How to Size Your HVAC System for Maximum Grow Margin

And Create **Optimum Indoor Conditions** for Plant Development

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AVOID MISTAKES AND GET YOUR DESIGN AND EQUIPMENT DONE RIGHT THE FIRST TIME!

CONGRATULATIONS!

This guide unlocks everything our team of engineers, botanists and growers at Desert Aire know about the science behind grow room air quality, dynamics, how it affects Cannabis, your margin, and ultimately your business success.

By the time you're done reading this guide you'll know more than some and more than most.

At the end, we have a simple worksheet to fill out and send us. In return we will provide you with appropriately sized equipment needed for your space. This is at no cost to you.

Should you have any questions throughout your journey, don't hesitate to call us at 636.537.1919 or email us at info@midwestmachinery.net, we check this email address hourly.

Good luck on your journey and take care.

Sincerely,

The Midwest Machinery Team

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1. GROW ROOM LOAD DETERMINATION

INTRODUCTION

This guide provides a general understanding of Desert Aire's approach to determining the sensible and latent loads of indoor farms. The approach supports Desert Aire's design of climate control solutions that create optimum conditions for plant development and for indoor farms to operate at the highest efficiency.

As part of in-depth facility planning, the proper determination of loads is critical to correctly sizing climate control systems at the lowest initial costs.

THE INDOOR CLIMATE CHALLENGE

Industrial cultivation and indoor farming facilities create very unique and difficult challenges to the design of indoor climate control and HVAC systems. These facilities have diverse, specific requirements for humidity, temperature and airflow control that change as plants develop; and according to the types of crops being grown.

To design and specify solutions that respond to and control space conditions efficiently, Desert Aire employs a comprehensive approach.

This comprehensive approach combines the company's knowledge of the following areas:

- Botanical processes
- Thermodynamics
- Fluid dynamics
- Grow room support systems including lighting
- Proven agricultural methods
- Refrigerant-based dehumidification and climate control technologies

Desert Aire then designs, engineers and builds on a custom, case-by-case basis GrowAire™ indoor climate control solutions to reflect the physical phenomena listed below.

- The botanical processes of photosynthesis and evapotranspiration have a critical impact on sensible and latent loads.
- Lighting loads including lighting power inputs and lighting cycles dramatically affect sensible and latent loads.
- Irrigation methods have a major impact on evaporation in grow room spaces and their latent loads.
- Properly directed air movement facilitates beneficial vapor pressure differentials and transpiration rates (see note in the highlighted box). This also avoids stagnant, high humidity zones.
- Indoor climate control systems must react to changing Sensible Heat Ratio (SHR) requirements. The sensible heat or cooling loads are divided by the total (sensible + latent) heat or cooling loads. These vary depending on plant growth and levels of vegetation as well as whether lights are on or off.

PLANT DYNAMICS

Desert Aire begins with an understanding of how a plant impacts sensible and latent loads in a space.

To feed itself through the process of photosynthesis, a plant that is exposed to light converts water and carbon dioxide into food. Through another process called transpiration, plants use water to carry nutrients throughout their tissues then release this water as water vapor via tiny openings in plant surfaces called stomata to the surrounding, boundary layer air (Refer to Figure 1).

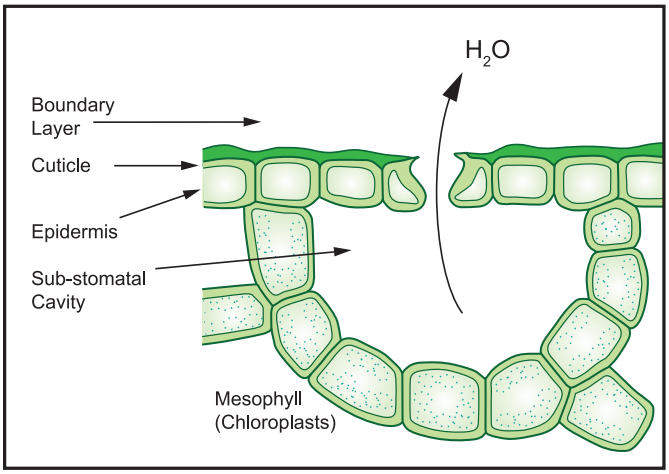

Figure 1- Transpiration through stomata

1. GROW ROOM LOAD DETERMINATION

This exchange of gases is driven by the temperature of leaves and their internal vapor pressures; and the vapor pressure being exerted on leaves by the boundary layer air. The process of changing internal liquid water into a gaseous state consumes energy. For indoor grow rooms the sources of this energy are lighting systems.

Vapor Pressure Terminology

The indoor farming industry uses the term Vapor Pressure Deficit (VPD) when referring to one of the forces that drives transpiration. From a moisture load calculation and modeling perspective Desert Aire uses the term Vapor Pressure Differential. Using the latter term facilitates in-depth discussion among indoor climate control planners of the design rating points that should be used for a specific crop and the surrounding air, within the wider context of an indoor farm's support systems.

Gases and liquids move from areas of high concentration to low concentration. Vapor pressure differentials drive transpiration and provide the force for nutrients to be brought from roots to the upper areas of the plant. Because the vapor pressure inside hydrated plants and their stomata is high, water vapor will exit the stomata if the air outside of the leaves has a lower vapor pressure.

The temperatures of leaves impact their internal vapor pressures. As the temperatures of leaves increase at any given air temperature and relative humidity, transpiration rates through stomata tend to increase. Water is essentially evaporating within the plant, absorbing heat while the phase change occurs between liquid and vapor. In this way plants regulate their internal temperatures. The water usage from this process is beneficial for plant growth unless plants are not able to conduct enough water from their roots to their stems. If not enough water is available at the leaves, heat stress and damage will result. Close control over the vapor pressure differential between the surrounding air and plants is critical to creating the most beneficial conditions.

Because plants rely so heavily on water to create food during photosynthesis and for transpiration, approximately 99% of water delivered to plant roots travels up through the plant before passing through stomata to become water vapor – and become a latent load that must be controlled if plant processes are to be facilitated on an ongoing basis.

Thus, simultaneously controlling and responding to temperatures and relative humidity from the perspective of the plants is a key component of Desert Aire's GrowAire™ series of climate control systems.

HEATING, COOLING & MOISTURE LOADS

The heating load is the amount of heat energy that must be added to the grow room space to maintain a target air temperature level. This is often considered the heat loss calculation as it calculates the level of heat that must be added to offset the loss through the building's ceilings and walls. This heat loss is especially significant in the winter when the outside temperature is much lower than the inside temperature.

The cooling load is the amount of heat energy that needs to be removed to attain the target indoor temperature. This is the heat gain calculation with heat from lighting systems being the most significant portion of this load plus some contributions from solar gain and the building envelope.

The moisture load is the amount of moisture that needs to be removed to attain a target moisture or dewpoint level. The moisture load has three components: transpiration from plants; evaporation from soil, irrigation systems and grow room wetted surfaces; and the moisture content from ventilation air.

To calculate heating, cooling and moisture loads to specify and size grow room climate control equipment, these loads are expressed as sensible and latent. Sensible heat loads are analogous to the heat building occupants feel on their bodies and are temperatures that can be measured by a thermometer. Latent heat loads are the energy and heat stored in humidity, a product of its change in state from liquid to gaseous.

Once determined, Desert Aire engineers combine sensible and latent loads to provide design rating points for the total grow room climate control system.

1. GROW ROOM LOAD DETERMINATION

As noted above lighting systems are usually the largest part of the sensible loads in indoor farming facilities. When lighting systems are in lights-on modes, plants convert light energy into the food they need to grow and exchange gasses with the surrounding air.

APPLYING THE PENMAN-MONTEITH FORMULA

The most direct method of determining the moisture load in a grow room is to calculate the net water usage of plants. In theory this can be accomplished by measuring the volume of irrigation water added to the grow room less the volume of water that exits down the drain. The difference is the volume of moisture that is transpired or evaporated from plants and the growing system. However, this method would require the irrigation system to be in an active mode while appropriate measurement devices record data.

To make the calculation of sensible and latent loads more practical for the specification of grow room climate control systems, Desert Aire engineers modified a version of the proven Penman-Monteith formula.

The Penman-Monteith formula has evolved over the past 50 years and is an important worldwide tool in traditional outdoor agriculture for estimating evapotranspiration, the combination of evaporation and plant transpiration processes where water changes state from liquid to gas.

Just as agricultural engineers and scientists introduce localized data and specific crop properties or coefficients into the formula for their purposes, Desert Aire engineers modified the formula to provide a guide to estimating the latent load in a grow room space and the resultant evaporative cooling effect when exact watering rates are not known.

Details of the Penman-Monteith formula are beyond the scope of this application note. Traditionally the formula generates a reference crop value that estimates the moisture released per day for a large field of a uniform crop. To generate a reference crop value for indoor grow rooms, Desert Aire modified the formula to use a shortwave radiation value of 1.53 MJ/m^2 each hour during the lights on period. For reference, this is equal to approximately 50% of the sun's average daily total shortwave radiation at the equator. In addition the soil heat flux is set at zero since it is assumed the plants are adequately watered in an indoor grow room. Desert Aire also uses the following key variables in its calculations:

- Net radiation of the indoor lighting systems
- Design air temperatures of the grow rooms
- The velocity of ventilation air at a level 3 feet above the plant canopies
- Vapor pressure differentials

Additional key variables that impact evaporation are the actual crop canopy size at full growth, the space temperature and humidity values, and the number of hours lighting systems are on.

Once the reference crop value is known, then it must be converted into a rate for the particular crop being grown. Desert Aire calculates one value for emergent plants to determine the evaporative cooling credit and a second value for the peak moisture release of full-grown plants.

LOW PLANT CANOPY/HIGH PLANT CANOPY

As described above, Desert Aire uses the Penman-Monteith formula to determine evapotranspiration rates in both the low plant canopy and high plant canopy phases. Low canopy is the aboveground collection of individual plant crowns when plants are in their immature, shorter stages of development; high canopy refers to when crops are mature and at peak height.

The formula is of particular use to Desert Aire during low canopy phases. Our engineers regard the formula as a means of more precisely estimating the lowest evapotranspiration rate in a healthy grow room.

By using the formula Desert Aire avoids overestimating the evaporative cooling effect of evapotranspiration that occurs at low canopy. This also provides a safety factor by conservatively estimating the sensible cooling effect created by evapotranspiration as plants grow.

During high canopy, Desert Aire calculates the latent load based on owner/operator projections of water usage. The formula provides a supporting method of estimating and verifying the latent load when compared to the actual water usage given.

1. GROW ROOM LOAD DETERMINATION

MODULATING SENSIBLE HEAT RATIOS

The bottom line for grow room climate control systems is that as plants develop they change the amount of moisture they release. The lighting systems of grow rooms create different levels of heat depending on whether they are in on or off modes. Climate control systems must have the ability to meet the challenges of these changing conditions.

When the plants are small, with a low canopy, the evaporative cooling effects of the evapotranspiration that occurs will also be low. With the lights on, the sensible heat ratio (SHR) of the cooling equipment should be moderately high, greater than a 0.75 SHR. This moderately high sensible heat ratio can be achieved with almost any typical air conditioning unit. A problem occurs in the lights-off mode when the standard air conditioner meets the very low sensible demand and turns off before the latent moisture can be removed.

However, when the plants have grown, and the room is at high canopy, then the evaporative cooling effects of evapotranspiration will be high and the sensible cooling requirement will be greatly reduced. This is because plants use the ambient heat in the room to convert water into vapor through transpiration.

In the lights-on, high canopy scenario the design sensible heat ratio of the air conditioner units is now at a medium-high, 0.50 SHR to 0.60 SHR level. Typical air conditioning units will achieve temperature setpoints rapidly and index off. Without the units operating, the moisture loads (latent) will increase. In the lights-off mode, the same problem occurs as with low canopy plants.

One rudimentary method of dealing with this variable sensible heat ratio is to have a set of HVAC equipment that is sized for handling the high sensible load during the low canopy period. Traditional portable dehumidifiers are used to offset high latent loads during the high canopy period. Although it is possible to size such a system, there will be periods where sensible load is added by the dehumidifier and needs to be removed by the air conditioner. This combination is both difficult to balance and significantly inefficient and may result in higher equipment and energy costs.

The advanced, more efficient method Desert Aire uses is to design a single integrated platform that modulates sensible heat ratios in response to the demands of grow rooms. When grow rooms have high sensible heat ratios then the majority of energy removed is sensible. In periods of low sensible heat ratios the majority of energy removed is latent.

Water-Cooled and LED Lighting Systems

The specification of water-cooled and LED lighting systems may impact the design rating points of equipment that will modulate sensible heat ratio requirements. Because these lighting systems can produce sensible loads at levels up to 50% less than air-cooled lighting technologies, the climate control systems they are teamed with may need to produce an extremely low sensible heat ratio with lights on.

CONCLUSION

Indoor farming facilities have diverse, intense requirements for humidity, temperature and airflow control that change as plants develop. To design and specify solutions that respond to and control space conditions efficiently, Desert Aire employs a comprehensive approach to determine the loads indoor climate control systems must monitor and manage. This comprehensive approach ensures the recommended solution is properly sized to reconcile changing biological processes with lighting and crop support systems.

Please contact your nearest Desert Aire Representative for assistance in determining your grow room loads and the design of your indoor farm's climate control system.

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2. GROW ROOM ENVIRONMENTAL CONTROL

INTRODUCTION

Desert Aire developed its GrowAire™ series of temperature and humidity environmental control systems to provide owners with peace of mind their crops will flourish in the most tightly controlled environments – while consuming the least amount of energy. This is a double win for owners.

This application note provides a summary of plant, grow room and indoor farm needs and describes the reasons for the success of Desert Aire's purpose-built, dehumidification-based environmental control systems.

PLANT REQUIREMENTS

To feed themselves through the process of photosynthesis, plants that are exposed to light convert water and carbon dioxide into food. Photosynthesis consists of two stages, the light-dependent reactions or photo stage; and the Calvin cycle or light-independent stage. Through another process called transpiration, plants use water to carry nutrients throughout their tissues then release this water as water vapor. Plants release water vapor via tiny openings in plant surfaces called stomata to the surrounding, boundary layer air (Refer to Figure 1).

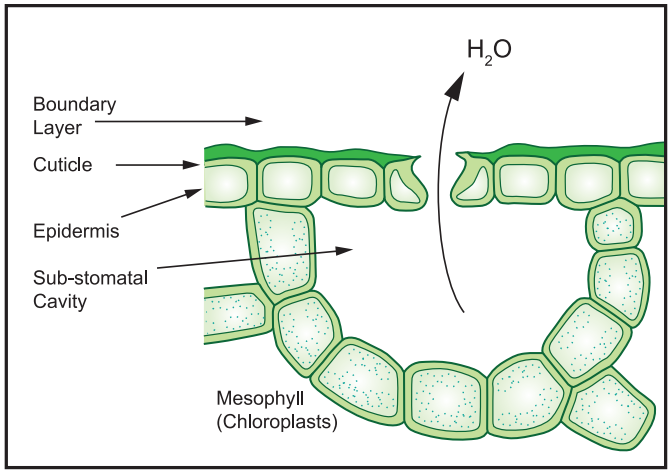

Figure 1- Transpiration through stomata

The temperature of leaves and their internal vapor pressures drive this exchange of gases; and the vapor pressures exerted on leaves by boundary layer air. The process of changing internal liquid water into a gaseous state consumes energy. For grow rooms and indoor farms the sources of this energy are facility lighting systems.

Gases and liquids move from areas of high concentration to low concentration. Vapor pressure differentials, sometimes known in the grow room industry as vapor pressure deficits, drive transpiration and provide the forces for nutrients to be brought from roots to the upper areas of plants. Because the vapor pressures inside of hydrated plants and their stomata is high, water vapor will exit the stomata if the air outside of leaves has lower vapor pressures. Think of the plant leaf and its stomata as a series of little balloons that are filling with moisture-laden air. We all know that when you heat air it expands. When the pressure inside the balloon is greater than outside the air escapes the balloon. The light energy as well as the chemical reaction created by the photosynthesis process provides the heat that expands the air inside the stomata and creates a higher vapor pressure in the stomata. At the same time the dehumidification system is also providing air outside the stomata that has a lower vapor pressure.

In grow rooms and indoor farms it is important to surround plant leaves with air that has lower concentrations of water vapor than their internal vapor pressures; establishing and maintaining the conditions for optimal transpiration rates. This builds on the work of HVAC system designers and grow room owners. They collaborate on the design of ductwork and air distribution systems that ensure air (a combination of supply air from air handlers and additional localized fans) is dispersed evenly throughout plant canopies at desirable airflow rates. This ensures that localized areas do not form that would have higher vapor pressures should the canopies retain the transpired moisture.

2. GROW ROOM ENVIRONMENTAL CONTROL

In general the greater the transpiration rates the more nutrients will travel through plant root systems, creating faster growing cycles. There are upward limits to these transpiration rates however.

Transpiration rates that are too high can cause unhealthy conditions that lead to wilting and tip-burn. The key to healthy transpiration rates is to provide controlled vapor pressure differentials as well as stable temperature conditions. Air directed at plant leaves should be at temperatures above design dewpoints so that condensation on leaves does not occur and create conditions for mold and fungi growth.

Therefore in order to have optimized plant growth indoor growing facilities must control space temperatures as well as absolute humidity levels. More importantly, these must be controlled uniformly across and throughout plant canopies.

STANDARD SYSTEM PROBLEMS

The commercial marketplace is in its infancy with most growers adapting their knowledge from small scale and residential operations. To maintain indoor conditions in those operations they used standard air conditioners and small portable dehumidifiers. When they apply this approach to today's considerably larger commercial operations they create problems for themselves. Growers soon become frustrated with the following issues:

- Temperature and relative humidity are constantly fluctuating (See Figure 2).
  - The air conditioners and dehumidifiers are not controlled together.
  - Relative humidity is the incorrect control parameter.

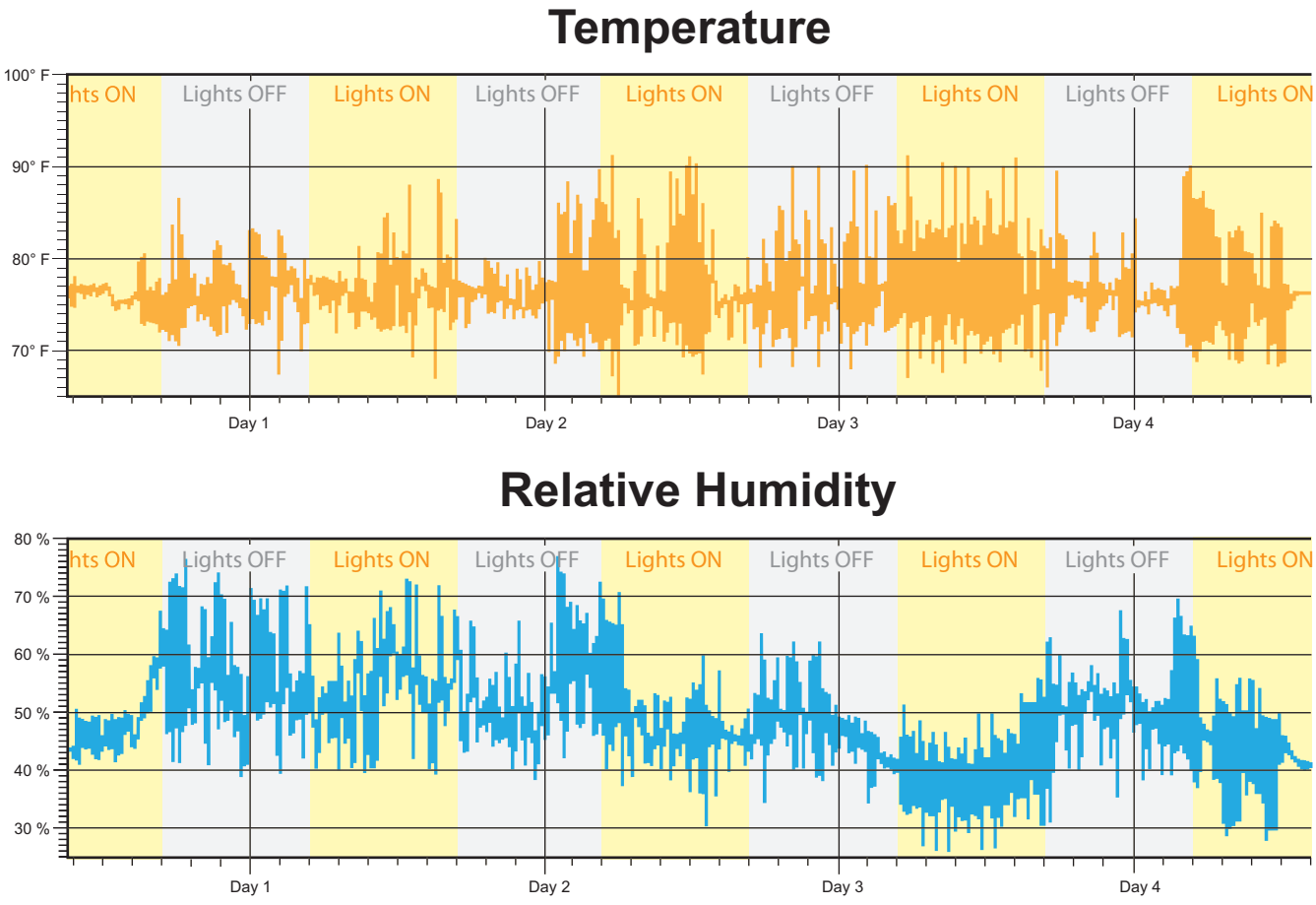

Figure 2- Air conditioner/portable dehumidifier control results for grow room A

2. GROW ROOM ENVIRONMENTAL CONTROL

- The air conditioners must be oversized to remove excess heat introduced into the spaces by the small portable dehumidifiers. This brute force method creates fluctuating temperature and humidity conditions. Significantly, this method also wastes large amounts of energy as the dehumidifiers put heat into the spaces and then the air conditioners must switch on to take the heat out of the spaces.

INTRODUCING DEWPOINT

Relative humidity is a misapplied term. It is often used in place of absolute humidity. The key is the word "relative." As the air temperature increases, the total volume of the air molecules increases. Conversely when air temperature decreases, the volume of the air molecules decreases. Water, however, is not compressible. Therefore given a specific amount, it will always occupy the same amount of volume. Figure 3 illustrates graphically how this works. As moisture-laden air is heated or cooled the air volume changes but the amount of moisture in the air does not.

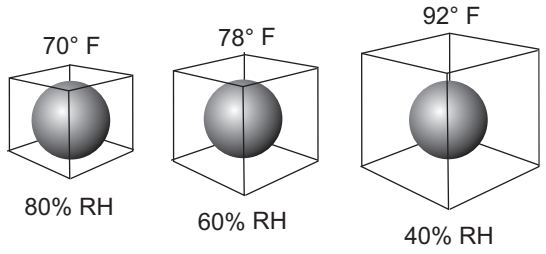

Figure 3- Relative Humidity example

This is important to understand because water condensation occurs at an absolute humidity concentration regardless of its relative humidity. This is known as the constant dewpoint temperature, the key metric in creating vapor pressure deficits for healthy plant growth.

GROWAIRE™ SOLUTIONS AND SUCCESS

The phenomenon of relative humidity presents some challenges for conventional dehumidifier control. Since somewhat small changes in the temperature can impact the relative humidity, monitoring the relative humidity of a space for dehumidification control can cause premature indexing to the dehumidification mode, hunting or short cycling. Although humidity control is set and read in terms of relative humidity, Desert Aire's GrowAire™ systems constantly convert the setpoint and sensor values internally to dewpoints. Since dewpoints are direct measurements of the total moisture contents in air, dewpoints provide more stable values and are more representative of the required changes in operating modes or stages of GrowAire™ systems.

Dewpoints also reflect the true operational conditions growers desire. More knowledgeable growers will understand that vapor pressures in the air are the main driving factors in the growth of plants. Like dewpoints, vapor pressures are not dependent on relative humidity.

Internally, GrowAire™ systems calculate the desired dewpoints based on temperature and humidity setpoints and then control indoor environments based on these dewpoint values. Operation based on dewpoints is one of the main advantages of GrowAire™ systems, providing stability and efficiency. This is especially important when conditions change from photosynthesis periods to dark periods and vice versa; and there may be separate temperature and humidity setpoints programmed. Figure 4 demonstrates the stability of using this control method.

2. GROW ROOM ENVIRONMENTAL CONTROL

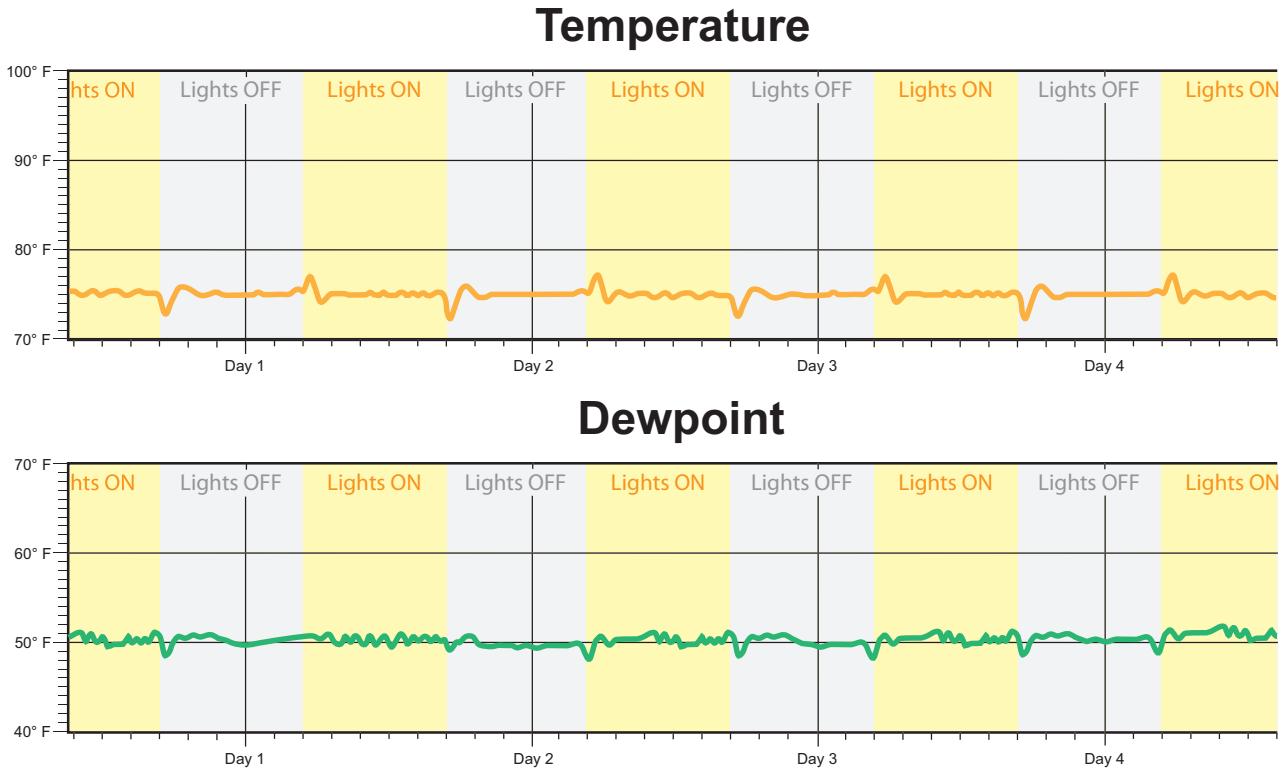

Figure 4- Desert Aire's GrowAire™ system dewpoint control for grow room B

GrowAire™ systems use a unique controller that has a zone-reset function for both temperature and dewpoint control. In everyday terms, this means that systems are constantly monitoring the difference between the setpoints and the actual grow room conditions. As differences increase, the calculated supply setpoints of temperatures or dewpoints decrease. The GrowAire™ systems constantly monitor intake conditions to determine the number of compressor stages required to bring conditions entering the intakes to the calculated supply conditions; and to engage the correct number of compressor stages to do so.

While this is occurring, the operating controllers also modulate the hot gas to the reheat coils. This maintains the temperatures leaving the systems to the current commanded supply air temperature setpoints. Because GrowAire™ controllers are looking at both temperatures and absolute humidity values, they can eliminate the wild swings of conventional systems.

CONCLUSIONS

Desert Aire's GrowAire™ solutions combine the functions of air conditioners and dehumidifiers, helping to establish and maintain the conditions for optimal transpiration rates and plant growth. Desert Aire bases GrowAire™ solutions on unique refrigeration-based dehumidification systems that meet the high cooling and dehumidification demands of lights-on modes, without the need to oversize the environmental equipment for the added heat rejection associated with conventional portable dehumidifiers. In lights-off modes, they continue to maintain dewpoint control to protect the plants and crops without over-cooling the grow rooms and indoor farms.

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3. HVAC SYSTEMS AND GROW ROOM ENERGY USE

INTRODUCTION

In an effort to control temperature and humidity in grow rooms many growers install HVAC systems that haven't been integrated. For example, when conventional air conditioners cannot manage the moisture load, portable dehumidifiers are introduced to the grow room. In addition to the systems fighting each other as they operate, they fail to provide the precise temperature and humidity control required to maintain healthy plants. They also consume more energy.

This Application Note summarizes the energy inputs of HVAC systems in grow rooms and compares the total energy consumption of four types of systems. We will also discuss the reasons why Desert Aire's application-specific equipment meets the performance needs of growers, while minimizing energy consumption.

This will provide readers with an understanding of how to minimize the power consumption of the HVAC systems needed to maintain optimal grow room conditions. In addition to providing better control of temperature and humidity, a correctly designed system can reduce grow room energy usage by a third or more in the pursuit of desired yields and crop traits.

SYSTEM REQUIREMENTS AND ENERGY FLOWS

From an HVAC perspective indoor farming is a process where exposing the plants to light increases the temperature of the space while plant evapotranspiration is actually cooling the space. Plant evapotranspiration also adds moisture to the grow room.

The HVAC industry expresses these increases and decreases in temperature, and increases in humidity, as sensible and latent loads.

Sensible loads are analogous to the heat building occupants feel on their bodies and are temperatures that can be measured by a thermometer. The sensible heating load is the amount of heat energy that must be added to the grow room space to maintain a target air temperature. The sensible cooling load is the amount of heat energy that needs to be removed to attain the target temperature.

Latent or moisture loads are the energy and heat stored in humidity, a product of its change in state from liquid to gaseous. For an in-depth discussion of loads, refer to Desert Aire's Application Note 25 – Grow Room Load Determination.

HVAC SYSTEMS AND ENERGY CONSUMPTION

Grow room HVAC systems should regulate and match the sensible and latent process loads to maintain the design setpoints of growers. Knowing that grow environments impact crop characteristics, the growers choose the room design setpoints based on the genetic makeup of the plants; and to maximize crop yields. Refer to Desert Aire's Application Note 26 – Grow Room Environmental Control, for details on the methods for regulating the conditions in a grow room.

Readers will benefit from recalling the First Law of Thermodynamics, a version of the Law of Conservation of Energy from physics. The Law states that the total energy of a closed system is constant; energy can be transformed from one form to another, but cannot be created or destroyed. This Law is a guiding principle for HVAC engineers and equipment manufacturers who design systems to control temperature and humidity in grow rooms, regardless of the type of crops being grown.

The following comparison of four types of HVAC systems and their energy consumption examines all of the key modes of operation. This energy consumption discussion also examines the impact that plants have on cooling the room through their transpiration process. The comparison is based on a grow room that has insulated walls and ceiling and is installed within a larger building.

Energy considerations included in the comparison include:

- Electrical energy input to the air conditioners and/or dehumidifiers
- Heat always added by portable dehumidifiers (System A)

3. HVAC SYSTEMS AND GROW ROOM ENERGY USE

- Cooling of the enhanced dehumidifier with heat exchanger (System B)
- Cooling of the grow room zone via plant transpiration
- Heat required to overcome lights-off transpiration (Systems A, B, C)

The HVAC energy profile of a grow operation has two elements to consider. The room may have outdoor energy loads known as building thermal loads. This could be the heat gain during the summer months and heat loss during the winter. The second element is the load caused by the growing process. This includes the lighting heat gain as well as the moisture from the plant watering.

We will be reviewing four types of typical systems as summarized below.

- **System A** - Conventional Air Conditioning with Supplemental Portable Dehumidification Units
- **System B** - Conventional Air Conditioning with Enhanced Dehumidification
- **System C** - Conventional Air Conditioning with Split Dehumidification Systems
- **System D** - Desert Aire GrowAire™ Environmental Control System

Large Plants		Emergent Plants	
Sensible Cooling Btuh	**Latent Dehum. lb/hr**	**Sensible Cooling Btuh**	**Latent Dehum. lb/hr**
55,000	24	55,000	24
444,000	-	444,000	-
(117,000)	110	(70,000)	66
382,000	**134**	**429,000**	**90**

- Building Load - Summer
- Lighting
- Evaporative cooling effect of plants
- **Totals Lights On Sizing Loads**

Table 1 - Example Grow Room Loads - Summer

❑ **System A - Conventional Air Conditioning with Supplemental Portable Dehumidification Units**

The air conditioner in System A is sized to handle the entire sensible cooling load and will remove a portion of the moisture during the lights-on mode. The supplemental portable dehumidifier uses an internal hot gas reheat coil to reject all of the collected energy and is sized to remove all of the moisture in the lights-off mode. The dehumidifier supplements the work of the air conditioner in the lights-on mode. When in operation the leaving air temperature of the dehumidifier is 25°F warmer than when it entered, thus adding heat to the space. This heat load must be removed either by the evapotranspiration process or the air conditioner.

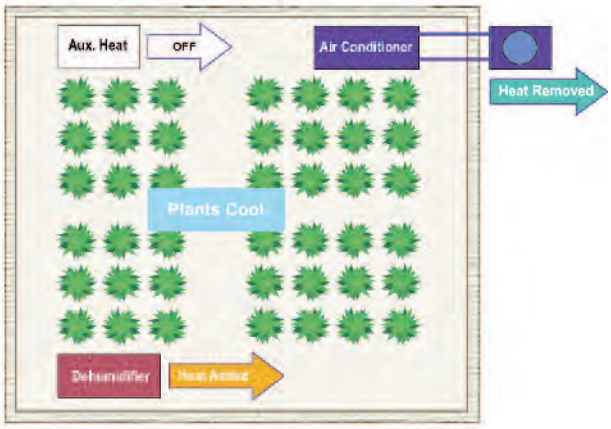

Figure 1- (System A) – Energy flow of Standard Air Conditioner with Portable Dehumidifier – Lights on

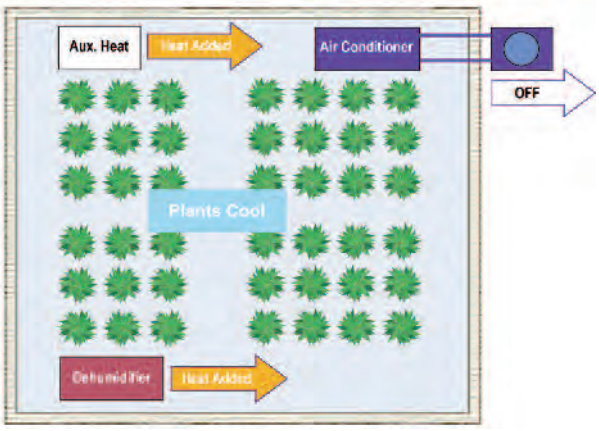

Figure 2 - (System A) – Energy flow of Standard Air Conditioner with Portable Dehumidifier – Lights off

3. HVAC SYSTEMS AND GROW ROOM ENERGY USE

❑ System B - Conventional Air Conditioning with Enhanced Dehumidification

System B is an alternative method that uses a dehumidifier containing heat exchanger plates or heat pipes to improve the moisture removal capacity of the unit. This upgraded system removes more moisture per kilowatt of input power. The dehumidifier achieves the incremental improvement by reheating the leaving air after the plate or heat pipe in a step commonly called "free reheat." This is a fixed system that cannot change the temperature of the leaving air, thus requiring additional air conditioning for lights-on cooling or additional auxiliary heat for lights-off heating.

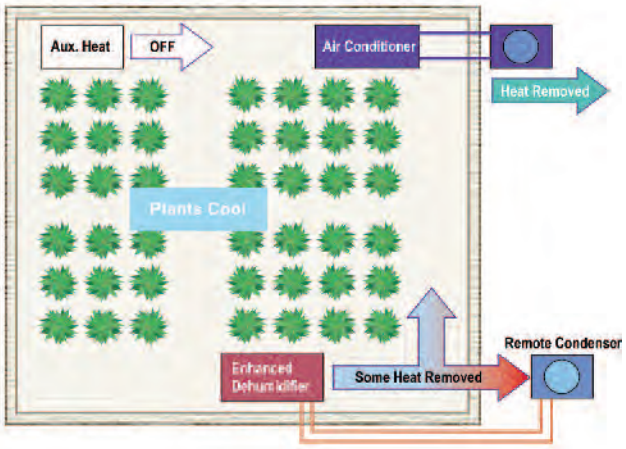

Figure 3 - (System B) – Energy flow of Conventional Air Conditioner with Enhanced Dehumidifier – Lights on

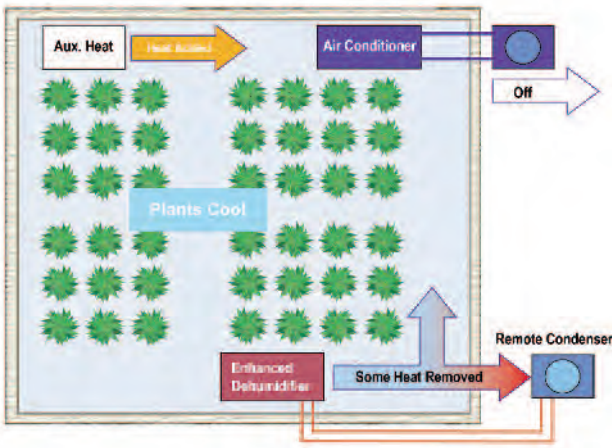

Figure 4 - (System B) – Energy flow of Conventional Air Conditioner with Enhanced Dehumidifier – Lights off

❑ System C - Conventional Air Conditioning with Split Dehumidification System

The baseline for System C is a conventional split system air conditioner and a split dehumidifier that has a remote air-cooled condenser. This remote condenser provides additional cooling as compared to only having the internal hot gas reheat function of portable dehumidifiers. In the lights on mode, the dehumidifier more effectively removes moisture while also cooling the space.

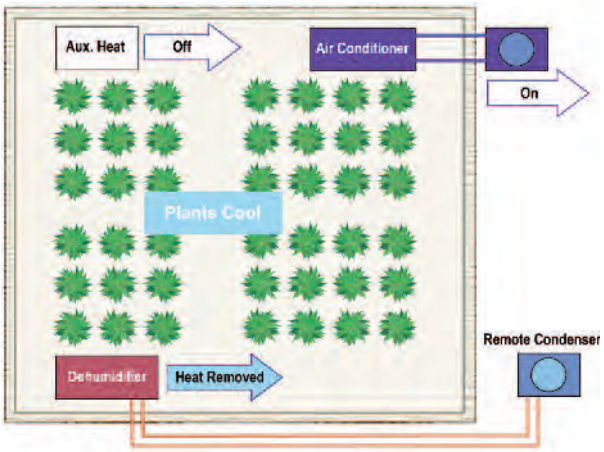

Figure 5 - (System C) – Energy flow of Conventional Air Conditioner with Split Dehumidification Systems – Lights on

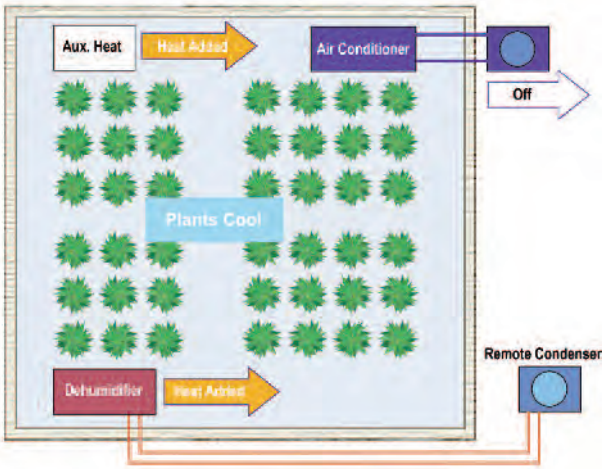

Figure 6 - (System C) – Energy flow of Conventional Air Conditioner with Split Dehumidification Systems – Lights off

3. HVAC SYSTEMS AND GROW ROOM ENERGY USE

❑ **System D - Desert Aire GrowAire™ Environmental Control System**

Desert Aire's GrowAire™ Environmental Control System is an integrated solution that performs the work of the conventional air conditioner and the dehumidifier by using controller logic to modulate sensible heat ratios. This controller logic enables the system to remove heat or add it back into the space as required during both lights-on and lights-off cycles.

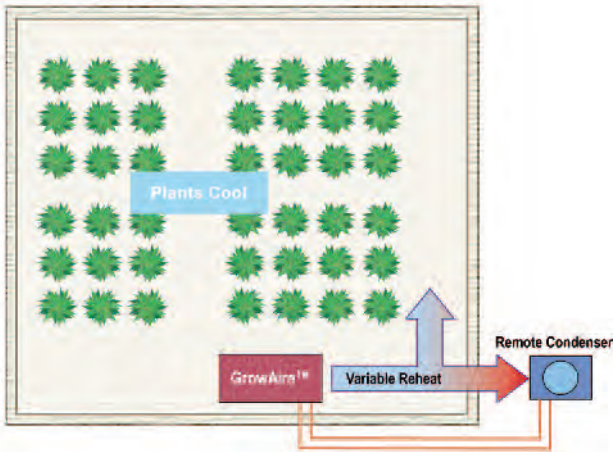

Figure 7 - (System D) – Energy flow of GrowAire™ Environmental Control System – Lights on

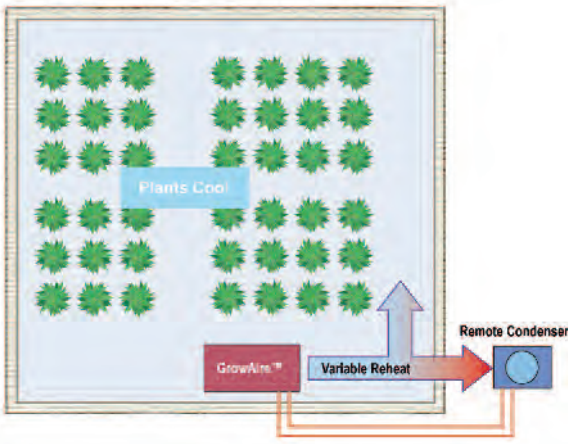

Figure 8 - (System D) – Energy flow of GrowAire™ Environmental Control System – Lights off

ANNUAL OPERATING COSTS

The performance factors for the various types of equipment are summarized in Table 2 below and normalized per nominal ton. The air conditioning system is based on a highly energy efficient design of 16 SEER and the portable dehumidifier complies with the latest AHAM rating of 2.7 liters per kWh. Performance data was established for each equipment manufacturer performing at a 75°F/50% RH condition.

Sens. Clg. Btuh	Latent Dehumidification Btuh	lb/hr	Latent Operational kW
8,100	3,600	3.4	0.72
(8,300)	4,200	4.0	0.85
7,800	4,500	4.2	0.63
1,600	6,000	5.7	0.68
8,000	4,600	4.3	0.70

- Air Conditioner
- Portable Dehumidifier
- Enhanced Dehumidifier
- Split Dehumidifier w/clg
- GrowAire™ System

Table 2 - Unit performance per nominal ton @ 75°F/50% RH

Table 3 displays the estimated annual operating costs for the four systems outlined above, based on an electricity cost of $0.12/kWh. The table is based on a grow room with a crop canopy area of 2,600 square feet and a watering rate of 0.5 gal./day/plant (0.15 gal./day/sq. ft.). The lighting load was based on 50 watts/sq. ft. with the lights on and a fully developed canopy. The table was created by calculating the loads in both the lights-on and lights-off modes and using the performance of each system type to estimate the energy consumption.

3. HVAC SYSTEMS AND GROW ROOM ENERGY USE

	AC w/Additional Systems			
	System A Portable Dehumidifier	System B Enhanced Dehumidifier	System C Split System Dehumidifier with clg.	System D GrowAire™ Environmental Control System
Lights ON				
Air Conditioner (kWh)	67	53	46	-
Dehumidifier (kWh)	24	9	13	-
GrowAire™ System (kWh)	-	-	-	49
Total Energy - Lights ON	91	62	59	49
Lights OFF				
Air Conditioner (kWh)	0	0	0	-
Dehumidifier (kWh)	24	13	18	-
GrowAire™ System (kWh)	-	-	-	16
Extra Heat Required (kWh)	0	28	0	0
Total Energy - Lights OFF	24	42	18	16
Totals				
Annual kW/sq. ft. Consumed	115	104	77	65
Electrical Cost Per Year/sq. ft.	$13.80	$12.48	$9.28	$7.80
Annual Energy Cost	$35,892	$32,452	$24,140	$20,284
Reduction in Annual Energy Costs From System A	-	10%	33%	43%

Table 3 - Four-system analysis of operating costs (kWh/sq. ft.)

IMPACT OF BUILDING ENVELOPE

The above analysis is based on a grow room that has an insulated ceiling and walls and is installed within a larger building. If the grow room has exterior walls the heat gain and heat loss through the walls must be included in the room's load calculations. The heat gain/loss information must be provided by a qualified engineer to ensure proper equipment sizing.

The system examples provide a relative operational cost per square foot of plant canopy and thus provide a scaling factor to compare any grow room. The watering or irrigation rate that each grower utilizes is a key variable as this is the prime driver for the humidity load in the zone. Figure 9 provides a summary of the energy expended per square foot based on the watering rate.

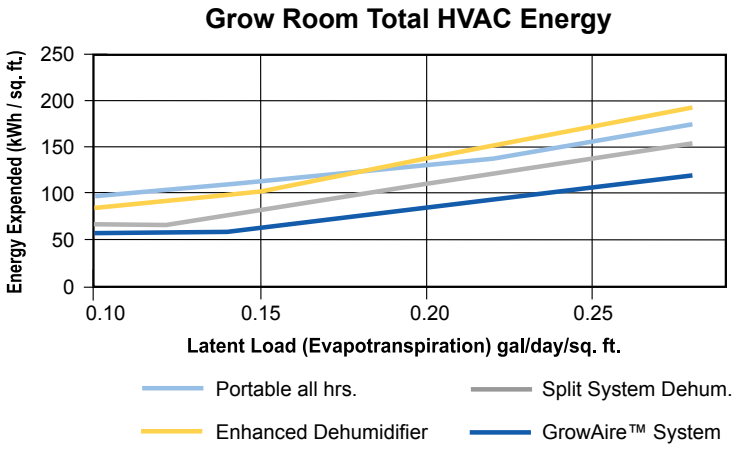

Figure 9 - Grow Room Total HVAC Energy Comparison

3. HVAC SYSTEMS AND GROW ROOM ENERGY USE

Figure 9 also depicts that different crops and different grow strategies change the watering rate being utilized in each specific application. If the watering load per square foot of canopy or tub space is known, then an estimated total energy comparison can be made for the four different types of systems. Table 4 provides a conversion to a watering rate per plant density based on cannabis plants.

Watering Rate Conversion

From gal/day/sq. ft. to gal/day/plants

GPD/sq. ft.	sq. ft. / plant	GPD/plants			
		1.0	2.0	3.0	4.0
	0.10	0.10	0.20	0.30	0.40
	0.12	0.12	0.24	0.36	0.48
	0.14	0.14	0.28	0.42	0.56
	0.16	0.16	0.32	0.48	0.64
	0.18	0.18	0.36	0.54	0.72
	0.20	0.20	0.40	0.60	0.80
	0.22	0.22	0.44	0.66	0.88
	0.24	0.24	0.48	0.72	0.96
	0.26	0.26	0.52	0.78	1.04
	0.28	0.28	0.56	0.84	1.12

Table 4 - Watering conversion rate gal/day/sq. ft. to gal/day/cannabis plants

CONCLUSIONS

The energy consumption of grow rooms and indoor farms will continue to be an issue not only for the growers, but also for the electric utilities that must provide power to the grow facilities and the surrounding communities.

Desert Aire's GrowAire™ purpose-built systems combine the functions of air conditioners and dehumidifiers into integrated packages. These engineered solutions provide growers with the lowest operating costs and the tightest temperature and humidity setpoint control available in the industry. GrowAire™ solutions eliminate the supplemental equipment required with other grow room HVAC equipment approaches, thus lowering energy consumption. An additional, critical benefit is the ability to precisely control the vapor pressure deficits of grow rooms. This is a key factor in maximizing crop yields.

Growers, HVAC system planners, utilities and equipment manufacturers need to build on the awareness of the upward-sloping energy demands of the grow room and indoor farming industries. In particular there is justification for growers and their HVAC system planners to include utility representatives in the early planning stages of renovation and new construction projects. This inclusive planning approach along with the approximately 40% energy savings of Desert Aire's GrowAire™ systems should pave the way for growers to receive incentive packages from utilities. This is especially true of utilities seeking to promote resource sustainability and efficiency beyond those merely offering demand-side management rate discounts.

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4. VAPOR PRESSURE DEFICIT AND HVAC SYSTEM DESIGN

INTRODUCTION

There exists a communication gap between different players in the grow room industry that at times complicates the ability for all parties to get on the same page. One of the largest gaps exists when growers and their botany consultants talk to HVAC engineers about the environmental control side of the cultivation business.

Each group has its own glossary of terms and, more importantly, has a different frame of reference on what is the most critical design element. One of the design elements most often at the center of misunderstandings and debates is Vapor Pressure Deficit (or Differential), commonly referred to as VPD.

This application note views the discussion from both perspectives by properly defining what is Vapor Pressure Deficit. We will also discuss the impact VPD has on plant yields, protecting crops, the sizing of environmental control equipment and associated costs.

PLANT GROWTH PROCESS

Plants obtain their water and nutrients from their root systems through a process known as osmosis. The plants use these elements, along with the photosynthesis process, to help convert light energy to create glucose. The glucose is used during cellular metabolism in plant tissues to create energy for immediate use or to create complex sugars – starches – for later use.

As byproducts of plant processes that include photosynthesis, plants release from their stomata oxygen and water vapor. This cycle requires the absorption of energy (see Figure 1) and is known as transpiration. Evaporation is the water that is converted from grow room soil or crop trays from a liquid state to vapor in the air. The total moisture release is known as Evapotranspiration. Refer to Desert Aire Application Note 25 – Grow Room Load Determination for a more detailed discussion of this topic.

Heat of Vaporization Summary

The amount of energy required to convert liquid water into vapor is approximately 1,060 Btuh per pound of liquid water. In grow room terms 2,600 watts of heat are needed to vaporize each gallon of water. The process requires approximately 50% of grow room light heat output to complete the conversion. This means that 5,200 watts of lighting would vaporize one gallon/hour.

Growers can estimate the maximum watering rate their plants can accommodate through use of the formulas below. The formulas calculate the volume of water that can be vaporized each day through the evapotranspiration process in grow rooms.

Gallons Per Day (GPD) watering rate estimate:

- For 12 hour lights-on GPD = Watts lighting / 325
- For 18 hour lights-on GPD = Watts lighting / 260

Figure 1- Heat of Vaporization Summary

Table 1 provides a summary of watering rates and corresponding dehumidification moisture removal capacities at various lighting loads.

	GPD		MRC lb/hr	
Watts	**12 hr**	**18 hr**	**12 hr**	**18 hr**
10,000	31	38	16	13
25,000	77	96	40	32
50,000	154	192	80	64
75,000	231	288	120	96
100,000	308	385	160	128
125,000	385	481	200	160
150,000	462	577	240	192
175,000	538	673	280	224

Table 1 - Watering Rates and Moisture Removal Capacities at various Lighting Loads

4. VAPOR PRESSURE DEFICIT AND HVAC SYSTEM DESIGN

Colder temperatures tend to slow down plant growth because the rate of photosynthesis is reduced. Temperatures that approach 65°F (18°C) or lower are likely to retard plant growth. In addition, at these lower temperatures the water in the root system begins to lose its ability to hold dissolved oxygen. This allows pathogens to multiply, as those pathogens that weaken plants grow better with less oxygen. Thus, plants are more susceptible to certain types of mold when grow rooms are cool, especially if grow rooms are also damp. Indoor plants are much more susceptible to cold than plants grown outdoors.

When temperatures rise above 80°F, the rate of cannabis growth slows. The cannabis plants must use part of their energy to dissipate heat and to keep their water content constant. The rate of growth continues to slow as the temperature rises. Photosynthesis and plant growth cease altogether somewhere above 90°F.

MOLD & MILDEW

Air with a high Relative Humidity (RH), greater than 80% RH, can create an environment conducive to the creation of mold and mildew. During this high RH condition plant stomata close, eliminating the transpiration of moisture from plant leaves. Instead, water can permeate the leaves or remain on them in the form of droplets and puddles. This provides the setting for quick mold and mildew formation.

VAPOR PRESSURE DEFICIT

Vapor pressure deficit is a metric that indicates the evapotranspiration potential of grow rooms based on current temperatures and humidity levels. The value is the deficit or differential between the pressure exerted by the moisture at a specific room condition, and the pressure at saturation. The assumption is made that the surface conditions of plant leaves are equal to that of the saturated conditions surrounding them.

When a space is at 100% relative humidity no further water can be absorbed by the air, consequently no further evapotranspiration can occur from plants. When the temperature increases, plants will need to transpire more. Growers and their HVAC systems must control VPD levels to ensure plants can transpire.

On the other end of the spectrum, when the relative humidity gets too low, then stomata will also close to try and preserve the moisture in plants. This weakens the plants and makes them more susceptible to disease, just as humans in stressed states become susceptible to illness.

We should note that VPD and RH are inversely proportional to one another when the air temperature is static. A high VPD is associated with a low RH while the inverse is true that a low VPD occurs at a high RH.

VPD is a direct method of evaluating the potential water stress on plants by providing growers with a predictive value of expected evapotranspiration. Growers are more familiar with RH, but the key element of this metric is the term “relative,” as this value does not reflect the absolute moisture in the air unless the simultaneous temperature is known. Refer to Desert Aire Technical Bulletin #3 – Dehumidification and the Psychrometric Chart for a detailed discussion. RH is a measure of what percentage of moisture is in the air at that specific temperature.

The vapor pressure and dewpoint are direct measures of the amount of moisture in air. The indoor grow industry has used vapor pressure because it provides the best link to plant health. Vapor pressure accounts for both temperature and humidity levels. This is important because growers may want to change the temperatures for day vs. night, different stages of growth, and different product strains or types.

PSYCHROMETRIC DEFINITION

Vapor pressure deficit can be demonstrated on a psychrometric chart. The example below demonstrates the change in the vapor pressure at a fixed temperature. The calculations can also easily be completed at other conditions.

4. VAPOR PRESSURE DEFICIT AND HVAC SYSTEM DESIGN

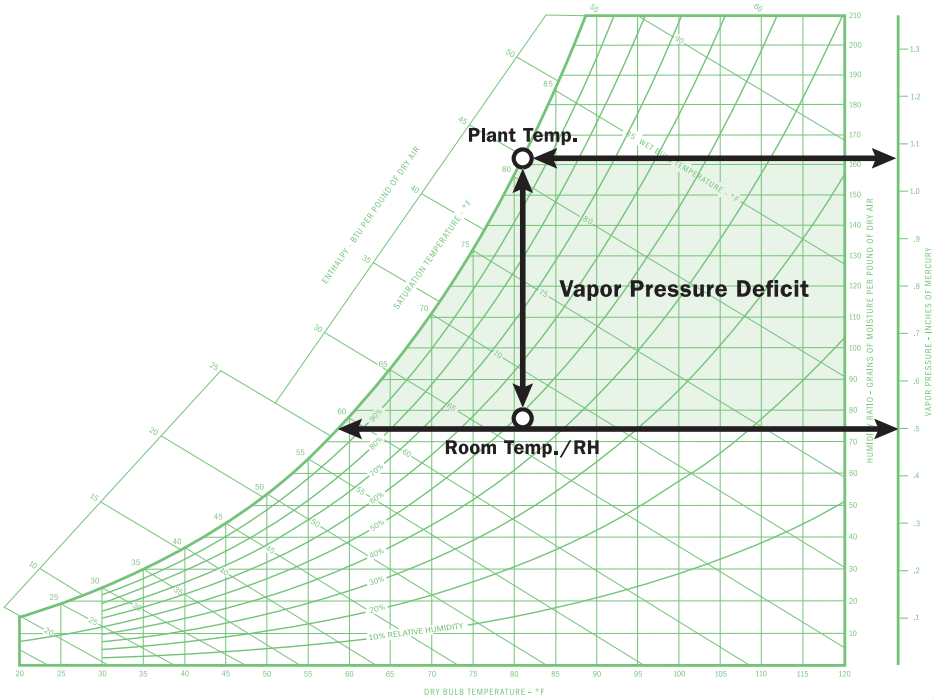

Figure 2 - VDP plotted on psychrometric chart

Fahrenheit	Celsius	75%	70%	65%	60%	55%	50%	45%	40%
60	15.6	0.4417	0.5301	0.6185	0.7068	0.7952	0.8836	0.9719	1.0603
65	18.3	0.5268	0.6322	0.7376	0.8430	0.9484	1.0538	1.1592	1.2645
70	21.1	0.6259	0.7512	0.8764	1.0016	1.1268	1.2520	1.3773	1.5025
75	23.9	0.7410	0.8892	1.0374	1.1857	1.3339	1.4822	1.6304	1.7787
80	26.7	0.8741	1.0489	1.2238	1.3987	1.5735	1.7484	1.9233	2.0982
85	29.4	1.0275	1.2331	1.4386	1.6442	1.8498	2.0554	2.2610	2.4666

Table 2 - VPD values for Cannabis Plants in the Vegetative Stage (kPa)

Fahrenheit	Celsius	75%	70%	65%	60%	55%	50%	45%	40%
60	15.6	0.4417	0.5301	0.6185	0.7068	0.7952	0.8836	0.9719	1.0603
65	18.3	0.5268	0.6322	0.7376	0.8430	0.9484	1.0538	1.1592	1.2645
70	21.1	0.6259	0.7512	0.8764	1.0016	1.1268	1.2520	1.3773	1.5025
75	23.9	0.7410	0.8892	1.0374	1.1857	1.3339	1.4822	1.6304	1.7787
80	26.7	0.8741	1.0489	1.2238	1.3987	1.5735	1.7484	1.9233	2.0982
85	29.4	1.0275	1.2331	1.4386	1.6442	1.8498	2.0554	2.2610	2.4666

Table 3 - VPD values for Cannabis Plants in the Flowering Stage (kPa)

Table 2 and Table 3 display VPD values at a range of temperatures and relative humidities for cannabis plants in the vegetative and flowering stages respectively. The green bands are typical target operating ranges. As will be explained later, the choices of temperature and relative humidity will have a significant impact on the sizing and total ownership costs of HVAC equipment. Once growers establish target VPDs, they should select conditions to minimize the capital and operational costs of environmental control equipment.

The control and management of indoor grow environments requires an understanding of crop types as well as desirable crop temperatures, relative humidities and vapor pressures. The photosynthesis requirements of plants must also be understood.

Vapor pressure deficits indicate the evapotranspiration potential of grow rooms and their plant canopies. Ideal VPDs change with the different stages of plant growth and vary with the types of lighting used in grow rooms. Vapor pressure deficits can be determined by looking up corresponding values on a psychrometric chart or through calculations using known formulas. Today these formulas are readily available in apps or spreadsheets. The most common unit of measure for growers is kilopascals (kPa). Design engineers typically use either kPa or inches of Mercury (in Hg).

4. VAPOR PRESSURE DEFICIT AND HVAC SYSTEM DESIGN

Vapor Pressure Conversion Factors

The following conversion factors can be used to translate between vapor pressure values used by growers and engineers.

kPa = 3.386 x in Hg

in Hg = 0.296 x kPa

HectoPascals = 10 x kPa or 33.86 x in Hg

Figure 3 - Vapor Pressure Conversion Factors

Most plants will have a unique VPD requirement for individual stages of growth. These VPD values may be different for lights on vs. lights off modes. Botanists generally list the growth stages of plants as the following:

- Germination / Cloning
- Vegetative
- Flowering or early fruit generation
- Mature fruit formation

At 100% RH, the VPD is zero. A target VPD rate for optimized transpiration generally falls within a range of 0.5 to 1.5 kPa depending on the growth stage of the plant. By altering the VPD, growers can regulate the uptake of water and nutrients by plants. Thus VPD becomes a metric that growers and the engineers designing their climate control systems can use as the basis of understanding the grow room conditions they seek to create.

Stage of Growth	Air Temp	RH	VPD	Watering Rate
Cloning	70°F (21.1°C)	80%	0 to 0.2 kPa (0 to 0.06 in Hg)	Saturated soil
Vegetative	78°F (25.6°C)	70%	0.8 to 1.1 kPa (0.24 to 0.33 in Hg)	Medium as plant is smaller, producing leaves for support
Early Flowering	75°F (23.9°C)	60%	1.0 to 1.4 kPa (0.30 to 0.41 in Hg)	Maximum to grow full buds
Late Flowering	75°F (23.9°C)	50%	1.3 to 1.5 kPa (0.39 to 0.44 in Hg)	Medium to start to dry out and preserve terpenes

Table 4 - Typical Cannabis VPD values

VPD IMPACT ON GROWTH

When VPD is held constant, growth and yield will improve with increasing temperature. In contrast, growth declines when the VPD is increased and temperature is held constant. The slower or reduced growth is in response to plants reaching a maximum transpiration rate.

When VPDs are relatively high, between 0.5 and 1.2 kPa, plants increase growth–inducing transpiration by opening stomata and releasing a considerable amount of water vapor into the air. This increase in transpiration results in an increase in plant photosynthetic activity, requiring more nutrients to improve overall growth. However, at high VPD (> 1.5 kPa) the plant would close its stomata to avoid releasing water vapor to the air, preventing dehydration due to excessive transpiration.

In flowering rooms where the VPD is too low (< 0.80 kPa), plants close their stomata to prevent releasing more water into the air. This reduces transpiration and the rate of photosynthesis. These reductions would significantly reduce crop yields.

VPD is essential when it comes to providing the best conditions for the development of plants, to understanding the watering requirements according to the nutrients used, and adjusting them correctly to meet grower expectations. The best way to keep a suitable VPD value is to use an integrated environmental control system to maintain a tight temperature and dewpoint condition in the space.

Understanding the fundamental impact that temperature and VPD have on growth and yield, it is important for growers to define these variables first as they plan their facilities. Once those have been determined, growers can decide on relative humidity targets for their grow spaces.

Table 5 presents values for relative humidities at certain temperatures and VPDs that are required to maintain ideal growing conditions.

4. VAPOR PRESSURE DEFICIT AND HVAC SYSTEM DESIGN

		Veg		Early Flower		Late Flower	
	VDP (kPa)	0.8	1.1	1	1.4	1.3	1.5
Fahrenheit	Celsius	Min	Max	Min	Max	Min	Max
65	18.3	62%	47%	52%	33%	38%	28%
66	18.9	63%	49%	53%	36%	40%	31%
67	19.4	64%	50%	55%	38%	42%	33%
68	20.0	65%	52%	57%	40%	44%	35%
69	20.6	67%	54%	58%	42%	46%	37%
70	21.1	67%	56%	60%	44%	47%	40%
71	21.7	68%	57%	61%	46%	49%	42%
72	22.2	70%	58%	62%	48%	51%	43%
73	22.8	71%	59%	64%	49%	52%	45%
74	23.3	71%	62%	65%	51%	54%	47%
75	23.9	72%	63%	65%	53%	55%	49%
76	24.4	74%	64%	66%	54%	57%	51%
77	25.0	74%	64%	68%	56%	59%	52%
78	25.6	75%	65%	69%	57%	60%	54%
79	26.1	75%	67%	70%	58%	61%	55%
80	26.7	77%	68%	70%	59%	62%	56%
81	27.2	77%	69%	72%	60%	64%	58%
82	27.8	78%	69%	73%	62%	65%	59%
83	28.3	78%	71%	73%	63%	66%	61%
84	28.9	80%	72%	74%	64%	67%	62%
85	29.4	80%	72%	75%	65%	67%	63%
86	30.0	81%	73%	76%	66%	69%	64%
87	30.6	81%	75%	76%	68%	70%	65%
88	31.1	81%	75%	77%	69%	71%	67%
89	31.7	83%	76%	77%	69%	71%	68%
90	32.2	83%	76%	79%	70%	73%	68%

Table 5 - Relative Humidities Required to Create Target VPD Values (Lights-on Mode)

HVAC PERFORMANCE

The impact of temperature and relative humidity on equipment performance is a significant element in the cost of purchasing and installing HVAC equipment. These operational variables will also influence the amount of energy required to operate the HVAC equipment.

Table 6 displays the size of the environmental control system needed to remove the moisture in an indoor flowering room that has 2,000 square feet of cannabis canopy, watered at a rate of 270 gallons per day. Note that all of these design conditions have the same vapor pressure deficit. This analysis is for a maximum watering rate in a flowering room at full plant growth.

A key design consideration is the selection of the design temperature. As Table 6 demonstrates, while a constant growth potential is being maintained for the plants, the design temperature and relative humidity selected will dictate the actual size and total ownership costs of the environmental control system needed. If the grower selects design condition #4, initial capital expenditures or first costs for the increased system size will be more than double the baseline system #1. Then the grower will incur higher annual operational costs to maintain this environment at the lower design conditions.

	#1	#2	#3	#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
VDP (kPa)	1.4	1.4	1.4	1.4
HVAC Size (nominal tons)	34	36	43	53
Increase in size		5%	26%	57%

Table 6 - System performance at different entering air design conditions

AIR DISTRIBUTION

Air distribution is an important component in optimizing the capital costs of grow room climate control systems, and ensuring the health of crops. If good air distribution systems are utilized, growers can obtain very uniform climatic conditions in grow rooms and eliminate the possibility of damaging microclimates under plant canopies. With homogenous environments the growers can operate at higher air temperatures and still ensure appropriate vapor pressure deficits across and throughout plant canopies. This eliminates the possibility of mold and mildew forming while improving the growth rate and quality of plants.

Air Change Calculation

A method to measure the effectiveness of your air distribution system is to calculate the air changes in the space. To calculate HVAC system air changes, use the following formula:

$$\text{Air Change} = \frac{\text{Total cubic feet of room}}{\text{[Cubic feet per minute (CFM) of the systems / 60 minutes per hour]}}$$

Figure 4 - Calculating Air Changes

4. VAPOR PRESSURE DEFICIT AND HVAC SYSTEM DESIGN

The targeted air change for environmental control systems should be a minimum of eight air changes per hour. Most growers install supplemental fans to provide additional recirculation capacity by aiming the fans at plant canopies. The value of these fans is they move air at target conditions while the HVAC supply air might need to be at temperatures as cold as 55° F.

For example, if the grow space is maintained at 78°F db and 57% RH the grow space dewpoint is 61.5°F. If any of the HVAC supply air is below this value and directly hits the plants this will create condensation on the plants. The potential for mold and fungi to grow is significant.

This is one of the main reasons why discharge supply air from HVAC systems should be directed toward the walls and

open aisle areas so it does not strike the plants. Additional recirculation fans will assist in blending the HVAC supply air with the room air to quickly create a mixture that is above the room dewpoint.

An example of a desirable supply air and return air configuration is shown in Figure 5. Note supply air is directed along grow room walls. Return air vents are at high and medium vertical positions in the wall opposite the supply air entry point.

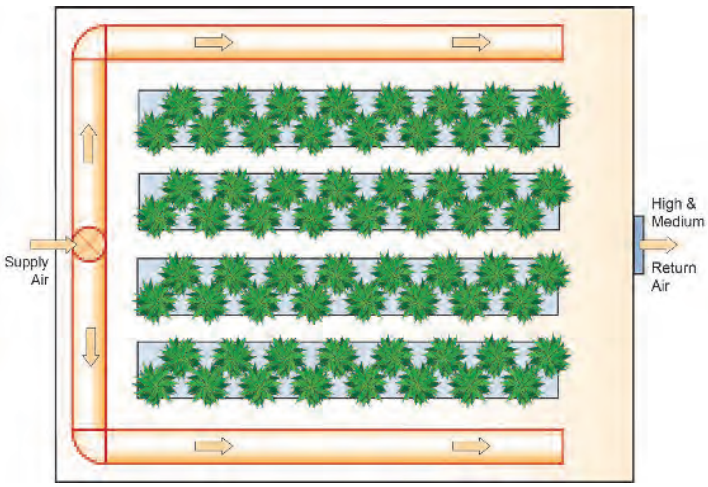

Figure 5 - Top view of desirable grow room duct layout

CONCLUSIONS

Growers and HVAC design engineers must agree on what the most challenging environmental design conditions will be for each grow room depending on its cultivation and production purpose. Typically these peak load design conditions will be for lights–on modes with the plants at the maximum watering rate for that growth stage. Partial load conditions will be met if the systems have the capacity for peak loads and proper environmental controls are part of the overall system designs. Refer to Desert Aire Application Note 26 – Grow Room Environmental Control, for more information on controlling grow room climates.

Due to capital cost implications, growers need to carefully define the desired air temperatures and vapor pressure deficits they will use to produce maximum yields. Arbitrarily choosing low temperatures to avoid condensation problems does not provide proper solutions.

Understanding the interplay of watering rates, plant growth cycles, room temperatures, humidity requirements and air distribution is essential. All must be carefully orchestrated to achieve successful grow room designs. Detailed communication between growers and HVAC design engineers must take place before the engineers begin designing grow room environmental control systems.

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Are You Ready for
Maximum Grow Margin?

NEXT STEPS

1. Fill out the form on the next page(s) or email us and we can send you an excel version to info@midwestmachinery.net

2. Once received, we will begin sizing the correct equipment for your ideal grow scenario.

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GrowAire™ Environmental Control Systems

*Ask us about **Free Cooling!***

*Desert Aire's GrowAire™ Systems can meet all your environmental control needs to enhance and protect crops -- and provide **Free Cooling**!*

We have included a Grow Room Project Information Form on the other side of this document so we can respond faster to your request for more information.

Thank you for your interest in Desert Aire!

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Desert Aire Grow Room Project Information Form

We'd like to help you plan for a successful grow room.
To begin the planning process, please tell us more about your needs.

Please enter information about your project in the spaces provided. This will help us respond faster to your information request. Once completed, scan the document and send via email to info@midwestmachinery.net

Project Name _____ **Location (City/State)** _____

Name _____ **Email** _____ **Work Phone** _____

Room Use and Number

Activity

In the top row of fields in this section, describe the Type of Activity in your grow spaces using these abbreviations: Mothering (M); Cloning (C); Combined Veg & Flower (CVF); Veg Only (VO); Early Flower (EF); Late Flower (LF); All Flower (AF).

Activity					
Number of Rooms					

Room Conditions and Size

Lights ON Room Design Temperature (°F)					
Room Design RH (%)					
Room Width (ft)					
Room Length (ft)					
Room Height (ft)					

Watering and Canopy

Net Water Use (gallons/day)					
Select Watering Technique	☐ Drip	☐ Hand	☐ Flooding	☐ Spray	
Plant Canopy Width (ft)					
Plant Canopy Length (ft)					

Lighting

Total Lighting Output (Watts)					
% of Watts Contributing to Space Heat Gain					
Ballasts in Room (Y/N)					
Ballast/Driver Efficiency (%)					

Room Heat Gain/Loss

Summer Room Heat Gain (Btuh)					
Winter Room Heat Loss (Btuh)					
Ventilation Air Volume (CFM)					

Additional Information

Desired Equipment Location ☐ Indoor ☐ Outdoor

Select Air/Water Cooled ☐ Air Cooled ☐ Water Cooled