APPLICATION GUIDE

A1

Moisture Management in Waterborne Climate Systems

Swegon

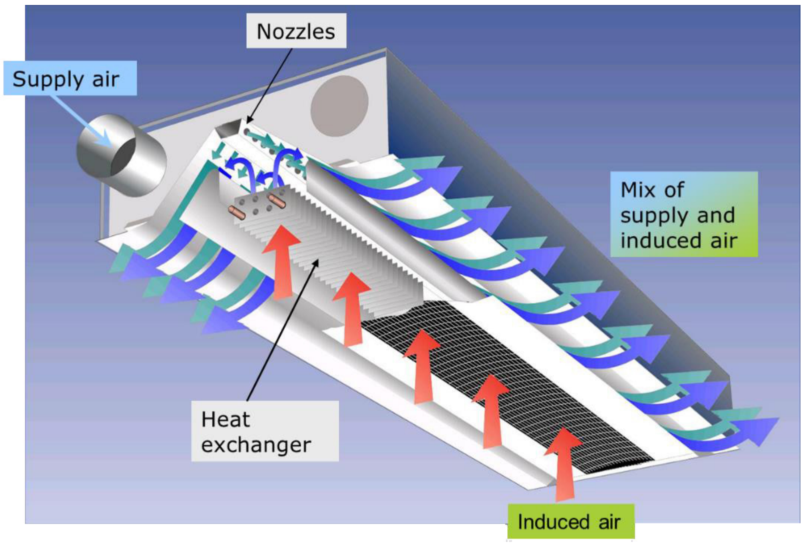
Contents

Introduction

Waterborne Climate Systems (WBCS) or “chilled beams” as they more popularly known are a dry system. The chilled water temperature and thus the beam are kept above the dewpoint of the space. The beam only performs sensible cooling so no condensation is formed.

Since the beam coil remains dry, there is no need for a drain pan or the complex sloped piping that serve the drain pans. There is also no need for a filter and so there is virtually no maintenance required for a climate beam (there are no motors either).

Figure 1: Typical Climate Beam



For those that have not designed or experienced a WBCS system, the concept there are no drain pans can seem risky. What happens if the dewpoint in the spaces goes above the chilled water temperature? Won’t there be damage from the condensate that might form?

The fact is that WBCS have been used for more than 25 years in places as humid as Florida and India. There are literally tens of thousands of beams being used every day. The systems stay dry and condensate is not an issue. This application guide will review moisture management with WBCS solutions.

WBCS Concept

Figure 2: Typical WBCS

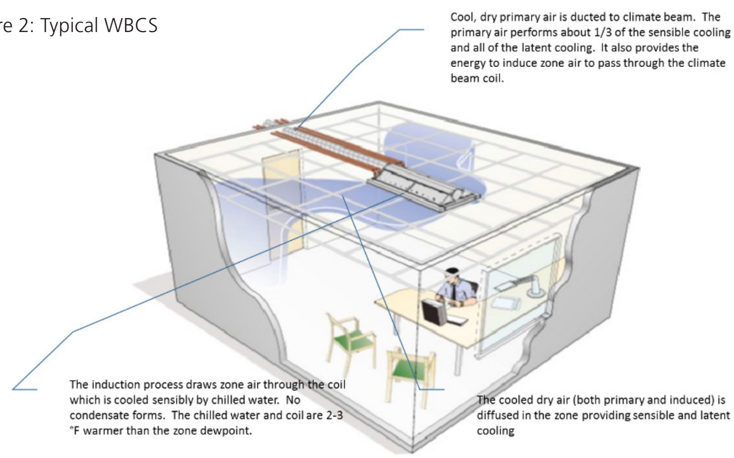


Figure 2 shows how the climate beam provides cooling to the space. The primary air is delivered from a dedicated outdoor air system (DOAS) that both cools and dehumidifies the air enough to meet the local zone latent load requirement. The climate beam further cools the air to meet the zone sensible cooling requirement. The cooling capacity is modulated by a chilled water control valve at the beam providing local zone control. The chilled water temperature is maintained 2–3 °F above the space dewpoint to avoid condensation issues.

The DOAS unit is effectively the same as the air handling unit in a Variable Air Volume (VAV) system where the air handling unit cools and dehumidifies the air to meet the entire zone latent and sensible cooling requirements.

The process to properly size the primary air flow is straightforward and is covered in detail in **Application Guide A2 – Establishing Primary Airflow for Waterborne Climate Systems.** (Figure 3)

Condensation

Condensate may form if there is something in the space with a temperature that is lower than the dewpoint of the air. A real world example is taking a shower in the hotel room. The water from the shower will raise both the temperature and humidity of the air in the bathroom much faster than surfaces in the bathroom can warm up. This can result in condensate forming on a surface like a mirror.

Dewpoint is the temperature where the humidity content (humidity ratio) in the air will start to condense. Figure 4 shows the typical design condition of 75 °F and 50% RH (point 1). This condition has a dewpoint of 55.2 °F. If the air in the space was cooled to 55.2 °F (point 2), the air would be at 100% RH and would be considered saturated. Any further cooling would result in condensation.

In a typical WBCS the chilled water is maintained at 57°F (point 3). This temperature is above the space dewpoint. Air around an exposed part of the chilled water system would be cooled close to 57 °F but it still would not condense.

However, if the moisture content in the space (humidity ratio) increased, then the dewpoint would rise. At some point it is possible that the space dewpoint would cross the chilled water dewpoint and condensate could form.

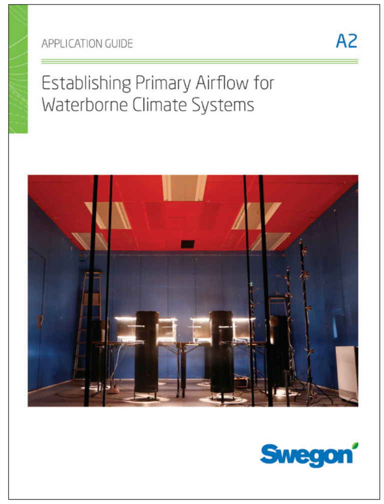
Moisture Sources in the Space

While the shower example above is an obvious source of humidity, there are other sources that need to be managed. The three main sources in most buildings are, the moisture from processes, moisture from the occupants and moist air infiltrating from outdoors.

Moisture from Processes

Commercial laundry and kitchen areas are good examples of spaces that have large moisture sources. It is not recommended to use climate beams in such spaces. Other moisture sources are residential kitchens, showers etc. Climate beams can be used in these spaces with some additional care.

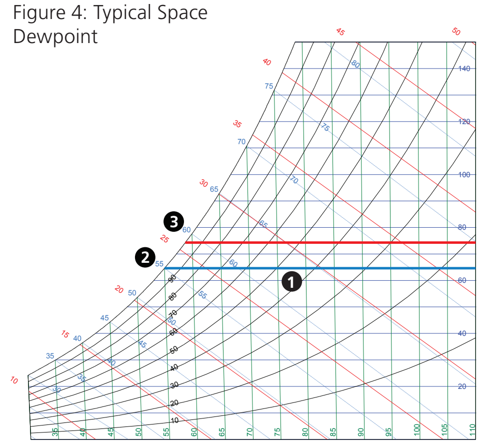
Figure 3: Establishing Primary Airflow for Waterborne Climate Systems


APPLICATION GUIDE A2

Establishing Primary Airflow for Waterborne Climate Systems

Swegon

Figure 4: Typical Space Dewpoint



1. Space condition 75 °F, 50% RH
2. Dew point 55.2 °F, 100% RH
3. Chilled water temperature 57 °F

Moisture from Occupants

Occupants release moisture into the space as a means of cooling. The amount of moisture released is closely connected to the occupant's activity (running in a gym vs. working at a desk). The amount of moisture released can be described either as a mass flow rate (grains/second where there are 7000 grains in a pound) or as the amount of cooling it would take to condense the moisture to a liquid (Btu/h).

Moisture from Infiltration

Generally outdoor air has a higher moisture content (a higher humidity ratio) than indoor air during the cooling season. Any path that allows outdoor air to enter the space is a source of moisture that can raise the dewpoint. This can be as simple as opening a window.

Most commercial spaces do not have operable windows. It is also common to design the HVAC system to positively pressurize the space so if there are any openings, air will leak out rather than in. In a modern building with tight construction, it can be assumed that there is no infiltration while the HVAC system is operating.

Not all buildings are new. In Europe, WBCS systems are often used in buildings constructed long before there were air or vapor barriers. In these applications, it is practical to assume some infiltration and increase the primary airflow to offset the local zone infiltration. (Increasing the primary air flow is the means to increase local zone dehumidification.)

Even a modern building with tight construction is likely to shut down the HVAC system during unoccupied hours. This allows the possibility that moisture can enter the building as the HVAC fans are not pressurizing the space. If the humidity in the space climbs during unoccupied hours, the DOAS unit can be started in recirculating mode to dehumidify the affected zone.

It is generally not necessary to increase the design dehumidification capacity of the primary air system to deal with unoccupied infiltration humidity. The dehumidifying capacity of the DOAS unit allocated for occupants and other sources during occupied hours is usually enough to dehumidify the space during unoccupied hours.

Impact of a High Moisture Load

Many are concerned that as soon as the moisture level (dewpoint) in the spaces rises above the chilled water temperature that condensate will start dripping off pipes and result in serious damage. Figure 5 shows condensate forming on cool surface of a drink outdoors which suggests from personal experience condensate will from very quickly once the dewpoint is reached.

This is NOT what actually happens building applications. Studies[1] have shown that condensate actually forms very slowly in buildings meaning that temporary saturation conditions will not lead to difficulty. Figure 6 shows a surface who temperature was deliberately held 14 °F below dewpoint for 8.5 hours. Not one droplet fell.

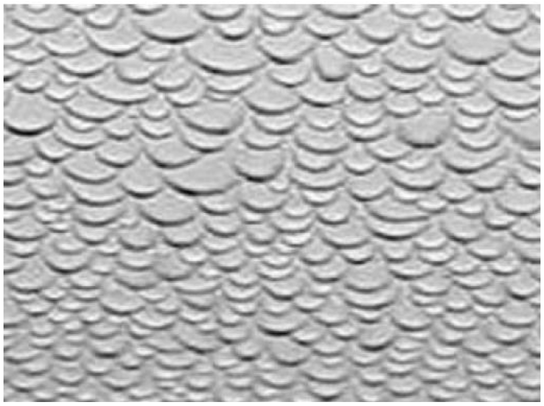
Unlike the outdoor example shown in Figure 5 which has an effectively infinite source of moisture, there is relatively much less water vapor available in the building. There simply is not enough moisture available to cause significant condensation.

Table 1: Typical Loads by Occupants Based on Activity

Activity Level	Sensible Load	Latent Load	Water Vapor Generation
	Btu/h	Btu/h	gr/s
Seated at the theater	225	105	0.216
Seated, very light work	245	155	0.276
Moderately active office work	250	200	0.339
Standing, light work, walking	250	200	0.339
Walking, standing	250	250	0.432
Light bench work	275	475	0.864
Athletics	710	1090	1.944

Figure 5: Condensation Outdoors

Figure 6: Condensation on a surface chilled 14 °F below dewpoint for 8.5 hours



Mumma (2002) analyzed a radiant cooling panel application where the occupant density was doubled from design conditions. A person generates less than 0.2 lb/h of moisture. At this rate, the thickness of moisture on the cooling panel was less than 0.0005 inches after one hour. This is less than the thickness of a human hair.

Transient Loads

Designing a system that will maintain dewpoint low enough to avoid condensation is generally not the main concern. Unexpected transient loads caused by opening windows, showers, unexpected high occupancy, equipment (controls) failure are all cited as reasons for concern.

Figure 7 shows further analysis by Mumma on transient response times. The figure shows that it would take an hour for the humidity ratio to climb to the chilled water temperature dewpoint if the occupancy was doubled beyond design levels.

Analysis by Mumma and others show the science behind what is well proven in Europe and other areas where WBCS are used routinely in a wide variety of buildings – Condensation issues are rare in properly designed systems.

Designing to Manage Condensation

There are several key considerations that should be made to ensure a successful WBCS system.

Building Envelope

The building envelope including windows has a major impact on any HVAC design. It is often said that the building envelope is part of the HVAC system. The thermal and radiant performance for the envelope has just as much an impact on WBCS systems and it does on any other HVAC system selection and sizing.

The infiltration capacity of the envelope is particularly important for WBCS systems. Modern buildings are generally tight enough that no design changes are required for the WBCS. The combination of tight envelope and space pressurization is enough to not require additional dehumidification from the primary air.

The dehumidification capacity of the primary air used to meet internal latent loads should be enough to manage any infiltration that could occur during unoccupied hours. If the space humidity rises close to the chilled water dewpoint, then the primary system can be started in recirculation mode to lower the humidity.

Older buildings will likely require additional dehumidification capacity from the primary air unit. This should be estimated in the cooling load calculations so the primary unit is sized properly. If the windows are old, strong consideration should be given to upgrading. The cost of the windows will be mostly offset by the reduced HVAC system sizing and the operating cost will recover the balance of any additional capital in short order.

Figure 7: Transient Humidity Ratio Response to a Sudden Doubling of Design Occupancy Followed by a Sudden Return to Design Occupancy.

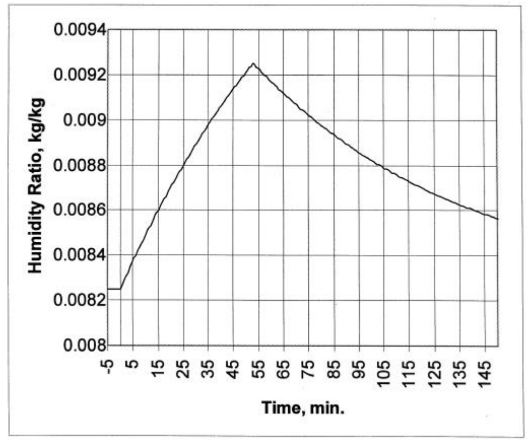


Figure 8: Building Envelope - Winn Center

[1] Mumma, S. – Chilled Ceilings in Parallel with Dedicated Outdoor Air Systems: Addressing the Concerns of Condensation, Capacity, and Cost. ASHRAE Transactions 2002.

DOAS Design

The primary air is supplied from a Dedicated Outdoor Air System (DOAS). While not an absolute requirement most WBCS systems use 100% outdoor air for primary airflow. The primary air is sized to meet the largest of the flowing;

- IAQ Ventilation rate
- Latent Cooling load (dehumidification)
- Sensible Cooling Load

A properly designed DOAS system will dehumidify the outdoor air not only to the same conditions as expected in the space but enough to offset any latent loads generated in the space (process, people, infiltration). Energy recovery such as enthalpy wheels are commonly used to reduce both sensible and latent cooling loads.

Condensate Controls

The first step in managing humidity in the space is to properly estimate the latent and sensible loads and then size the HVAC system to meet those loads. The next step is to introduce controls to monitor and manage the HVAC system to meet the loads and avoid condensation.

The most common control is to include condensate sensors (Figure 10) on at least one beam in the zone. The sensors are mounted on the chilled water supply piping to the space. If condensate starts to form, the chilled water valve is shut off to avoid any more condensate forming and the risk of drips.

This situation should happen only if the space dewpoint has risen above the dewpoint of the chilled water temperature. If such an occurrence happens, it is likely a transient event. Once the space dewpoint drops (the primary air will do this) the sensor will allow chilled water flow. It should be noted that for high sensible heat ratio spaces like offices, the primary air provides about 1/3 of the sensible cooling so even though the beam may be temporarily disabled, these will still be some sensible cooling. For spaces like classrooms, the primary air provides closer to half of the sensible cooling.

Humidity Sensors

An alternative to a condensate sensor is a humidity sensor (Figure 11). A humidity sensor monitors the space humidity and will also stop chilled water flow if the space dewpoint climbs however it will do this before any condensate forms. Whereas the condensate sensor is reactive, the humidity sensor is proactive.

Window Switches

Figure 12 – Window Switch

WBCS systems are used in applications such as apartment, hotel rooms etc where there may be operable windows or patio doors. In such applications window switches can be used to detect in the occupant has chosen to open the window or door and shut off the chilled water flow to the beams. This has two positive effects. First it avoids trying to air condition the outdoors and secondly it avoids any condensation forming due to infiltration.

Figure 9: WBCS with DOAS

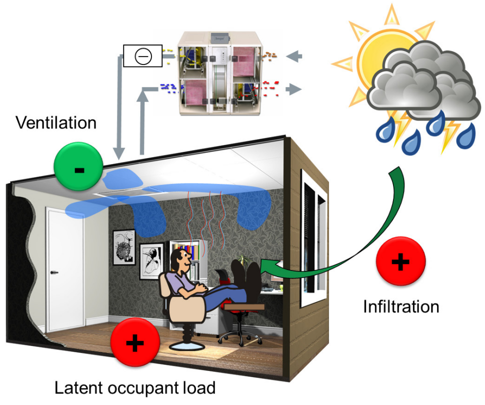


Figure 10: Condensate Sensor

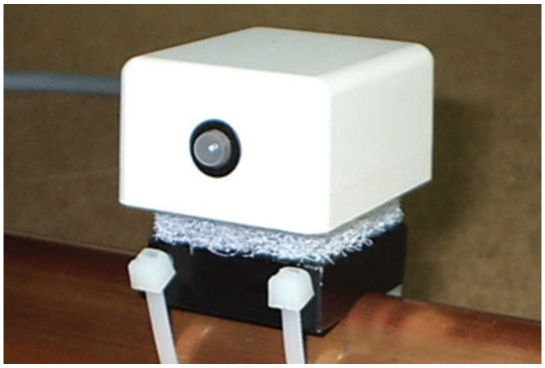


Figure 11: Humidity Sensor

Figure 12: Window Switch

Control Sequences

The sensors described above are cost effective and commonly used. The use of integrated control sequences can improve condensate management, energy efficiency and most importantly comfort.

Demand Control Ventilation

Demand control ventilation (DCV) allows the amount of primary air delivered to the space to be adjusted based on needs. The amount of primary air is based on design load conditions but this only happens about 2% of the time. The rest of the time, much less primary air is required. Reducing the primary airflow when possible is the single most important thing to reduce energy cost in a WBCS system.

Combining humidity sensors with DCV can provide outstanding condensate control. A high space humidity signal from the humidity sensor can be used to increase the primary airflow to the space and thus dry it out without having to override chilled water flow to the beams. This maintains temperature and humidity comfort for the occupant and only happens when required (energy savings).

Primary Air Boost

While overriding chilled water flow to the beams is a cost effective way to resolve condensate issues, it impacts occupant comfort. The best method to manage rising dewpoint in the space is to increase primary airflow. Demand control ventilation integrated with humidity sensors is the best method to increase primary airflow when required.

Another option is to use a boost function. In this system, the humidity is monitored through zone sensors or return air sensors. If the space dewpoint climbs, the primary airflow in the DOAS unit is increased to all beams served by the DOAS unit. Assuming the DOAS unit has variable airflow control, the primary airflow rate can be increased to help dry out the space. This does not require all the zone airflow controls found in a full demand control ventilation system.

Primary Air Humidity Ratio Control

The humidity ratio of the primary air is typically controlled by the leaving air condition off the cooling coil in the DOAS unit. These conditions were selected to meet the building design conditions. By using the zone or return air humidity sensors in a similar fashion to boost control, the primary air can be cooled below design conditions thus lowered the primary air humidity ratio. The drier primary air will then provide more dehumidification to the zones served by the DOAS unit.

Chilled Water Temperature Control

Managing the chilled water temperature is another means to control condensation and reduce energy costs. The chilled water temperature is chosen to meet the needs of a design day which rarely happens. By integrating the chiller, DOAS and beam controls, the chilled water temperature can be reset to meet the dehumidification requirements. The chilled water supply temperature to the DOAS unit can be lowered when more dehumidification is required.

Figure 13: Demand Control Ventilation

Figure 14: Variable Airflow Fan in a Swegon Gold DOAS Unit

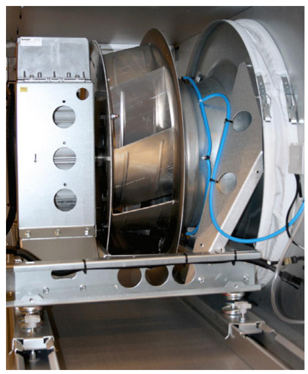
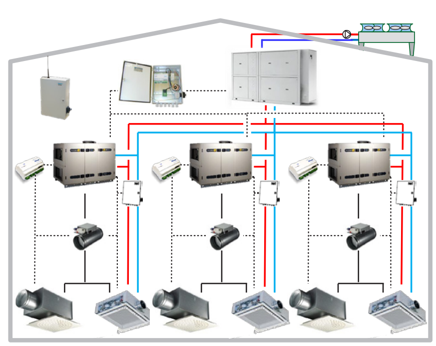


Figure 15: DOAS Unit with Cooling Coil

Figure 16: DOAS Unit with Cooling Coil



This is particularly advantageous on smaller WBCS systems where there is a common chiller plant for both the beams and the DOAS units. In this system design, the chilled water supply temperature is set to meet the needs of the DOAS unit – typically around 44°F. A secondary loop is run to serve the beams typically operated at 57°F. While cost effective to build, it requires running the entire chiller plant at conditions that only the DOAS unit require (which is about 20% of the chiller plant load).

By using integrated controls, the chilled water temperature can be reset up during any time the weather and building usage allows. The chilled water temperature is only lowered to design conditions when the space humidity cannot been maintained. Raising the chilled water temperature from DOAS to beam conditions is about a 30% energy savings for the chiller.

Application Considerations

Different building applications will impact latent loads and thus the best method to manage the moisture level. The following will consider several approaches for various building types.

Offices

A New construction office building benefits the most from a WBCS. The building will have a high sensible heat ratio with low internal humidity sources. There will be very few envelope penetrations and a new construction building will have tight construction. From a moisture management point of view, condensate or humidity sensors at the beams will suffice in most applications.

Studies have shown than occupants are at their workstations between 22 and 38% of the time. From an energy management point of view, adding DCV may make sense. Once this decision is made, adding additional moisture management control only makes sense as the cost has been occurred and only control sequences remain. Spaces such as conference rooms, cafeterias and lunch rooms will all greatly benefit from DCV plus humidity control.

Schools

Schools are the opposite building type of office buildings. They have a low sensible heat ratio with a high moisture source from the students. There is also a high ventilation requirement due to the high occupant density. Energy standards such as ASHRAE Standard 90.1 require DCV for such spaces.

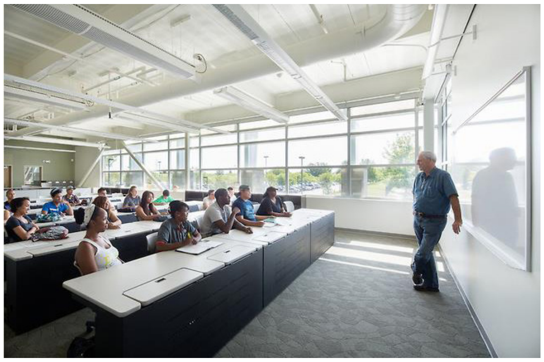
Since DCV will be used, it only makes sense to include humidity sensors and improve the control sequences to adjust the primary airflow rate based on IAQ (CO_2), sensible cooling load or humidity level.

Hospitality

Hotel rooms are spaces most likely to introduce transient humidity levels. This can occur because there may be operable windows and the humidity from the shower or bath. If there are operable windows, then window switches are recommended. The humidity load from a shower is a steep but short lived spike. Using condensate or humidity sensors to stop chilled water flow until the primary air can dry out

Figure 17: Office Building

Figure 18: School



space is the most common method to deal with these spikes.

Retrofit Applications

Retrofit, while not specifically a building type, has specific challenges that should be considered. It is unlikely that a retrofit application will have air or vapor barriers or other modern means to manage infiltration. The windows may also be old with poor thermal performance and high infiltration rates. It may seem that this is the least likely candidate for a WBCS system due to infiltration humidity concerns. However, an old building will likely not have much space available for a HVAC system and for this reason, WBCS can be a great solution. WBCS do not require much ceiling space for the beams, the piping or primary air ducting. There is no condensate piping either. In many applications, it may be one of the few systems that will fit.

To manage the infiltration the following should be considered;

- Try to include upgraded windows as part of the project. If the owner does not spend the money on the windows, they will spend most of it on a larger HVAC system (which will be harder to fit in the building) and they will have to pay to run the larger HVAC system. The reduced window infiltration will help significantly with humidity management.
- Account for infiltration in the design loads and size the primary airflow accordingly.
- Include a recirculation section in the DOAS unit to allow off-hour operation to dehumidify without using outdoor air.
- Consider DCV to both for energy savings and humidity control.

Latent Control Comparison for Various HVAC Systems

The first part of this guide has discussed in detail how to manage humidity in the space to avoid condensation issues. It almost appears that humidity management is a weakness of WBCS systems. Condensation forming from a transient issue in the space, rare as it is, is something to be avoided. However, WBCS actually have a distinct advantage over most other HVAC systems in how they do manage humidity level in the space. They are one of only a few systems that has dedicated equipment to manage the latent load (the DOAS unit) and the sensible load (climate beams).

How this works will be discussed here using a classroom as an example.

Figure 19: Hotel Room

Figure 20: Retrofit Application

Table 2: Typical Classroom Zone Cooling Load

	Sensible			Latent			Total		
	Btu/h	Btu/h-ft²	%	Btu/h	Btu/h-ft²	%	Btu/h	Btu/h-ft²	%
Wall 1 Load	2464	2.5	11%				2464	2.5	8%
Glass 1 Conduction	564	0.6	2%				564	0.6	2%
Glass 1 Solar	1422	1.4	6%				1422	1.4	5%
Light Load	3412	3.4	15%				3412	3.4	11%
Plug Load	6824	6.8	30%				6824	6.8	22%
Occupant Load	7576	7.6	33%	7576	7.6	94%	15152	15.2	49%
Infiltration Load	475	0.5	2%	516	0.5	6%	990	1.0	3%
Subtotal	22736	22.7	100%	8091	8.1	100%	30828	30.8	100%
Safety Factor	2274	2		809	0.8		3083	3.1	
Total	25010	25		8901	8.9		33910	33.9	

Table 2 shows the sensible cooling loads for a typical classroom with a south exposure in Toronto, Canada. Only the space latent load will be considered because various different HVAC systems manage the ventilation load in a wide range of manners. The ventilation latent load will be discussed separately.

WBCS Ventilation and Latent Load Calculations

The classroom ventilation and latent load primary airflow calculations for a Waterborne Climate System (WBCS) will be used as a base line. The ventilation calculation is the same for packaged rooftop units, Fan fan coils, Water Source Heatpumps (WSHP), Ground Source Heatpumps (GSHP) and Variable Refrigerant Flow (VRF) systems. Ventilation rates for VAV is little more complex due to the multi-zone calculation requirements. Using the classroom example in Table 2;

Ventilation Rate

The ventilation rate is based on ASHRAE Std 62.1 single zone systems. This is the most straightforward method in ASHRAE Std 62.

$V_{bz} = R_p \times P_z + R_a \times A_z$

$V_{oz} = V_{bz} / E_z$

V_{ot} = all zones V_{oz} (For 100% outdoor air systems like WBCS)

where

V_{bz} = outdoor airflow rate in the breathing zone (cfm)

R_p = people outdoor air rate (cfm/person)

P_z = number of people

R_a = area outdoor air rate (cfm/ft²)

A_z = area (ft²)

V_{oz} = zone airflow rate (cfm)

E_z = zone air distribution effectiveness (E_z = 1.0 for ceiling chilled beams)

Occupancy (NP) = 30

Area = 1000 ft²

R_p = 10 cfm/person

R_p = 0.12 cfm/ft²

Ventilation rate = 30 × 10 cfm + 0.12 × 1000 ft² = 423 cfm

Latent Rate

The latent load in a classroom will dominate the primary airflow sizing for a WBCS system. The change in humidity ratio will likely be 20 gr/lb or more. Such a large change will require a higher humidity level in the space and a lower humidity level from the primary unit.

$Q_p = P_{latent}/(0.68*(W_r - W_{primary\ air}))$

where

$W_{primary\ air}$ = the humidity ratio of primary air in gr/lb

W_r = the humidity ratio of the design space condition in gr/lb

P_{latent} = the latent load in Btu/h

Q_p = the primary air flow in cfm

$Q_p = P_{latent}/(0.68 \times (W_r - W_{primary\ air}))$

Latent load Platent = 7165 Btu/h

W_r = 71.2 gr/lb (Note: this is based on 75 °F and 55% RH)

$W_{primary\ air}$ = 51.6 gr/lb (Note: this is based on 50 °F leaving coil temperature)

Primary air flow for latent load = 7165 / (0.68 × (71.2 – 51.6) = 538 cfm

Table 3 shows the summary of the calculations for a WBCS system. In this case, the latent airflow requirement is dominant so the primary airflow rate should be 538 cfm or 0.54 cfm/ft². For other decentralized HVAC systems, the primary airflow will just be the ventilation airflow. Depending on the design of the ventilation unit, the primary air may handle some of the zone latent load. The rest of the zone latent load will be managed by the terminal unit (fan coil, WSHP, etc.)

Comparing Latent Load Management

Consider using a VAV system for the classroom example. The design airflow rate to meet the sensible load will be;

Q_p = 25010 / (1.085 × (75 – 57)) = 1280 cfm or 1.28 cfm/ft²

The latent airflow rate will be;

Q_p = 7165 / (0.68 × (71.2 – 62.4)) = 1197 cfm or 1.2 cfm/ft².

The supply air will pass through the cooling coil being cooled to 55 °F DB and 62,4 gr/lb. The fan heat will reheat the air 2 °F to 57 °F as shown in Figure 21.

Figure 22 and 23 (right) show the latent and sensible cooling curves for both VAV and WBCS systems as the sensible load goes from 0 to 100%.

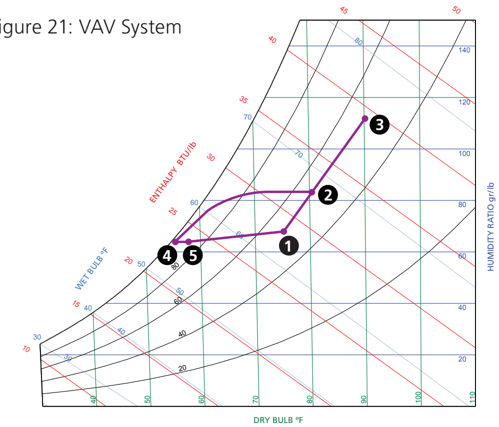
In a VAV system (Figure 22) the supply air is reduced as the sensible load drops. The system will spend the bulk of its operating hours around 50%. The primary airflow will drop to 50% meaning the latent capacity will also drop to 50%.

In a WBCS system (Figure 23) the latent load is controlled independently of the sensible load. A WBCS system will deliver the same latent capacity regardless of sensible load.[1]

Table 3: Summary of Primary Airflows for Classroom using WBCS System

Rate	cfm	cfm/ft²
Design Sensible Rate	419	0.42
Design Ventilation Rate	423	0.42
Design Latent Rate	538	0.54

Figure 21: VAV System



1. *Space condition 75 ˚F DB 55% RH, 71.2 gr/lb*
2. *Mixed air condition*
3. *Outdoor air condition 90 ˚F DB, 75 ˚F wb*
4. *Off coil condition 55˚ F DB 54.5 ˚F wb*
5. *Fan heat 2 ˚F*

Figure 22: Latent Performance for VAV System

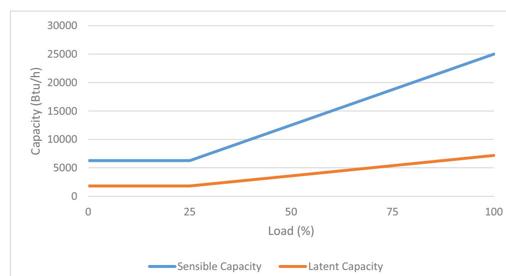
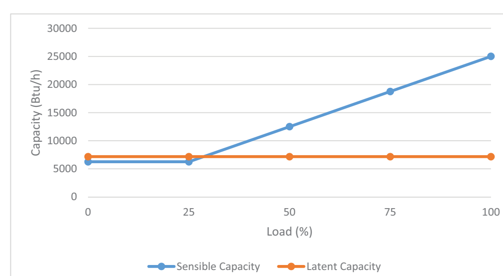


Figure 23: Latent Performance for WBCS system



[1] At 50% sensible load, the WBCS still provides the design latent cooling capacity.

In a VAV office design with a high sensible heat ratio, the drop in latent cooling capacity as the sensible load drops is generally not an issue (a conference room could be problematic). However, in a classroom application, the latent load generally remains constant (the students are in the classroom all day). Most classrooms have an exterior exposure which has a large impact on the sensible load. As the sensible load drops with a VAV system, humidity control can be lost.

Latent Load Management with Decentralized HVAC Systems

Other popular decentralized HVAC systems for classrooms include;

- Fan coils
- WSHP
- GSHPs
- Variable Refrigerant Flow (VRF) systems

The decentralized systems have dedicated outdoor air systems (DOAS) to manage the ventilation load. For the most part, the latent load of the ventilation air is handled by the DOAS unit. Only the space latent load is managed by the terminal unit to reduce unit capacity.

These are all constant airflow variable supply air temperature systems. As the cooling load drops, the supply airflow rate remains constant and the supply air temperature is raised.

Figure 24 shows the part load cooling performance of a typical constant volume, variable supply air temperature unit. This is how most energy modelling programs model this style of equipment. At 50% capacity, the supply air temperature has been raised to 65 °F, significantly lowering the latent cooling capacity of the terminal unit.

A fan coil with a modulating control valve can actually modulate the supply air temperature, although in many applications an off-on style valve is used. For a typical classroom-sized unit (3 to 5 tons), most of the other terminal units are either on-off or may have two-stage cooling. When an on-off style unit operates at 50% sensible cooling capacity, the unit cycles on and off so over the course of an hour the unit runs 30 minutes. While it might appear that the unit will fully dehumidify the supply air for at least 30 minutes in an hour, this has been proven to be false.

Figure 25 shows that unless a unit operates at least 50% of the time, there is almost no dehumidification. While the unit is operating (dehumidifying), condensate forms on the coil and collects in the drain pan. When the unit cycles off, the condensate is re-evaporated into the airstream.

In recent years several innovations have been added to improve part load performance. Both WSHPs and GSHPs can be supplied with Hot Gas Reheat (HGRH) and dehumidification controls. When the controls sense high humidity, the unit cools the air to remove the latent load and then reheats the air using waste heat from the refrigeration circuit. This maintains the space dry bulb temperature while removing moisture. Two-stage and now inverter (modulating compressors)

Figure 24: Part Load Performance for Constant Volume HVAC Unit

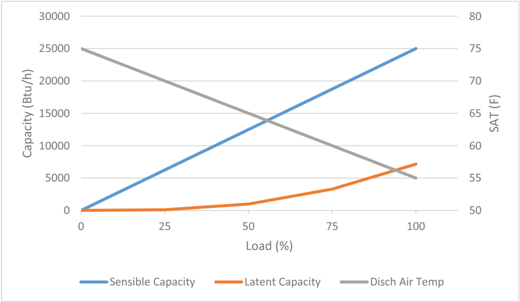
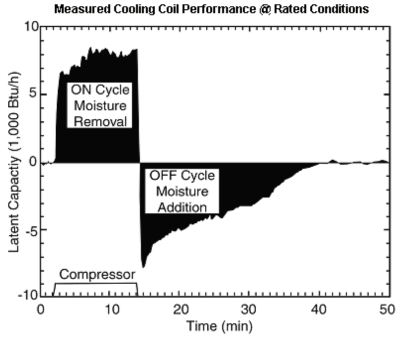


Figure 25: Dehumidification Performance for On-Off Style Units[1]



[1] Henderson, H. 1998 "The impact of part-load air conditioner operation on dehumidification performance. Validating a latent capacity degradation model" Proceedings of the 1998 Indoor Air Quality Conference.

have also become available. This matches the cooling capacity to the actual space sensible load and allows the compressor to stay on, dehumidifying all the time.

The use of ECM motors on the fans has also allowed for improved dehumidification by reducing the airflow at part load conditions, thus lowering the supply air temperature so there is condensate removal.

Latent Load Management with Package Rooftop HVAC Systems

Packaged rooftop units can be used in school applications where typically there is one unit per classroom. Packaged rooftop units differ from decentralized systems because they include the ventilation air. While this is a low cost solution, it can have severe latent management issues.

Packaged rooftops unit are designed for office space conditions. Their capacity is based on about 10 to 15% outdoor air whereas a classroom application is closer to 35% outdoor air. They are not intended to be used for such high latent load applications.

Basic rooftop units in this size range are either on-off or two-stage cooling. They are constant supply air units that cycle the cooling on-off to maintain overall space sensible temperature. During the off cycle, humid outdoor air is being introduced into the space as well as re-evaporating the condensate that has formed on the coil and collected in the drain pan.

Hot gas reheat can be added to the unit to keep the compressor operating and not re-evaporate condensate. By doing so, however, the supply air temperature will rise at part load, quickly negating the latent cooling capacity of the unit. Using hot gas bypass also means the unit will operate at full power regardless of the actual cooling load. This will be a very expensive system to operate.

Except for a few select areas that favor this system, packaged rooftops are a poor choice for school classroom applications. They can be improved by adding an energy recovery module but latent performance is still compromised during part load operation. In recent years, several specialty manufacturers have introduced packaged rooftop units specifically designed for high latent load applications. They include modulating DX cooling, hot gas reheat and energy recovery.

Conclusions

WBCS systems are dry systems. This has many advantages including;

- No drain pans or condensate piping
- No filters to maintain in the space (coils stay clean)
- The primary air (DOAS) unit manages the latent load for the whole building thus separating sensible cooling control from latent cooling control

To keep the climate beams dry requires managing moisture load sources such as process, occupant and infiltration. This is not a complicated process and has been successfully done in thousands of buildings worldwide.

Even if there is a transient spike in humidity level the low moisture content in the air within the building means condensation forming to a point where a drip occurs is very unlikely. Managing transient humidity levels is easily achieved with controls. Many of the control sequences used to manage unusual humidity levels can be used to greatly reduce annual energy usages and thus pay for themselves.

Having dedicated equipment to manage the latent (moisture) load and the sensible cooling load is not common in HVAC systems. WBCS is one of the few that can offer this level of control and it is one of the reasons the WBCS offer superior comfort in many applications.