

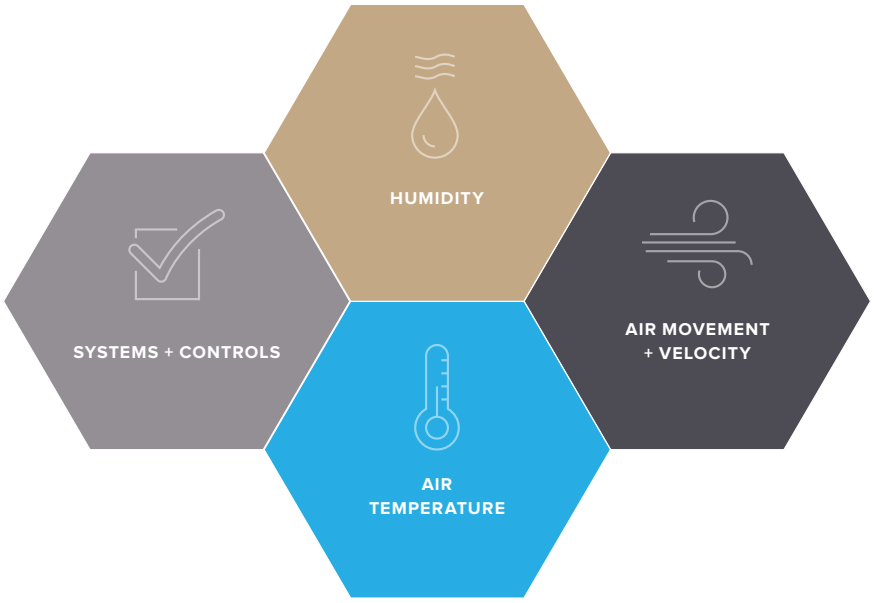
HARRIS

GROW FACILITIES
MECHANICAL SYSTEMS FOR PLANT SUCCESS

design studio

TECHNICAL SNAPSHOT

FEBRUARY 2022



GROW FACILITIES **MECHANICAL SYSTEMS FOR PLANT SUCCESS**

With changing legislation in some US states, cannabis cultivators are calling for improved heating, ventilation and air-conditioning (HVAC) systems to enhance thermal environmental conditions of enclosed growing facilities. Indoor cannabis grow facilities are preferred over outdoor facilities for improved environmental control and security. But growing indoors raises challenges.

Cannabis plants have specific and varying responses to temperature, air movement, humidity and lighting levels in different stages of growth. Typically, grow facilities require HVAC system redundancy as any loss of crop due to system down time incurs financial losses. For plants to grow to their full potential and to maximize their yield, it is essential to tightly control the environmental conditions at each growth stage.

Ventilation rate, air speed, CO2 levels, contaminant control and potential odors are among other challenging aspects of designing indoor grow facilities. In the following pages, we address these issues and offer insight into future trends.

GROWTH PROCESS AND FACILITY CONDITIONS

Building an optimal growing environment requires an understanding of the cannabis plant and what is essential for healthy growth. While beginner growers prefer growing cannabis from seeds (which includes the germination and seedling stages), veteran growers typically prefer cloning from a mother plant to capture the best attributes of the strain and reduce the amount of time that it takes for the crop to grow to size and mature.



Mothering

- Carefully chosen to make new clones
- Kept in vegetative stage by providing minimum light and water, except just before and after taking cuttings
- Mother plants can live for multiple years



Cloning/ Propagation

- Covered by a dome to retain humidity around the leaves
- Exclusively female to eliminate pollination
- Stage lasts until roots develop



Vegetative

- Plant growth accelerates
- Water and nutrient (especially nitrogen) demand increases
- Reducing the lights timer triggers flowering stage
- Stage lasts until gender-specific flowers start to grow



Flowering

- Occurs when plants receive less than 12 hours of light a day
- Buds with milky pistils, a pungent smell develops
- Male cannabis plants will not have the pistils and must be separated at this stage if pollination is not desirable



Drying

- Harvest is hung upside down and dried evenly at low temperatures using supplemental fans in a dark room to preserve potency, vibrancy and color
- After drying, the product is trimmed and cured

	RELATIVE HUMIDITY	TEMP (°F)	AIR SPEED	LIGHT
GERMINATION	60% and lower gradually as sprouting	Lights On 75 - 80°F	Not Important	No Light Required
SEEDLING	65% - 70%	Lights On 68 - 77°F	Less Important	18 - 24 Hours On
MOTHER	60%	Lights On 70 - 80°F	Important	18 Hours On
CLONE	100% lower to 70% as roots develop	Lights On 68 - 78°F	Less Important	18 - 24 Hours On
VEGETATION	70% lower by 5% per week to 40%	Lights On 72 - 82°F	Important	18 Hours On
FLOWERING	40% - 50%	Lights On 68 - 79°F	Very Important	12 Hours On
DRYING	45% - 55%	65-70°F	Very Important	No Light Required

*Lights off temperature settings are generally 10°F lower than lights on.

KEY TERMS

GROW FACILITY
An entity licensed to cultivate, prepare, package and sell cannabis to retail stores.

VAPOR PRESSURE DIFFERENTIAL
The difference between the vapor pressure inside the leaves and the vapor pressure of the air.

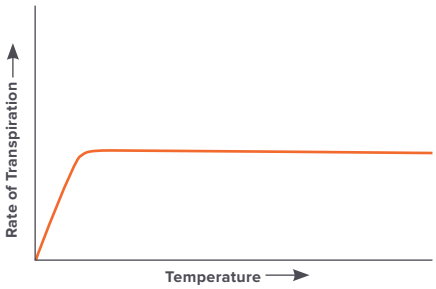
RELATIVE HUMIDITY
The amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature.

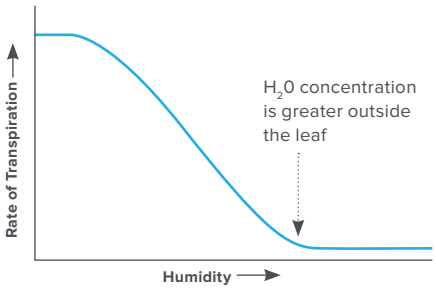
LATENT COOLING LOAD
A measure of the amount of energy that is necessary to dehumidify the air.

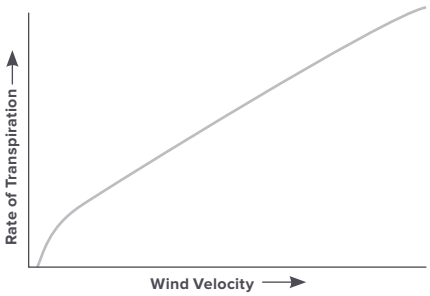
SENSIBLE COOLING LOAD
A measure of the amount of energy that must be removed in order to maintain a certain temperature.

TRANSPIRATION
Draws water and nutrients to the leaves for photosynthesis. More than 95% of water absorbed by plant is lost through transpiration, which contributes to the latent (moisture) increase in grow rooms.

ENVIRONMENTAL CONDITIONS







Temperature

- Temperature affects plants directly through thermal stresses and indirectly through influencing transpiration rate
- High temperature will increase transpiration rate and stress the plants
- Low temperature will detrimentally affect the root system and slow the plants' metabolism

Relative Humidity

- Relative humidity is very important in regulating the transpiration rate of plants. It should be higher during the germination stage and lower as the plants grow more leaves
- High humidity decreases transpiration rate and causes mold and mildew formation on plants
- Low humidity causes dryness, stresses plants and ruins bud quality

Air Movement

- Air distribution is important to eliminate stagnant air under the plant canopies which causes damaging microclimates for the plants
- High air movement increases transpiration, dries the plants and affects the quality of the yield
- Low air movement can lead to mold and mildew on a plant's surface

ROOM VPD: VAPOR PRESSURE DEFICIT RECOMMENDATIONS (kPa)

TEMPERATURE	RELATIVE HUMIDITY											
°F	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%
68	1.52	1.40	1.29	1.17	1.06	0.93	0.82	0.70	0.58	0.48	0.35	0.23
70	1.62	1.49	1.37	1.24	1.12	0.99	0.87	0.75	0.62	0.50	0.37	0.25
72	1.72	1.59	1.45	1.32	1.19	1.06	0.92	0.79	0.66	0.53	0.40	0.26
73	1.82	1.68	1.54	1.40	1.26	1.12	0.98	0.84	0.70	0.56	0.42	0.28
75	1.94	1.79	1.64	1.49	1.34	1.19	1.04	0.89	0.75	0.60	0.45	0.30
77	2.06	1.90	1.74	1.58	1.42	1.27	1.11	0.95	0.79	0.63	0.47	0.32
79	2.18	2.02	1.85	1.68	1.51	1.34	1.18	1.01	0.84	0.67	0.50	0.34
81	2.32	2.14	1.96	1.78	1.60	1.43	1.25	1.07	0.89	0.71	0.53	0.36
83	2.46	2.27	2.08	1.89	1.70	1.51	1.32	1.13	0.94	0.76	0.57	0.38
84	2.60	2.40	2.20	2.00	1.80	1.60	1.40	1.20	1.00	0.80	0.60	0.40

■ Mid/Late Flower ■ Early Flower/Late Veg ■ Propagation/Early Veg

CONSIDERATIONS FOR SYSTEM SIZING

Latent and Sensible Load

Plants act as small evaporative cooling systems.

- Latent load is calculated using the number of plants, evapotranspiration rate and net water
- The cooling effect created by plants should be deducted from the total sensible load
- Typical Sensible Heat Ratios (SHR) seen in grow rooms vary between 0.5 – 0.75 SHR depending on the size of plant canopy

Vapor Pressure Differential

VPD drives transpiration.

- Grow rooms must be maintained at optimum VPD levels to achieve maximum yield
- A high VPD increases the transpiration of water from the leaf to the air
- A low VPD can lead to moisture on the leaves, and ultimately mold or mildew.

Dehumidification

Optimal humidity ranges should be maintained throughout different stages of plant growth.

- Humidity levels need to be higher for younger plants and lower during the vegetative and flowering stages
- Dehumidification can be accomplished through an integrated system or stand-alone dehumidifiers

Airflow and Filtration

Airflow is required to prevent mold and mildew formation on plants.

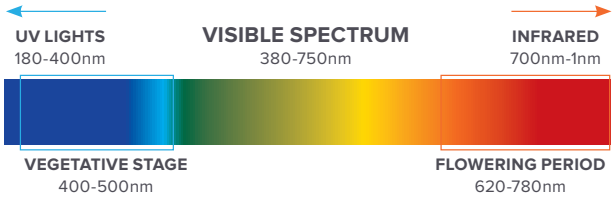
- Typically, airflow rate is assumed to be 350 cfm/ton of latent load
- The overall grow facility is typically kept at negative pressure for odor control
- Grow rooms are typically maintained at positive pressure and incorporate MERV 11 or 13 filters to eliminate mildew spores, pollens, dust and molds

Lighting: Impact On Load

Cannabis are photoperiod sensitive plants. They flower based on day length so grow room indoor lighting is designed to simulate the summer and fall seasons. Lighting intensity is increased as the plants grow larger and develop more leaves to promote photosynthesis.

Lighting accounts for the largest part of sensible loads in the grow rooms. Growers typically use LED, HPS and HID grow lamps or a combination of these.

High-intensity discharge (HID) lights give off much more heat than LED lights.





Often growers will encourage air movement with supplemental fans in the space.

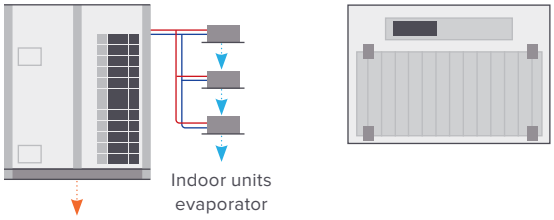
HVAC and lighting systems are the highest power demands in grow facilities. Interruption to the power supply could damage or kill the crop. A new power service needs to be established if the existing electrical capacity will not meet the peak demand.

SYSTEM OPTIONS

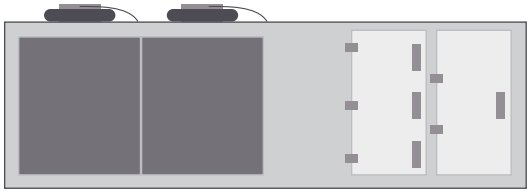
Sensible and latent loads in grow rooms can be managed by either (1) a separate thermal and dehumidification system or (2) a combined system that both conditions and dehumidifies the supply air.

	#1: THERMAL AND DEHUMIDIFICATION SYSTEM	#2: COMBINED SYSTEMS
ENERGY EFFICIENCY	Stand alone dehumidifiers add heat to the space making air-conditioners work even harder to remove the added heat	More energy efficient as dehumidification is taken care of by space conditioning system
COST	Low purchase cost	Costs more upfront but offers energy cost savings and potentially higher yields
SPACE CONDITIONS	Less precise control of room environmental conditions	Precise control of room environmental conditions

#1: THERMAL CONDITIONING + DEHUMIDIFIERS



#2: CLIMATE CONTROL WITH INTEGRAL DEHUMIDIFICATION



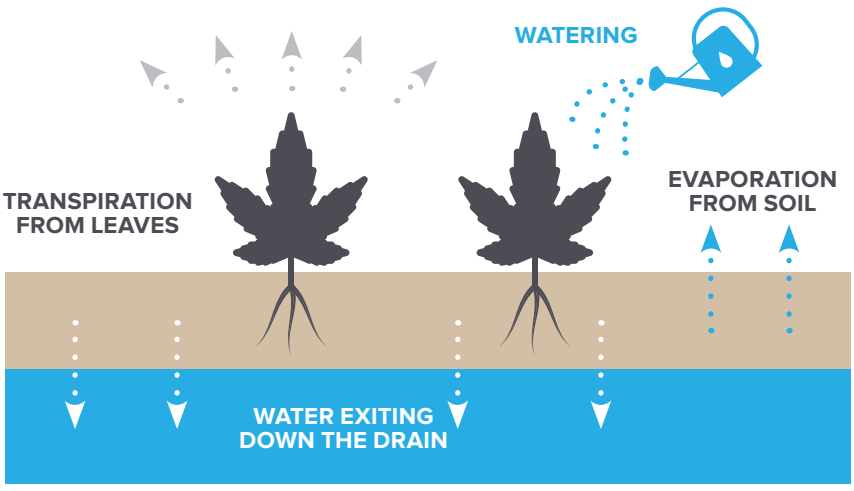
WATER AND NUTRIENTS

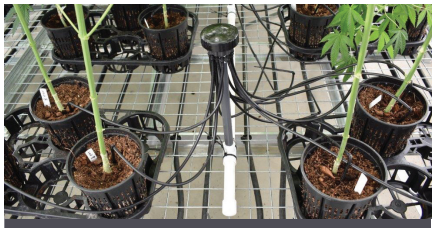
Irrigation

Cannabis plants are intolerant to dryness or excessive moisture so the watering rate is key to plant health. Latent load (moisture load) in a grow room is calculated from the net water usage of plants.

Net water = (Watering Rate) – (Water Drainage)

- Typical watering rates for grow rooms are **0.4 – 0.6 gallon/day/plant**
- Volume of water that exits down the drain **(usually between 10-30%)** depends on the irrigation method and grow media





Drip irrigation is widely considered the most water-efficient method. The system can fine tune the amount of water and nutrients each plant will receive over a given amount of time.

Some common irrigation methods for cannabis plants are as follows:

- Drip Irrigation
- Spray Irrigation
- Hydroponics
- Aeroponics
- Hand-watering

FUTURE TRENDS IN GROW FACILITIES

The global cannabis market is expected to grow rapidly due to increased legalization and applications. The economic laws of supply and demand will drive the industry and only those growers who produce high yields at low operating cost will survive. Hence, cannabis cultivators are calling for cutting-edge technology to reduce water and energy use, cut down on labor costs and increase yields and quality. Here are some future trends that marijuana growers could benefit from to make their facilities more productive.

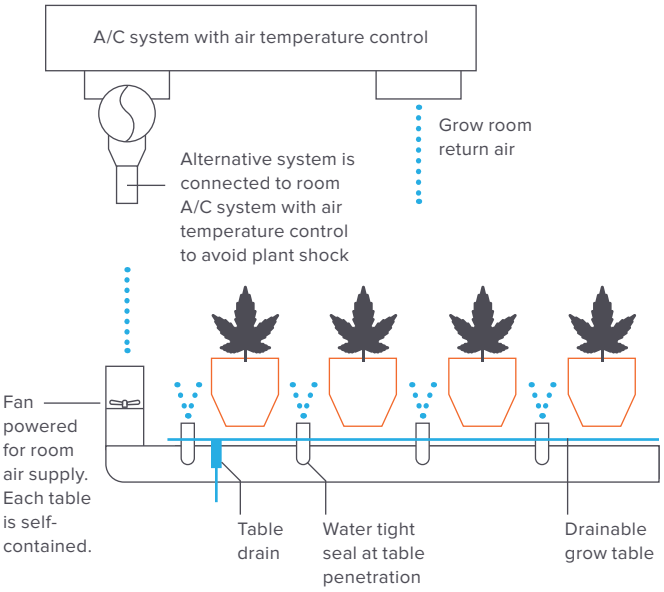
Under Canopy Supply Air System

- Wall or floor mounted circulating fans have limited speed control and cannot evenly distribute consistent streams of air to all areas of the canopy. Plants that are farther away from the fans receive fewer benefits than those closer to the fans.
- An under-canopy system can provide consistent and controllable air circulation direct to every plant. A controlled breeze on the plants strengthens the stems, which creates more robust plants.

Data Driven Systems and Sensors

Input-based or data-driven systems are taking growers from traditional control setups (that run on timers and thermostats) to nearly free-thinking control systems that interact with the environment and make necessary changes to equipment on the spot so crops never have to deal with adverse conditions. For example:

Grow Table Air Supply—Plan View

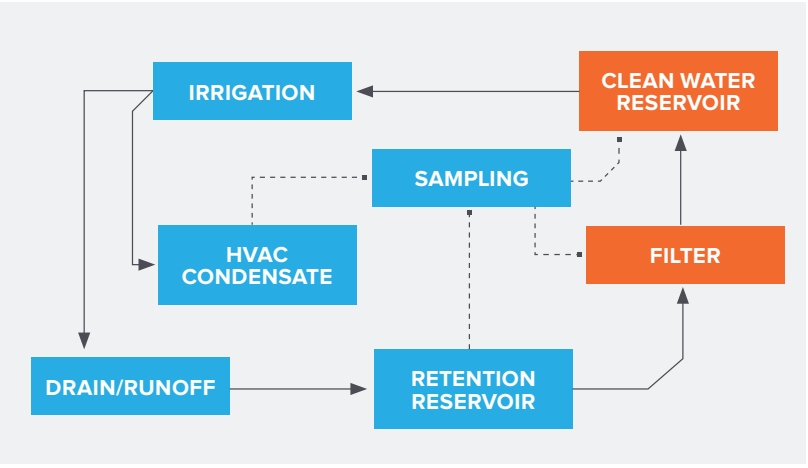


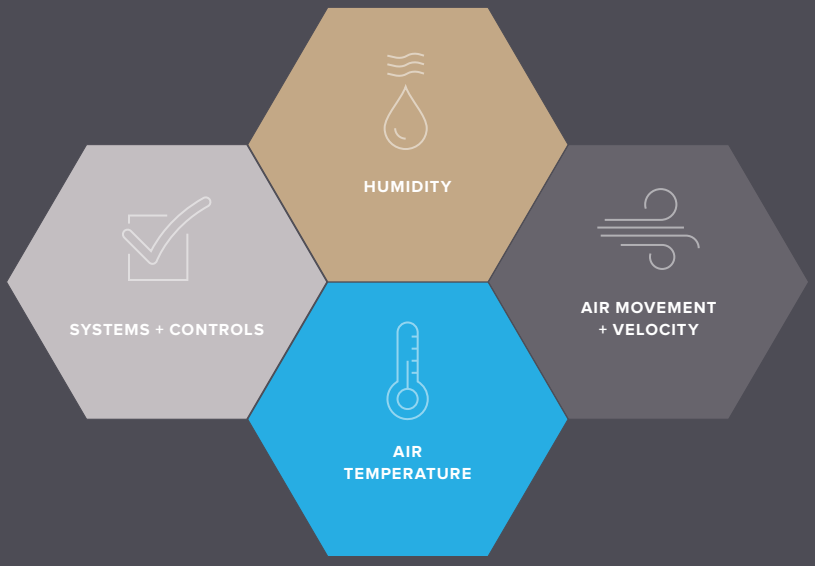
- Grow-media water sensors can evaluate soil moisture and the data driven system can make the decision regarding how much to irrigate the plants.
- Growers can create custom light recipes that can best increase the yield and quality of the strains they are growing. Cultivators can easily mimic sunrise, midday lighting and sunset.

FERTIGATION AND WASTEWATER MANAGEMENT

Fertigation automatically injects fertilizer, which is needed for healthy growth of plants, into the irrigation water, eliminating hand mixing. Many cities do not allow fertilized run-off water to be put down the sewer system.

Excess water runoff and water vapor could be captured, filtered and delivered back to the beginning of the watering process in the future in response to stricter water regulations.





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