Understanding HVAC & Plant Dynamics in Grow Rooms

Optimizing Solutions through Superior Dehumidification Technology SM
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
- $\text{CO}_2$
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

- Boundary Layer
- Cuticle
- Epidermis
- Sub-stomatal Cavity

$\text{CO}_2$  $\text{H}_2\text{O}$

Mesophyll (Chloroplasts)
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

Air Movement

Slowly moving canopy is goal
**Total Loads and Control**

2,600 ft²  
2,000 plants  
50 watts/sq ft.  
500 gal/day net water  
0 CFM Ventilation - **Lights On**

<table>
<thead>
<tr>
<th>Description</th>
<th>Sensible (btu/hr)</th>
<th>Latent (btu/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting and Appliance</td>
<td>443,690</td>
<td>0</td>
</tr>
<tr>
<td>Doors</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ceiling</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walls</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infiltration</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>0</td>
<td>256,608</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>443,690</strong></td>
<td><strong>256,608</strong></td>
</tr>
</tbody>
</table>

\[
\frac{443,690}{(443,690 + 256,608)} = 0.63 \text{ SHR}
\]
# Total Loads and Control

- **2,600 ft²**
- **2,000 plants**
- **50 watts/sq ft.**
- **500 gal/day net water**
- **0 CFM Ventilation - Lights Off**

<table>
<thead>
<tr>
<th>Description</th>
<th>Sensible (btu/hr)</th>
<th>Latent (btu/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting and Appliance</td>
<td>1,203</td>
<td>0</td>
</tr>
<tr>
<td>Doors</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ceiling</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walls</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infiltration</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>0</td>
<td>109,975</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,203</strong></td>
<td><strong>109,975</strong></td>
</tr>
</tbody>
</table>

No cooling required. Dehumidification Only Load.
Transpiration

Boundary Layer
Cuticle
Epidermis
Sub-stomatal Cavity

CO₂
H₂O

Mesophyll (Chloroplasts)
Evaporative Cooling Effect

- As water evaporates energy is absorbed.
  - Examples are evaporative coolers (swamp coolers) and misting systems.
- Plants also use this effect in the transpiration process to cool themselves. Through conduction and convection this in turn cools the air.

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

\[
ET_0 = \frac{0.408 \Delta (R_n - G) + \frac{900}{T + 273} u_2 (e_a - e_s)}{\Delta + \gamma (1 + 0.34 u_2)}
\]

Where:
- \(ET_0\) = 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)
- \(e_a\) = Saturation vapour pressure (kPa)
- \(e_s\) = Actual vapour pressure (kPa)
- \(e_a - e_s\) = Saturation vapour pressure deficit (kPa)
Total Loads and Control
2600 ft², 2,000 plants, Lights On
50 watts/sq ft.  500 gal/day net water

Light Vegetation

<table>
<thead>
<tr>
<th>Description</th>
<th>Sensible (btu/hr)</th>
<th>Latent (btu/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting and Appliance</td>
<td>443,690</td>
<td>0</td>
</tr>
<tr>
<td>Doors</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ceiling</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walls</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infiltration</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>0</td>
<td>50,434</td>
</tr>
<tr>
<td>Evaporative Cooling Effect</td>
<td>-50,434</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>393,256</td>
<td>50,434</td>
</tr>
</tbody>
</table>

\[
\frac{393,256}{393,256 + 50,434} = 0.89 \text{ SHR}
\]
Total Loads and Control
2,600 ft², 2,000 plants, Lights On
50 watts/sq ft.  500 gal/day net water

Full vegetation

<table>
<thead>
<tr>
<th>Description</th>
<th>Sensible (btu/hr)</th>
<th>Latent (btu/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting and Appliance</td>
<td>443,690</td>
<td>0</td>
</tr>
<tr>
<td>Doors</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ceiling</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walls</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infiltration</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>-0</td>
<td>0</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>0</td>
<td>256,608</td>
</tr>
<tr>
<td>Evaporative Cooling Effect</td>
<td>-256,608</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>187,082</td>
<td>256,608</td>
</tr>
</tbody>
</table>

\[
\frac{187,082}{(187,082 + 256,608)} = 0.42 \text{ SHR}
\]
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

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

Jim McKillip

- Western Regional Manager, Desert Aire
- JMckillip@desert-aire.com
- 503-936-5007
Think About Your Design