Understanding HVAC & Plant Dynamics in Grow Rooms

Optimizing Solutions through Superior Dehumidification Technology SM

Indoor Grow Rooms

Three species but many strains and varieties

- Sativa

- Ruderalis

- Indica

Male vs Female

- Male
- Female 

Active Compounds

Known as Cannabinoids

- Primary psychoactive compound:
  - THC
- Primary compounds for medical marijuana:
  - CBD
  - CBG

Terpenes

- Organic hydrocarbon compounds that give cannabis its fragrance and flavor
- Psychoactive effects – interacts with THC and CBD

Grow Facility Process Rooms

- Mother Room
- Cloning Room
- Vegetative Room
- Flower Room
- Drying Room and Curing Room

What does cannabis need to maximize yield? …This is a business!

- Lighting
- **Tight environmental control**
- Water
- Nutrients
- CO_2

Key Concepts for Grow Room Climate Control

- Temperature and Relative Humidity
- Dew Point
- Vapor Pressure Deficit
- Sensible Load
- Latent Load
- Sensible Heat Ratio

Importance of Temperature and Humidity Control

- Plants
  - Creates the condition for optimal plant growth
  - Avoids conditions for bacteria, fungus, mold, and pest growth
- Building
  - Condensation on surfaces in structure can cause major damage
- Occupants
  - Comfortable working environment and high productivity

Loads for Growing Facilities

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

Load Details – 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

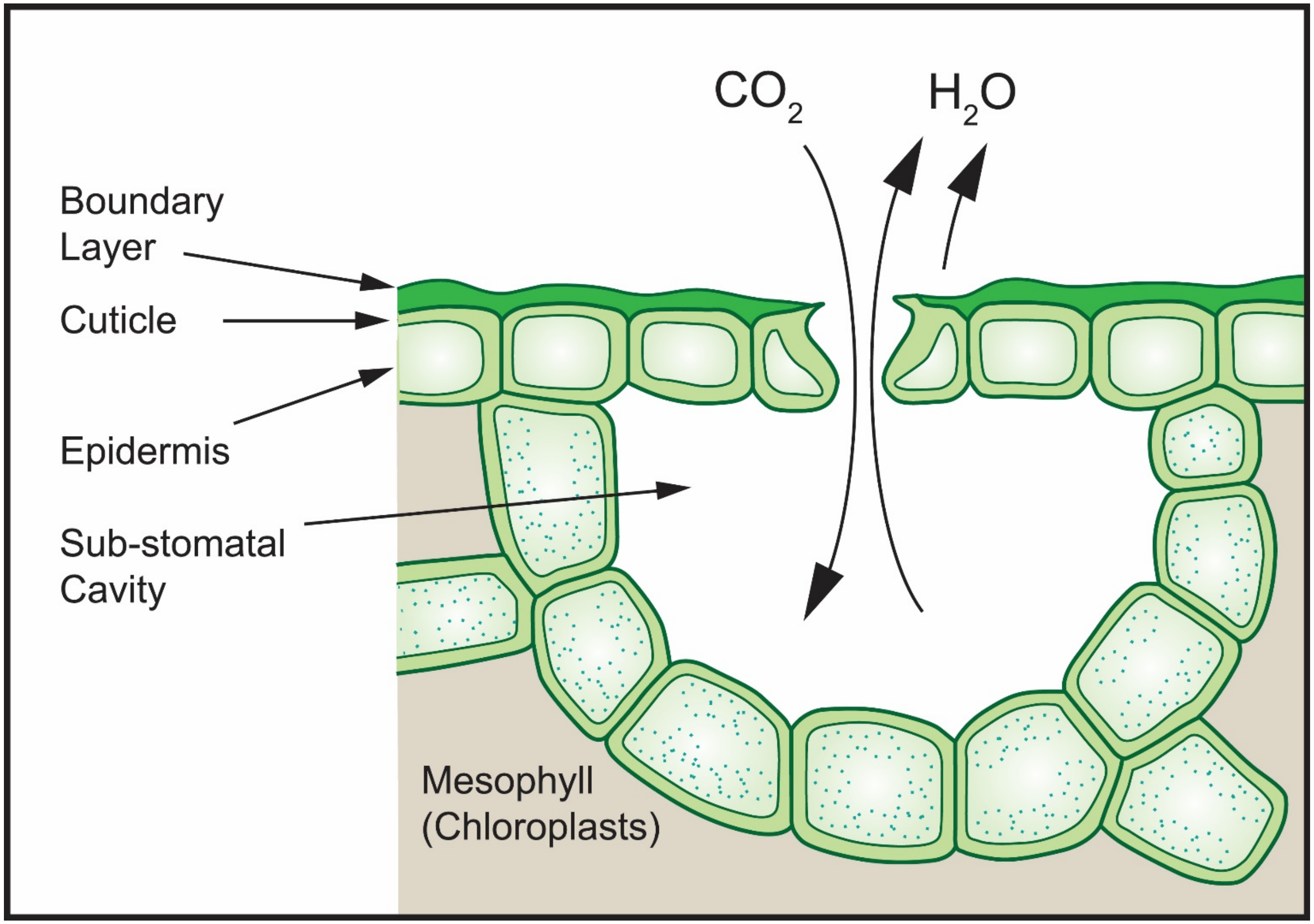
Transpiration

- 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

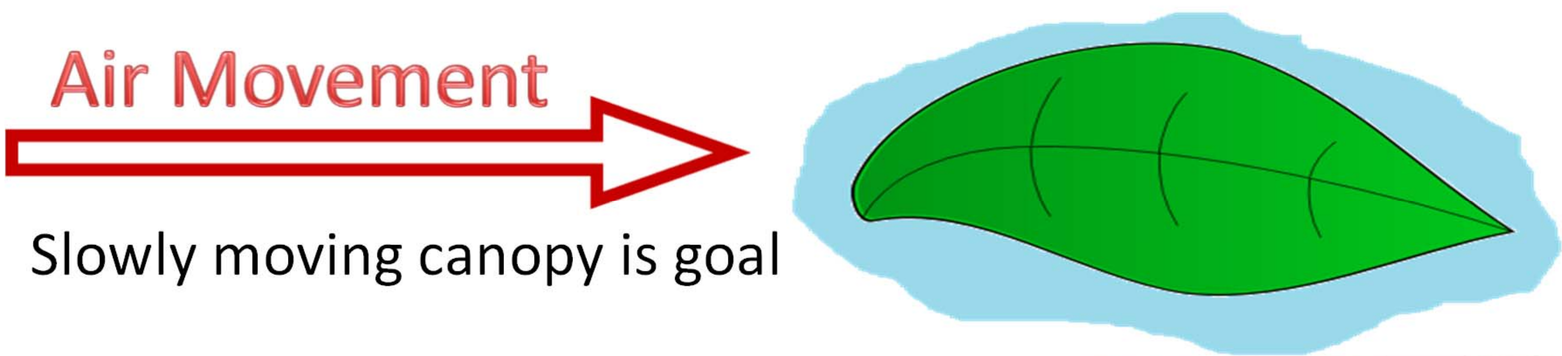
- Transpiration continues at a lower rate during lights out
- Slowly decreases over 60-120 minutes. Roughly 30% of full light moisture rate when full dark.
- This latent load can still be high while the sensible load is close to zero.

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

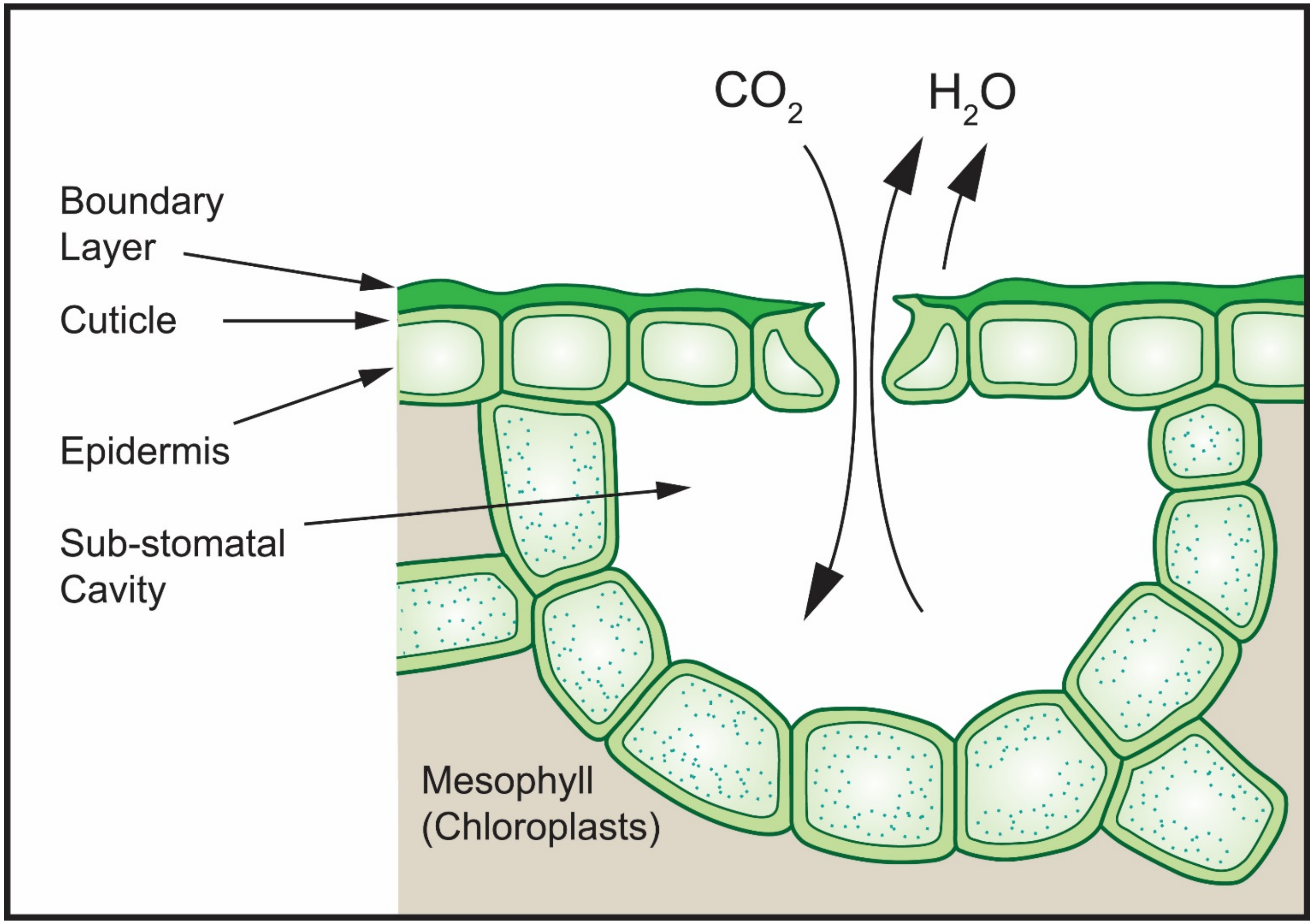
50 watts/sq ft. 500 gal/day net water

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 ... rs (swamp c...
- Pla ... e trar ... emselves. Thr ... ction this in turr...

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/m^2 per day)
G	=	Soil heat flux density (MJ/m^2 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

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

- VPD
  - Called Vapor Pressure Difference by HVAC
- Defined by combination of two parameters
  - Temperature
  - Absolute humidity (not relative humidity)
- Deficit or Difference
  - Pressure exerted at room conditions vs. pressure at saturation
  - Indicator of Evapotranspiration potential

Low VPD

- Occurs at higher RH values @ constant temperature
  - 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 RH values @ constant temperature
  - 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

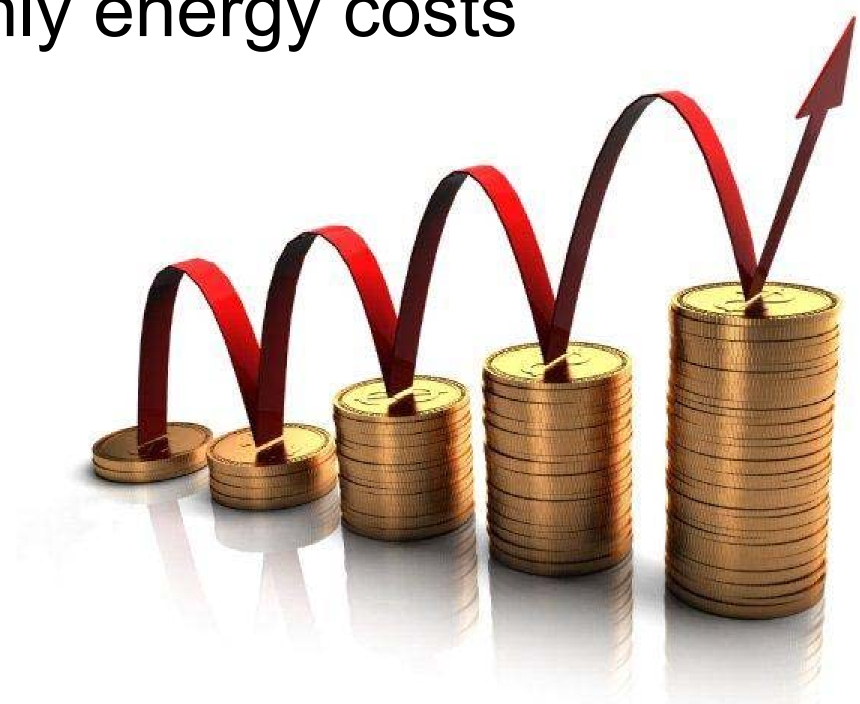
Sizing Comparison

Impact on unit size @ various design conditions

	Example #1	Example #2	Example #3	Example #4
Temperature (F db)	82	78	74	70
Relative Humidity	62%	57%	51%	44%
Wet Bulb (F)	71.9	67.0	61.9	56.8
Dewpoint (F)	67.7	61.6	54.7	47.1
VPD (kPa)	1.4	1.4	1.4	1.4
HVAC Size (nominal tons)	34	36	43	53
Increase in size	--	5%	26%	57%

Impact on Costs

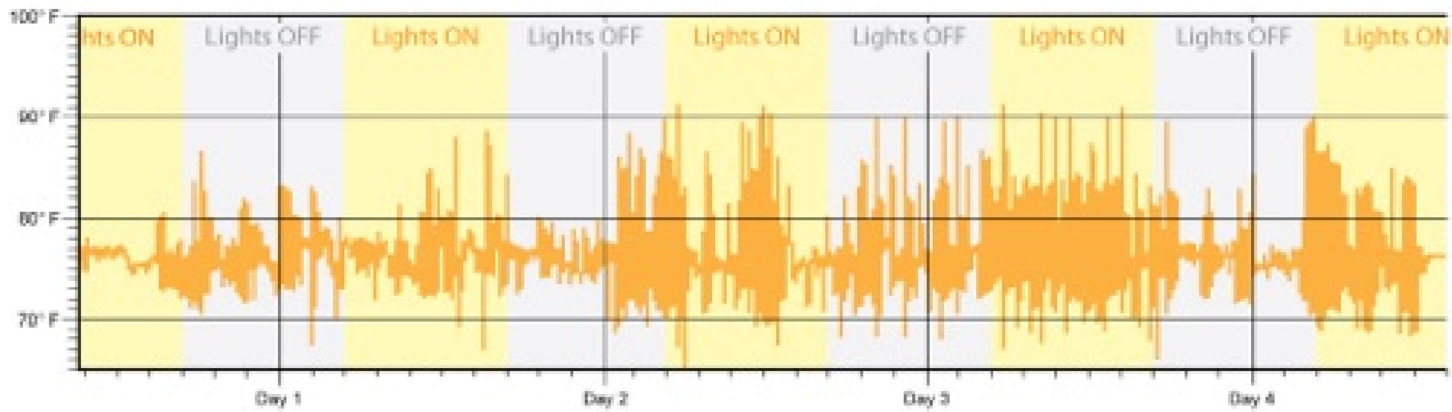
- Larger HVAC equipment
  - Increase in capital costs
  - Increase in monthly energy costs



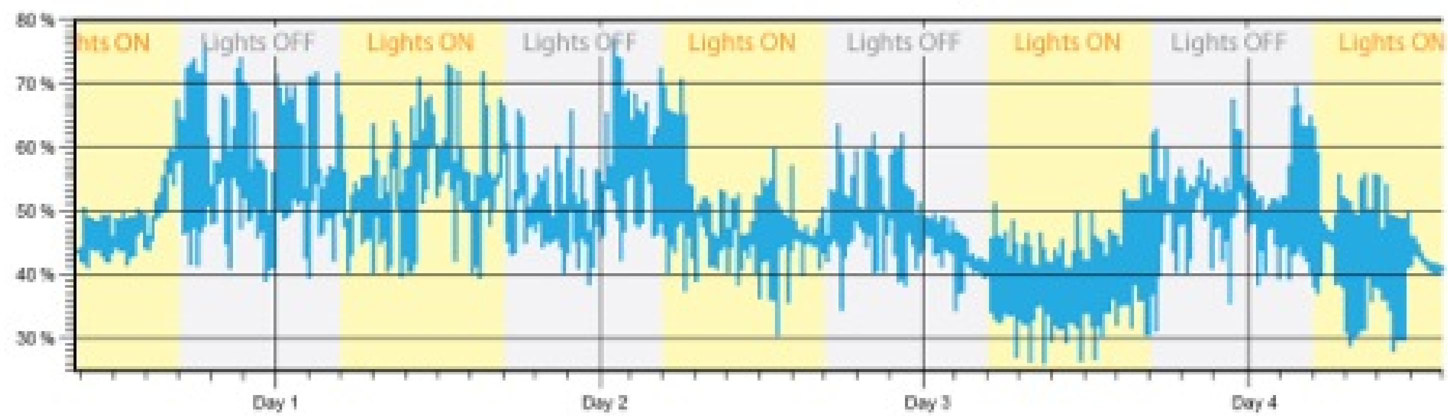
DOES THE TYPE OF SYSTEM DESIGNED MAKE A DIFFERENCE?

Monitoring of N. California Grow Room AC with Reheat Coil

Temperature



Relative Humidity



Monitoring of Oakland Grow Room Purpose Built Environmental Control Unit

Temperature

Dewpoint

Summary

- The grow room climate must be controlled to achieve effective yields
  - Temperature & Humidity (Vapor Pressure Deficit)
  - Lighting can be reduced too far. Complicated balance.

- HVAC energy optimization
  - Careful selection of temperature, RH, and VPD is critical to reduce capital & operating costs
  - Metrics must be scaled to achieve maximum yield
  - System to control both the sensible and latent components will be the most energy efficient

- Grower can achieve maximum product yield and a significant energy reduction with an appropriately designed and balanced system

Contact Information

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Think About Your Design