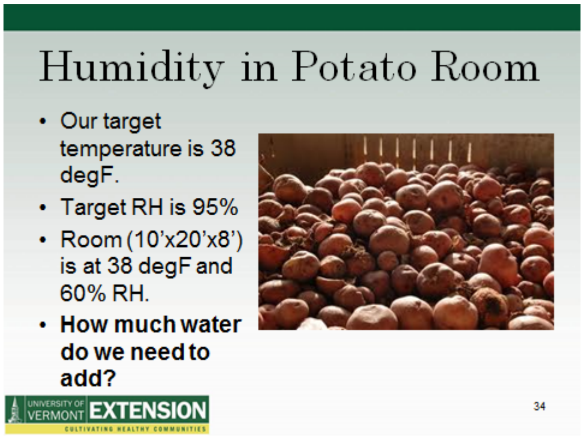
(Really Dry Bulb Temperature, Wet Bulb Temperature and RH)

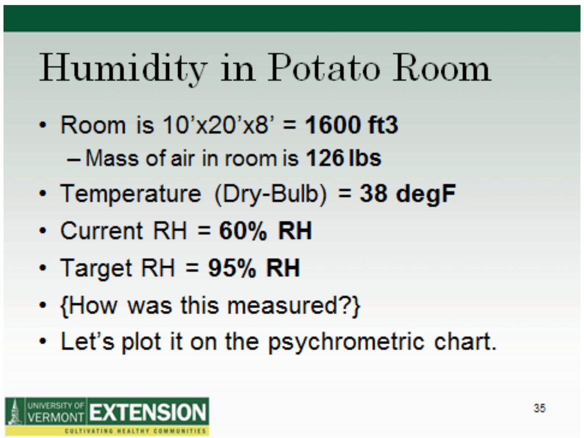


Remembering which axis to read for which data point is the hardest part of using these.



But if you're dealing with moist or dry air, they are very helpful.





- "Grains"?
  Unit of measure for mass.
  About 0.000143 lbs per grain. Handy when dealing with amounts of water in air.
- When converted, we need to add
  0.0017 lbs water per lb of air
  We know our room has 126 lbs of air
  So we need to add 0.22 lbs of water
  Or 3/100th gallon = **3.3 fluid ounces**

What does this mean?

- 3.3 fluid ounces isn't much water

- Some water vapor is produced through respiration.

- In this case, the naturally evolved water vapor is likely sufficient to raise the RH.

RenewAire
Energy Recovery Ventilators

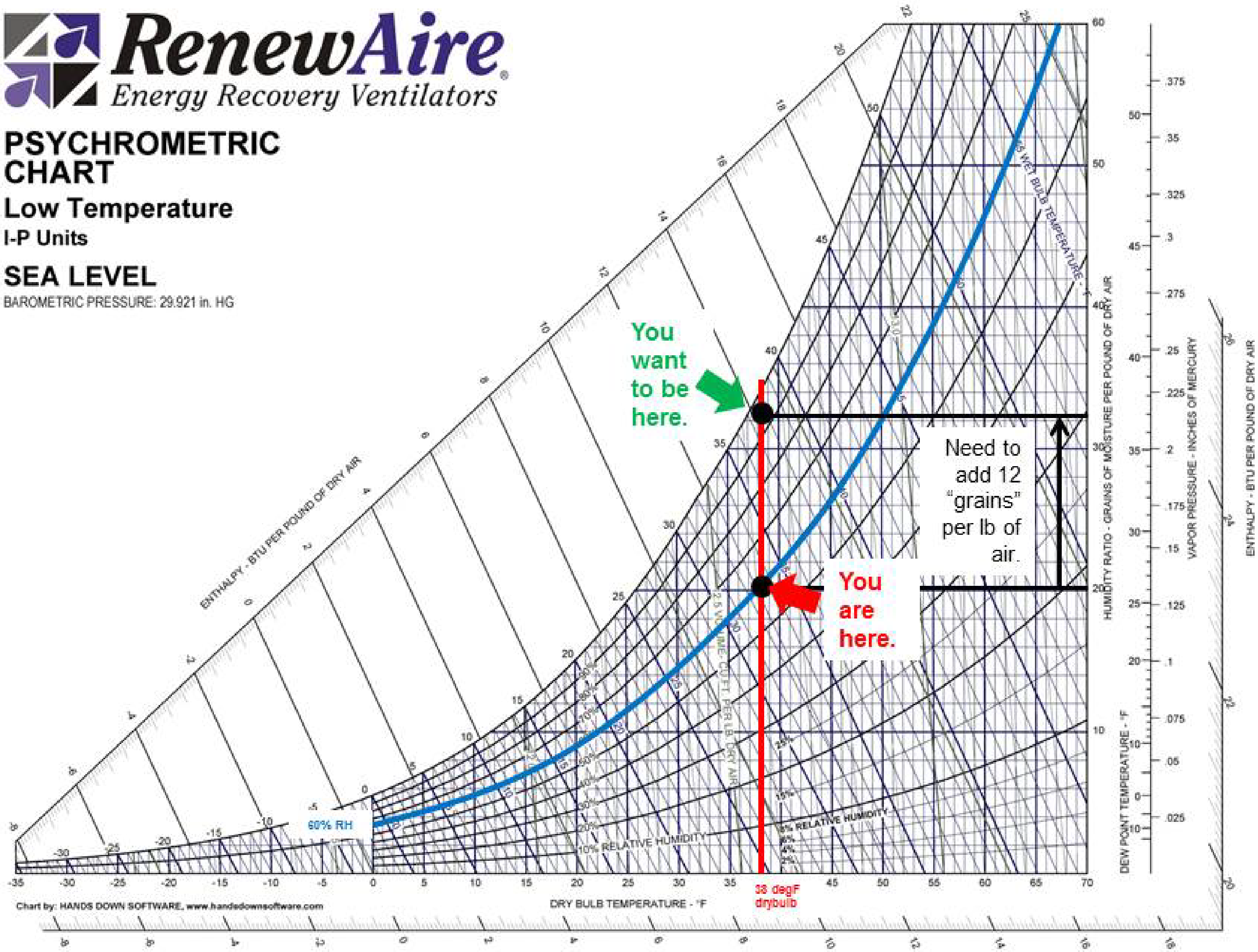
PSYCHROMETRIC CHART

Low Temperature

I-P Units

SEA LEVEL

BAROMETRIC PRESSURE: 29.921 in. HG



1 grain = 0.000143 lbs

Relative Humidity Table

Dry Bulb \ Wet Bulb	28.0	28.5	29.0	29.5	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5	40.0	40.5	41.0	41.5	42.0	42.5	43.0
30.0	77%	83%	88%	94%	100%																										
30.5	71%	77%	83%	89%	94%	100%																									
31.0	66%	72%	77%	83%	89%	94%	100%																								
31.5	61%	67%	72%	78%	83%	89%	94%	100%																							
32.0	56%	62%	67%	73%	78%	84%	89%	95%	100%																						
32.5	52%	57%	62%	68%	73%	78%	84%	89%	95%	100%																					
33.0	47%	52%	58%	63%	68%	73%	79%	84%	89%	95%	100%																				
33.5	43%	48%	53%	58%	63%	69%	74%	79%	84%	90%	95%	100%																			
34.0	38%	43%	49%	54%	59%	64%	69%	74%	79%	85%	90%	95%	100%																		
34.5	34%	39%	44%	49%	54%	59%	64%	70%	75%	80%	85%	90%	95%	100%																	
35.0	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%																
35.5	26%	31%	36%	41%	46%	51%	56%	61%	65%	70%	75%	80%	85%	90%	95%	100%															
36.0	22%	27%	32%	37%	42%	47%	51%	56%	61%	66%	71%	76%	81%	85%	90%	95%	100%														
36.5	18%	23%	28%	33%	38%	42%	47%	52%	57%	62%	66%	71%	76%	81%	86%	90%	95%	100%													
37.0	15%	20%	24%	29%	34%	39%	43%	48%	53%	57%	62%	67%	72%	76%	81%	86%	91%	95%	100%												
37.5	11%	16%	21%	25%	30%	35%	39%	44%	49%	53%	58%	63%	67%	72%	77%	81%	86%	91%	95%	100%											
38.0	8%	13%	17%	22%	26%	31%	36%	40%	45%	49%	54%	59%	63%	68%	72%	77%	82%	86%	91%	95%	100%										
38.5	5%	9%	14%	18%	23%	27%	32%	36%	41%	45%	50%	55%	59%	64%	68%	73%	77%	82%	86%	91%	95%	100%									
39.0	1%	6%	10%	15%	19%	24%	28%	33%	37%	42%	46%	51%	55%	60%	64%	69%	73%	78%	82%	87%	91%	96%	100%								
39.5		3%	7%	11%	16%	20%	25%	29%	34%	38%	42%	47%	51%	56%	60%	65%	69%	73%	78%	82%	87%	91%	96%	100%							
40.0			4%	8%	13%	17%	21%	26%	30%	34%	39%	43%	48%	52%	56%	61%	65%	69%	74%	78%	83%	87%	91%	96%	100%						
40.5			1%	5%	9%	14%	18%	22%	27%	31%	35%	40%	44%	48%	52%	57%	61%	65%	70%	74%	78%	83%	87%	91%	96%	100%					
41.0				2%	6%	10%	15%	19%	23%	27%	32%	36%	40%	45%	49%	53%	57%	62%	66%	70%	74%	79%	83%	87%	91%	96%	100%				
41.5					3%	7%	11%	16%	20%	24%	28%	33%	37%	41%	45%	49%	54%	58%	62%	66%	70%	75%	79%	83%	87%	92%	96%	100%			
42.0						4%	8%	13%	17%	21%	25%	29%	33%	38%	42%	46%	50%	54%	58%	63%	67%	71%	75%	79%	83%	88%	92%	96%	100%		
42.5						1%	5%	9%	14%	18%	22%	26%	30%	34%	38%	42%	46%	51%	55%	59%	63%	67%	71%	75%	79%	84%	88%	92%	96%	100%	
43.0							2%	6%	10%	15%	19%	23%	27%	31%	35%	39%	43%	47%	51%	55%	59%	63%	67%	72%	76%	80%	84%	88%	92%	96%	100%
43.5								3%	7%	11%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	84%	88%	92%	96%
44.0								1%	5%	9%	13%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	84%	88%	92%
44.5									2%	6%	10%	13%	17%	21%	25%	29%	33%	37%	41%	45%	49%	53%	57%	61%	65%	69%	72%	76%	80%	84%	88%
45.0										3%	7%	11%	14%	18%	22%	26%	30%	34%	38%	42%	46%	49%	53%	57%	61%	65%	69%	73%	77%	81%	84%
45.5											4%	8%	12%	15%	19%	23%	27%	31%	35%	38%	42%	46%	50%	54%	58%	62%	65%	69%	73%	77%	81%
46.0											1%	5%	9%	13%	16%	20%	24%	28%	32%	35%	39%	43%	47%	51%	54%	58%	62%	66%	70%	73%	77%
46.5												2%	6%	10%	13%	17%	21%	25%	28%	32%	36%	40%	44%	47%	51%	55%	59%	62%	66%	70%	74%
47.0													3%	7%	11%	14%	18%	22%	26%	29%	33%	37%	40%	44%	48%	52%	55%	59%	63%	66%	70%
47.5													1%	4%	8%	12%	15%	19%	23%	26%	30%	34%	37%	41%	45%	48%	52%	56%	59%	63%	67%
48.0														2%	5%	9%	13%	16%	20%	23%	27%	31%	34%	38%	42%	45%	49%	53%	56%	60%	64%
48.5															3%	6%	10%	13%	17%	21%	24%	28%	31%	35%	39%	42%	46%	49%	53%	57%	60%
49.0																4%	7%	11%	14%	18%	21%	25%	29%	32%	36%	39%	43%	46%	50%	54%	57%
49.5																1%	5%	8%	12%	15%	19%	22%	26%	29%	33%	36%	40%	43%	47%	51%	54%
50.0																	2%	6%	9%	13%	16%	20%	23%	27%	30%	34%	37%	41%	44%	48%	51%

Heat Transfer

- Heat will naturally flow from hot to cold (seeking equilibrium and the "*lowest energy state*").
- This is a blessing and a curse

We benefit from this in heating and cooling applications (think furnaces or evaporators)

We fight it when trying to keep a greenhouse warm in early spring or a cooler cool in mid summer.

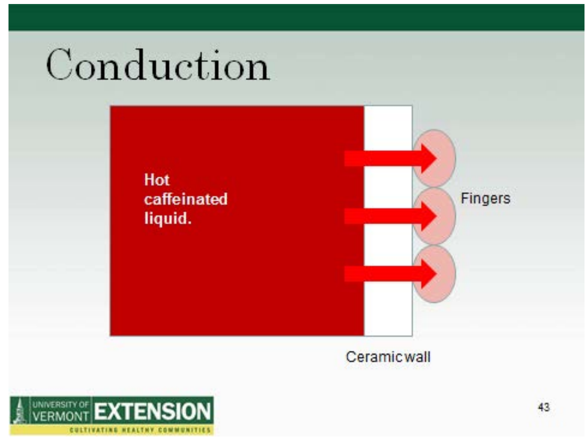
- Three modes

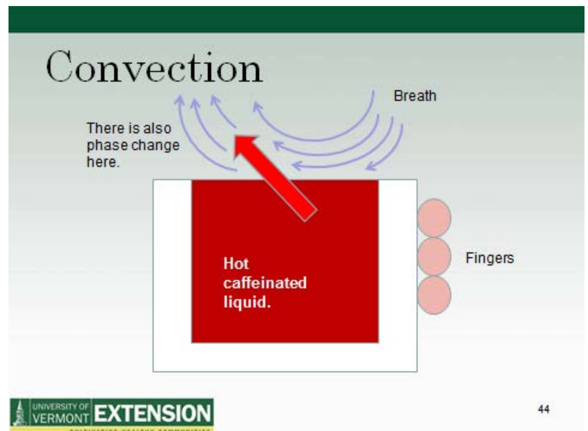
Conduction – through solids

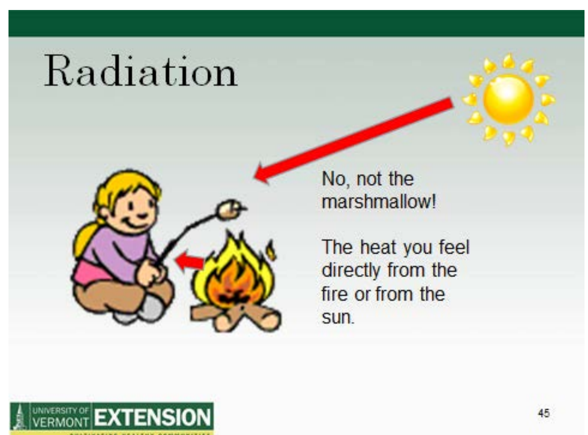
Convection – through fluids (liquid or gas)

Radiation – directly from one body to another

- All are proportional to temperature difference
- …and differ by how the heat flow is slowed (or enhanced.)







Components of a Storage System

Materials

- There are many options!

Pre-fabricated or homemade?
New or used?
Pros and Cons for each
Cost considerations

- Should be dictated by:

Your budget (including labor)

Existing infrastructure

Your short & long-term plans for the farm

What you're storing

- Beware of thermal conductors
    - Staggered stud walls are an option
- Framing with metal vs. wood
    - Must be structurally sound
- Buying a prefabricated box (e.g. pre-fab shed)

Interior materials should be:

- smooth;
- impervious;
- free of cracks and crevices;
- nonporous;
- nonabsorbent;
- non-contaminating;
- nonreactive;
- corrosion resistant;
- durable and maintenance free;
- nontoxic;
- easily cleanable.

- Examples of good materials to use for interiors:

Fiberglass Reinforced Plastic (FRP)

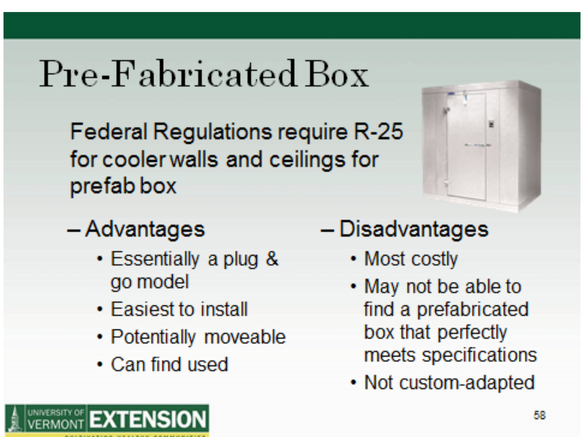
Sheet Metal

Recycled metal roofing or vinyl siding materials

- What not to use

Uncoated wood

Unsealed spray foam



Insulation

- Pre-Fabricated Box or Individual Panels
- Structural Insulated Panels
- Homemade panels
- Rigid insulation board
- Cellulose Insulation
- Spray Foam
- Other options:

Overseas Shipping Containers
Refrigerated Tractor-Trailer

Sealing

- Caulking during construction
- Overlapping foam board, don't cut to fit between studs
- Has to be tight or you're wasting money!

Both temperature and humidity implications

Drainage

- Lots of moisture collects on the floors in coolers

Build entire cooler slanted towards the door (or drain)
Incorporate a drain into the cooler

- Route condensation line intentionally.

Lighting

- Shatter-proof, shatter-resistant, or with a protective guard
- Must work in low temps/high humidity and turn on quickly

Compact fluorescent bulbs aren't great

- Should be bright enough to be able to see
- think efficiency!

Doors

- Buy pre-fab or make your own
- Just make sure it seals up
- Swing vs.Sliding vs. Overhead
- Plastic Curtains
- Weatherstripping

Containers

- Storage bins/pallet sizing (not all bulk bins are created equal)

- Consider: Wood vs. Plastic, Maneuverability, Stackability, Airflow & circulation

Winter Wash Station

- Many farms need to incorporate wash stations into winter storage systems

Consider:

- Will you be washing crops going into or coming out of storage
- Does there need to be space to wash crops indoors?
- Is there a creative way to combine a wash station with another storage area that needs humidity?
- implications

Rodent & Pest

- New construction vs. Retrofit
- Bait & traps
  - OMRI approved D3 rodenticide
  - Must have strict schedule for checking traps!
- Tight envelope excludes pests
- Wire mesh / hardware cloth
- Some storage bins help exclude rodents
- Cement curb

GAPS & FSMA

- SOPs& good recordkeeping are critical
- Minimize microbial contamination by using best practices
- Worker hygiene, sanitation schedules, proper culling of product, temperature monitoring, etc
- Producers need to show that best practices are being used with policies and documentation

Intro to Refrigeration

- Mechanical Refrigeration is a pumping system.
- We use the phase change of a refrigerant to move heat from one location (low temperature) to another (high temperature.)
    - “Pumping” heat from the cold source to the hot sink.
- Yes, we are moving heat from cold to hot.

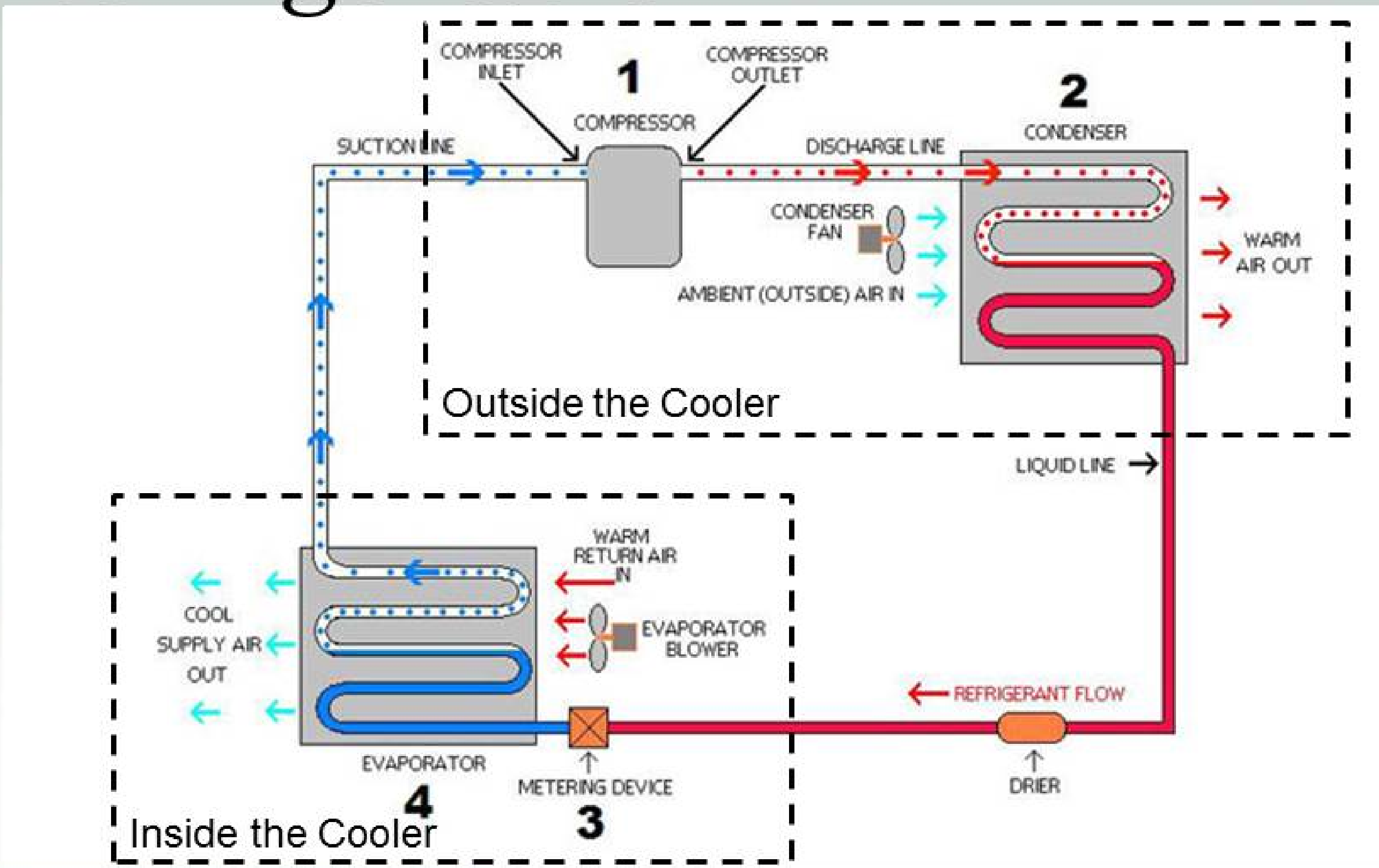
Heating

- Generally required for winter squash, pumpkins, etc.
- Same basic principles related to storage space / room.
- Air flow and circulation
- Heater controls

Ventilation and Airflow

- Seeking to have a well mixed storage space.
- Avoid hot spots
- Avoid high moisture
- Strip ethylene.
- 3-5 volume changes per day is rule of thumb.
- Higher for curing or pre-cooling.

Refrigeration



Controls - Thermostats

- Control a load based on temperature

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

101

Controls - Thermostats

- Dramm – Accurate to 1 degC (2 deg F)
  - Same model as greenhouse ones.
  - Single and dual stage
  - For heating and cooling
    - Different set of contactors.

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

102

Controls - Humidistats

- Control a load based on measured (or calculated) RH

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

103

Controls

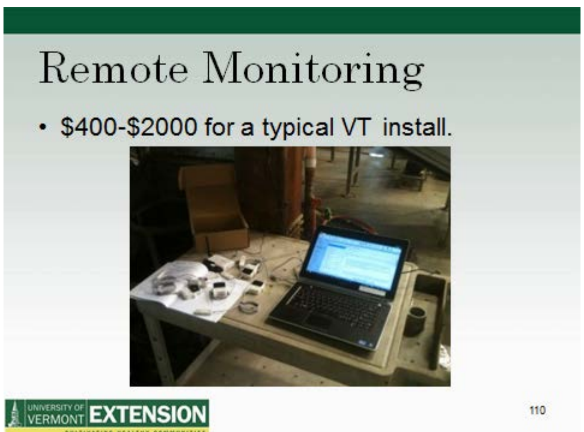
- Never trust your thermostat or humidistat
  - Precision and accuracy are different things.
- Always have a secondary, trusted measurement
  - Sling psychrometer is best.
- Check your **actual** conditions regularly

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

106

Measure and Monitor

- “The measured variable improves.”
- Temperature ***AND*** Relative Humidity
- Don’t assume you have the conditions you want. **Measure**.
- **Low tech** – wall sensors, daily checks, log book
- **High tech** – remote monitoring, email alerts
- Calibration and certification



Storage Characteristics of Food

- Respiration & Metabolism
- Temperature
- Humidity
- Ethylene
- Food Safety
- Pathology

Respiration

- Crops continue to respire and metabolize post-harvest

Through respiration crops use oxygen to break down energy (carbohydrates, fats or proteins)

- Respiration rates of different crops varies:

Low rate: Apples, potatoes

Moderate: Carrots, Cabbage

High rate: asparagus & sweet corn

Temperature

- General rule:

32-35˚ for cool season crops,

45-55˚ for warm season crops

Varies by crop!

See Handbook 66

- Beware of:

Freezing Injury

Chilling Injury

Humidity

- Relative Humidity (RH)

Amount of moisture in the air at a given temperature

Temperature dependent

Warmer air holds more moisture

- Transpiration

Crops release moisture into air through respiration

- Manage transpiration by managing RH

Ethylene

- C_2H_4
- Ripening hormone
- Produced in stored produce (at various rates)

plant hormone

physiologically active at very low concentrations

(0.1 to 10ppm)

Design and Sizing Considerations

Space Required

- List your storage crops

And quantity

- Check your loading density
- Group by temperature and RH
- Space dimensions

Product storage is 2/3 of overall space

Sketch the cooler

- Consider insulation thickness
- Load calculation

US Cooler
Calculator: http://www.uscooler.com/refrigeration-sizing-estimate
Ambient heat gain
Slab heat gain
Respiration
Door/Infiltration
Precooling

- Evaporator

Consider high temp / high humdity

- Compressor/Condenser
- Siting

Retrofit or new construction?
Retrofit considerations
Structural integrity of existing structure
Accessibility & efficiency
New construction

Where to put it? Out of direct sunlight! Shade of a tree or barn is nice

Efficiency as a piece in the whole farm system

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

Maintenance Checklist

Based on US Cooler's Recommendations: http://blog.uscooler.com/refrigeration-system-maintenance/

Unit Coolers (Evaporators)

At every six month interval, or sooner if local conditions cause clogging or fouling of air passages through the finned surface, the following items should be checked.

1) Visually inspect unit

• Look for signs of corrosion on fins, cabinet, copper tubing and solder joints.

• Look for excessive or unusual vibration of fan blades or sheet metal panels when in operation. Identify fan cell(s) causing vibration and check motor and blade carefully.

• Look for oil stains on headers, return bends, and coil fins. Check any suspect areas with an electronic leak detector.

• Check drain pan to insure that drain is clear of debris, obstructions or ice buildup and is free draining.

2) Clean evaporator coil and blades

• Periodic cleaning can be accomplished by using a brush, pressurized water or a commercially available evaporator coil cleaner or mild detergent. Never use an acid based cleaner. Follow label directions for appropriate use. Be sure the product you use is approved for use in your particular application.

• Flush and rinse coil until no residue remains.

• Pay close attention to drain pan, drain line and trap.

3) Check the operation of all fans and ensure airflow is unobstructed

• Check that each fan rotates freely and quietly. Replace any fan motor that does not rotate smoothly or makes an unusual noise.

• Check all fan set screws and tighten if needed.

• Check all fan blades for signs of stress or wear. Replace any blades that are worn, cracked or bent.

• Verify that all fan motors are securely fastened to the motor rail.

• Lubricate motors if applicable.

4) Inspect electrical wiring and components

• Visually inspect all wiring for wear, kinks, bare areas and discoloration. Replace any wiring found to be damaged.

• Verify that all electrical and ground connections are secure, tighten if necessary.

• Check operation/calibration of all fan cycle and defrost controls when used.

• Look for abnormal accumulation of ice patterns and adjust defrost cycles accordingly

• Compare actual defrost heater amp draw against unit data plate.

• Visually inspect heaters to ensure even surface contact with the coil. If heaters have crept, decrease defrost termination temperature and be sure you have even coil frost patterns. Re-align heaters as needed.

• Check drain line heat tape for proper operation (supplied and installed by others).

5) Refrigeration Cycle

• Check unit cooler superheat and compare reading for your specific application

• Visually inspect coil for even distribution

Air Cooled Condensing Units

Quarterly

1) Visually inspect unit

• Look for signs of oil stains on interconnection piping and condenser coil. Pay close attention to areas around solder joints, building penetrations and pipe clamps. Check any suspect areas with an electronic leak detector. Repair any leaks found and add refrigerant as needed.

• Check condition of moisture indicator/sightglass in the sight glass if so equipped. Replace liquid line drier if there is indication of slight presence of moisture. Replace refrigerant, oil and drier if moisture concentration is indicated to be high.

• Check moisture indicator/sightglass for flash gas. If found check entire system for refrigerant leaks and add refrigerant as needed after repairing any leaks.

• Check compressor sightglass (if equipped) for proper oil level.

• Check condition of condenser. Look for accumulation of dirt and debris (clean as required).

• Check for unusual noise or vibration. Take corrective action as required.

• Inspect wiring for signs of wear or discoloration and repair if needed.

• Check and tighten all flare connections.

<u>Semi-Annually</u>

2) Repeat all quarterly inspection items.

3) Clean condenser coil and blades

• Periodic cleaning can be accomplished by using a brush, pressurized water and a commercially available foam coil cleaner. If foam cleaner is used, it should not be an acid based cleaner. Follow label directions for appropriate use.

• Rinse until no residue remains.

4) Check operation of condenser fans

• Check that each fan rotates freely and quietly. Replace any fan motor that does not rotate smoothly or makes excessive noise.

• Check all fan blade set screws and tighten as required.

• Check all fan blades for signs of cracks, wear or stress. Pay close attention to the hub and spider. Replace blades as required.

• Verify that all motors are mounted securely.

• Lubricate motors if applicable. Do not lubricate permanently sealed, ball bearing motors.

5) Inspect electrical wiring and components

• Verify that all electrical and ground connections are secure, tighten as required.

• Check condition of compressor and heater contactors. Look for discoloration and pitting. Replace as required.

• Check operation and calibration of all timers, relays pressure controls and safety controls.

• Clean electrical cabinet. Look for signs of moisture, dirt, debris, insects and wildlife. Take corrective action as required.

• Verify operation of crankcase heater by measuring amp draw.

6) Check refrigeration cycle

• Check suction, discharge and net oil pressure readings. If abnormal take appropriate action.

• Check operation of demand cooling, liquid injection or unloaders if so equipped.

• Check pressure drop across all filters and driers. Replace as required.

• Verify that superheat at the compressor conforms to specification. (30°F to 45°F)

• Check pressure and safety control settings and verify proper operation.

<u>Annually</u>

7) In addition to quarterly and semiannual maintenance checks, submit an oil sample for analysis

• Look for high concentrations of acid or moisture. Change oil and driers until test results read normal.

• Investigate source of high metal concentrations, which normally are due to abnormal bearing wear. Look for liquid refrigerant in the crankcase, low oil pressure or low superheat as a possible source.

8) Inspect suction accumulator (if equipped)

• If the accumulator is insulated remove insulation and inspect for leaks and corrosion.

• Pay close attention to all copper to steel brazed connections

• Wire brush all corroded areas and peeling paint.

• Apply an anti-corrosion primer and paint as required. Re-insulate if applicable.

Air Cooled Condensers and Fluid Coolers

At every six month interval, or sooner if local conditions cause clogging or fouling of air passages through the finned surface, the following items should be checked.

1) Visually inspect unit

• Look for signs of corrosion on fins, cabinet, copper tubing and solder joints.

• Look for excessive or unusual vibration for fan blades or sheet metal panels when in operation. Identify fan cell(s) causing vibration and check motor and blade carefully.

• Look for oil stains on headers, return bends, and coil fins. Check any suspect areas with an electronic leak detector.

2) Clean condenser coil and blades

• Periodic cleaning can be accomplished by using brush, pressurized water or a commercially available coil cleaning foam. If a foam cleaner is used, it should not be an acid based cleaner. Follow label directions for appropriate use.

• Clear unnecessary trash and debris away from condenser.

3) Check the operation of all fans

• Check that each fan rotates freely and quietly. Replace any fan motor that does not rotate smoothly or makes an unusual noise.

• Check all fan set screws and tighten if needed.

• Check all fan blades for signs of stress or wear. Replace any blades that are worn, cracked or bent.

• Verify that all fan motors are securely fastened to the motor rail.

• Lubricate motors if applicable (most Heatcraft condenser motors are permanently sealed ball bearing type and do not require lubrication)

4) Inspect electrical wiring and components

• Visually inspect all wiring for wear, kinks, bare areas and discoloration. Replace any wiring found to be damaged.

• Verify that all electrical and ground connections are secure, tighten if necessary.

• Check operation/calibration of all fan cycle controls when used.

General Safety Information:

1. Installation and maintenance to be performed only by qualified personnel who are familiar with this type of equipment.
2. Some units are pressurized with dry air or inert gas. All units must be evacuated before charging the system with refrigeration.
3. Make sure that all field wiring conforms to the requirements of the equipment and all applicable national and local lodes.
4. Avoid contact with sharp edges and coil surfaces. They are a potential injury hazard.
5. Make sure all power sources are disconnected before any service work is done on the units.