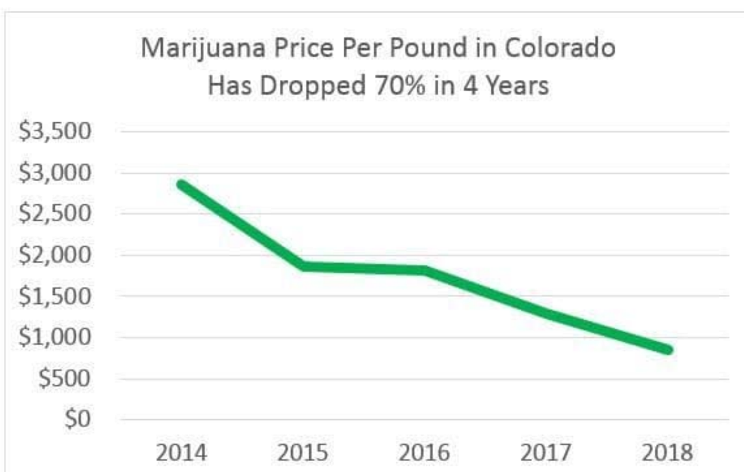
Understanding HVAC & Plant Dynamics in Grow Rooms

Indoor Grow Rooms

This is a business!

- No longer a basement industry
- The economic laws of supply and demand will drive this industry
- Only those growers who produce high yields at low operating cost will survive
- Cost of goods sold will be the metric



Source: Average sale price each spring calculated by Colorado Department of Revenue

Presentation Topics

- Is an indoor grow primarily a sensible load or a latent load?
- Is it temperature and relative humidity or vapor pressure deficit that drives plant growth?
- Can the HVAC design significantly reduce equipment size and energy use in a grow facility?

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Loads for Grow Facilities

- Major loads
  - Lighting (sensible)
  - Evapotranspiration (latent)
- Minor Loads
  - Building Skin Loss/Gain
  - Solar
  - Infiltration
  - Ventilation

Lighting

- Lighting is largest part of sensible load
  - Exercise care with “equivalent watts” marketing literature
  - Use power input data for fixture if available
  - Energy in equals energy out
  - LED lights add new variables
- Lighting hours change from vegetative to flowering stages

Evapotranspiration

- This is strictly a latent load
- Evaporation highly dependent on irrigation method
  - Drip Irrigation – Low evaporation
  - Flood or Trough Irrigation – Higher rate
  - Spray Irrigation – Extremely high evaporation
- Best estimated by water in = water out

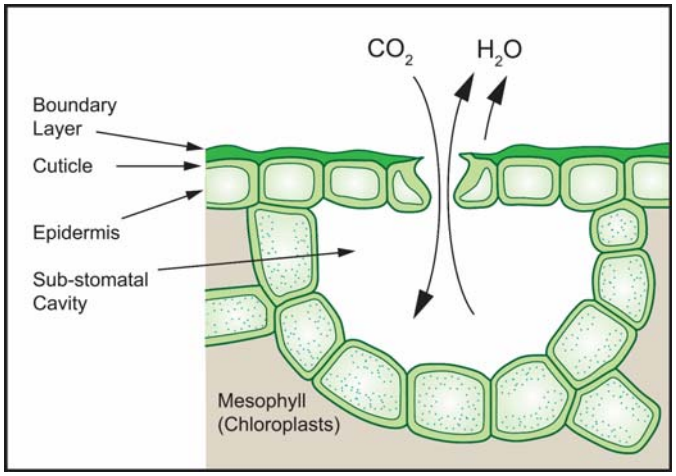
Transpiration

- Leaf temperature determines the vapor pressure in the leaf
- Air temperature and humidity determines the vapor pressure in the air
- Differential pressure drives transpiration – force for nutrients to be brought to upper areas of plant

Transpiration – Lights Out

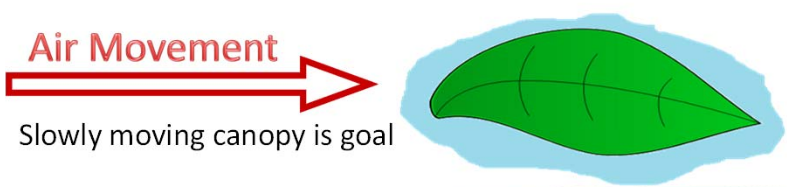
- Transpiration continues at a lower rate during lights out
- Slowly decreases over 60-120 minutes. Roughly 30% of full light moisture rate when full dark.
- This latent load can still be high while the sensible load is close to zero.

Transpiration



Importance of Air Movement Plant Leaf Boundary Layer

- Water vapor builds at leaf boundary layer
- Creates higher relative humidity and vapor pressure at leaf surface
- Buildup can happen under canopy
  - Dicots have most stomata on underside of leaf
  - 20-30% higher relative humidity under canopy if airflow is too low



Total Loads and Control

2,600 ft^2 2,000 plants
50 watts/sq ft. 500 gal/day net water
0 CFM Ventilation - Lights On

Description	Sensible (btu/hr)	Latent (btu/hr)
Lighting and Appliance	443,690	0
Doors	0	0
Ceiling	0	0
Walls	0	0
Infiltration	0	0
Ventilation	0	0
Evapotranspiration	0	256,608
Total	443,690	256,608

443,690/(443,690 + 256,608) = 0.63 SHR

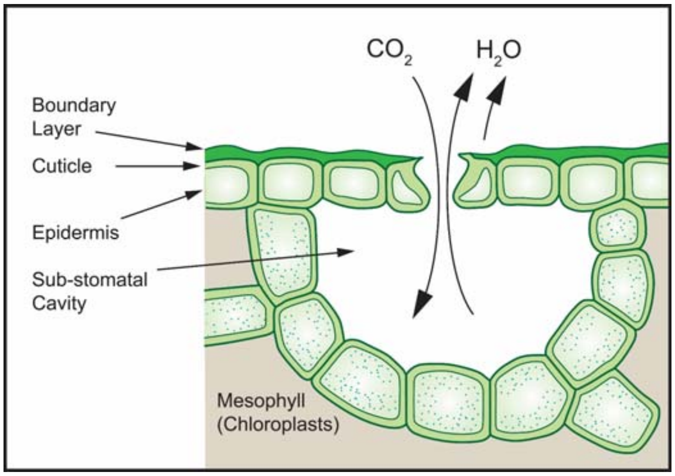
Total Loads and Control

2,600 ft^2 2,000 plants
50 watts/sq ft. 500 gal/day net water
0 CFM Ventilation - Lights Off

Description	Sensible (btu/hr)	Latent (btu/hr)
Lighting and Appliance	1,203	0
Doors	0	0
Ceiling	0	0
Walls	0	0
Infiltration	0	0
Ventilation	0	0
Evapotranspiration	0	109,975
		-
Total	1,203	109,975

No cooling required. Dehumidification Only Load.

Transpiration



Evaporative Cooling Effect

- As … absorbed.
  - E … s (swamp c…
- Pla … e trai … emselves. Thi … ction this in turi…

The Penman-Monteith Equation is given by the following equation (FAO, 1998a):

Equation 3

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma \frac{900}{T + 273} u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)}$$

Where:

ET_o	=	Reference evapotranspiration (mm/day)
R_n	=	Net radiation at the crop surface (MJ/m² per day)
G	=	Soil heat flux density (MJ/m² per day)
T	=	Mean daily air temperature at 2 m height (°C)
u_2	=	Wind speed at 2 m height (m/sec)
e_s	=	Saturation vapour pressure (kPa)
e_a	=	Actual vapour pressure (kPa)
$e_s - e_a$	=	Saturation vapour pressure deficit (kPa)

Total Loads and Control

2600 ft^2, 2,000 plants, Lights On
50 watts/sq ft. 500 gal/day net water

Light Vegetation

Description	Sensible (btu/hr)	Latent (btu/hr)
Lighting and Appliance	443,690	0
Doors	0	0
Ceiling	0	0
Walls	0	0
Infiltration	0	0
Ventilation	0	0
Evapotranspiration	0	50,434
Evaporative Cooling Effect	**-50,434**	-
Total	393,256	50,434

393,256/(393,256 + 50,434) = 0.89 SHR

Total Loads and Control

2,600 ft^2, 2,000 plants, Lights On
50 watts/sq ft. 500 gal/day net water

Full vegetation

Description	Sensible (btu/hr)	Latent (btu/hr)
Lighting and Appliance	443,690	0
Doors	0	0
Ceiling	0	0
Walls	0	0
Infiltration	0	0
Ventilation	-0	0
Evapotranspiration	0	256,608
Evaporative Cooling Effect	**-256,608**	-
Total	187,082	256,608

187,082/(187,082+ 256,608) = 0.42 SHR

Grow Facility Process Rooms

- Mother Room – Primarily Sensible
- Cloning Room – Sensible
- Vegetative Rooms - Latent
- Flower Rooms - Latent
- Drying Room and Curing Room - Latent

Temperature/RH or VPD?

- Temperature and relative humidity is grower's "secret sauce"
- Vapor pressure deficit is driving influence for plant development
- Critical factor when sizing HVAC equipment

Key HVAC Design Elements

- Maintain temperature
- Maintain humidity
- Control Vapor Pressure Deficit
- Maintain air movement through canopy
  - Homogenous environments
  - Eliminate possibility of mold/mildew

Vapor Pressure Deficit

- Defined by combination of two parameters
  - Temperature
  - Relative humidity
- Pressure exerted at room conditions vs. pressure at saturation
- Indictor of evapotranspiration potential

Low VPD

- Occurs at higher dewpoints
- Stomata close because transpiration is impaired
- Results
  - Water droplets/condensation on leaves
  - High probability of mold/mildew formation
  - Yield reduced

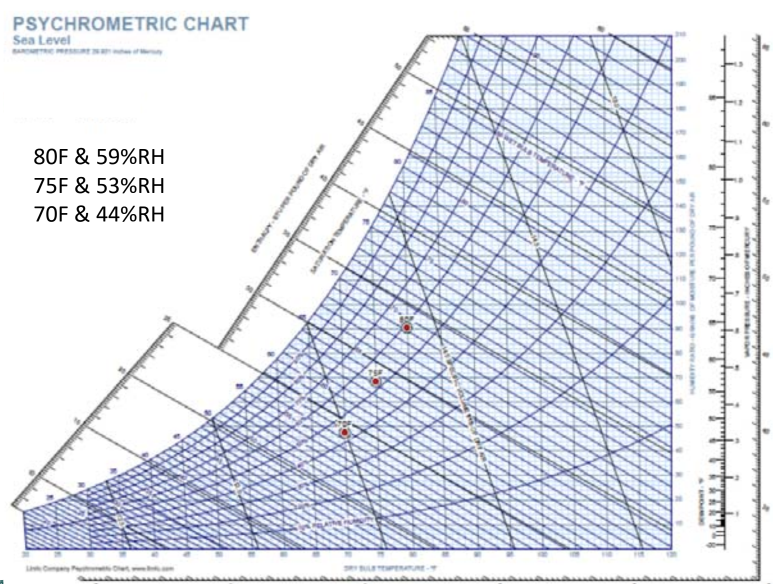
High VPD

- Occurs at lower dewpoints
- Plant wants to transpire at maximum rate
- However, stomata close to avoid dehydration
- Results
  - Yield is reduced
  - Plant health compromised

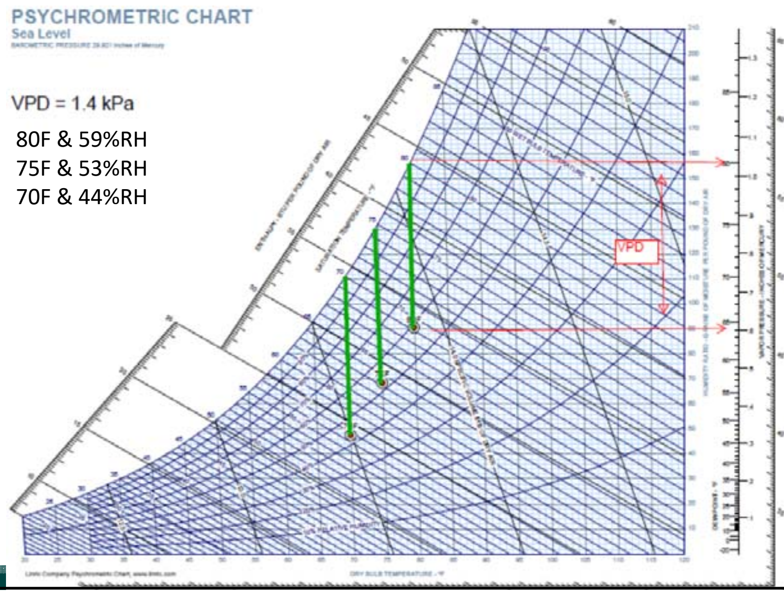
VPD Impact on HVAC

- Cooling
  - VPD has only small impact on performance of the cooling function
- Dehumidification
  - VPD has large impact
  - Dehumidifiers without cooling can add to load
  - Lower dewpoint air makes it harder to condense moisture
  - Larger equipment is required

Temperature and RH or VPD?



Temperature and RH or VPD?



VPD = 1.4 kPa

80F & 59%RH
75F & 53%RH
70F & 44%RH

Sizing Comparison

Impact on unit size @ various design conditions but same VPD

	Example #1	Example #2	Example #3
Temperature (F db)	80	75	70
Relative Humidity	59%	53%	44%
Wet Bulb (F)	69.2	63.2	56.6
Dewpoint (F)	64	57.5	47.1
VPD (kPa)	1.4	1.4	1.4
HVAC Size (nominal tons)	34	43	53
Increase in size	--	26%	56%

DIFFERENT DESIGN SOLUTIONS IMPACT ENERGY COSTS

Example Energy Comparison

- Assumptions
  - 2,600 sq ft Canopy
  - 5.2 sq ft per plant
  - 500 appx. # of plants
  - 50 Watts / sq ft canopy
- Watering Rate
  - 0.19 gal/day/sq ft
  - 1.00 gal/day/plant
  - 502 gal/day
- Utility Cost
  - $0.12/ kWh

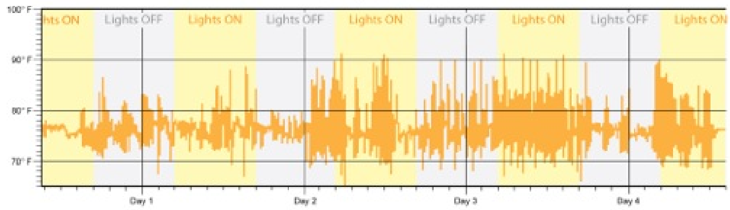
kWh per square foot of canopy

	AC w/ additional systems			
	Portable Dehum.	Enhanced Dehum.	Std. Dehum. w/clg	Combined System
Lights On				
Air Conditioner (kWh)	67	53	46	--
Dehumidifier (kWh)	24	9	13	--
Combined System (kWh)	--	--	--	49
Total Energy - Lights on	**91**	**62**	**59**	**49**
Lights Off				
Air Conditioner (kWh)	0	0	0	--
Dehumidifier (kWh)	24	13	18	--
Combined System (kWh)	--	--	--	16
Extra heat required (kW/hr)	0	28	0	0
Total Energy - Lights off	**24**	**41**	**18**	**16**
Totals				
Annual kW/sq ft Consumed	115	103	77	65
Electrical cost per year / sq ft	$13.80	$12.36	$9.28	$7.80
Annual Energy Cost	$35,880	$32,136	$24,140	$20,280

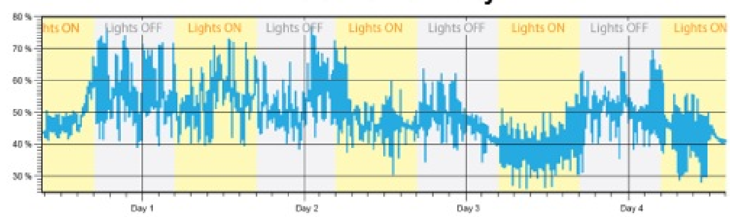
DOES THE TYPE OF SYSTEM DESIGNED MAKE A DIFFERENCE?

Monitoring of N. California Grow Room AC with Dehumidifiers

Temperature

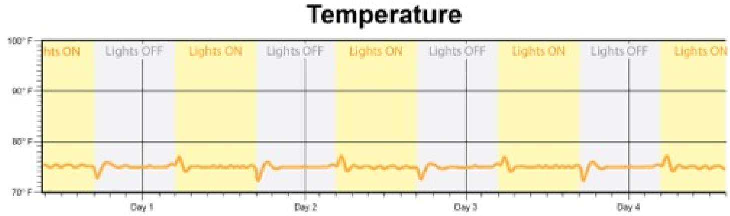


Relative Humidity

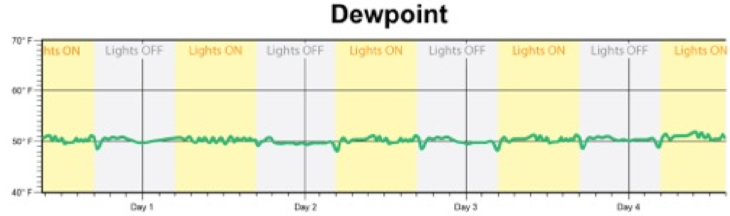


Monitoring of Oakland Grow Room Purpose Built Environmental Control Unit

Temperature



Dewpoint



Summary

- The grow room climate is a predominant latent load. Using sensible oriented equipment such as air conditioners, chillers, VRFs, etc, in the vegetative, flower, and drying rooms is a misapplication of that equipment.

- It is vapor pressure deficit and not temperature and relative humidity that is the driving force for moving water and nutrients through the plants. Work with growers to design to VPD and not temperature and RH. Significant reduction in equipment size can occur.

- Up to a 40% energy savings can occur by using the right equipment with the right controls. In addition, the grower will achieve a higher yield due to better room control.