Commissioning Humidity Control Systems in Critical Environments

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Synopsis

Control of humidity in a critical environment is as important to assuring reliability as temperature control, yet is often ignored until it's too late. Low humidity can lead to static damage. High humidity can lead to degradation of electronic equipment and swelling or delamination of printed circuit boards. The result will be equipment failure and reduced up-time.

There are many approaches to controlling humidity in a data center. The first decision is where to control from, ie: at the local computer room air conditioning units or centrally at the make-up / pressurization air handling units. Consideration must then be given to the type of humidification system to use. Spray pads, ultrasonic, steam, infrared systems have all been used in critical applications with varying degrees of success.

One of the most important factors in regulating humidity is proper sealing of the room and installation of an appropriate vapor barrier. Without a vapor barrier, it may be nearly impossible to add or remove enough moisture to precisely control the interior environment.

Only the Commissioning Authority can pull together these disparate issues, and address them during design reviews and construction inspections, when the CxA's impact will really be felt.

Functional testing of humidity control systems must include safeties and alarms. Improper setting of an air flow cutout can allow vapor to condense inside ductwork when the fan is off, but the humidifier is still running. If the duct is pitched towards the outlets, water can drip onto sensitive electronic equipment with predictably catastrophic results.

Maintenance requirements and costs vary considerably from system to system. Some work is well within the abilities of the typical facility engineer. Other systems would be better served by outside service agreements. Knowledge of various systems will assist the CxA in guiding training agendas.

This article will examine all of the above, plus control schemes and lessons learned.

About the Authors

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Control of humidity in a critical environment is as important to assuring reliability as temperature control, yet is often ignored until it's too late. Low humidity can lead to static damage. High humidity can lead to degradation of electronic equipment and swelling or delamination of printed circuit boards. The result will be equipment failure and reduced up-time.

The commissioning authority is in a unique position to influence the design intent to assure control of humidification is addressed early in the design process. If he understands the importance of humidity control, he can make a strong case in favor of this investment.

Why Control Humidity?

There are many data centers with no independent control over humidity. Do they function? Yes. Are they at risk? Definitely. Can we quantify the risks? Let's see.

Normal Conditions

Let's start with a look at the range of humidity conditions that may occur in the data center environment and how humidity is measured. Humidity is a measure of the amount of water vapor in the air. The common measures of humidity are relative, specific and absolute. Absolute humidity is a measure of the actual mass of water vapor in an air water vapor mixture, (lb_{water}). Specific humidity (or humidity ratio) is the ratio between the actual mass of water vapor present in moist air - to the mass of the dry air (lb_{water} / $lb_{dry\text{-}air}$). Relative humidity can be expressed by partial vapor and air pressure (p_w / p_{ws}), density of the vapor and air, or by the actual mass of the vapor and air. Relative humidity is usually expressed in per cent and abbreviated by RH.

Relative humidity can be expressed as the ratio of the vapor pressure of the air - to the saturation vapor pressure of the air at the actual dry bulb temperature. That is, at any given temperature the relative humidity is the ratio of water vapor in the air to the maximum amount of water vapor that the air can hold. If the relative humidity is 0% there is no water vapor; if the relative humidity is 100%, the air can hold no more water, **at that temperature—**it is saturated. This is important to consider when analyzing the consequences of rapid temperature changes and consequent humidity changes that can occur during non-normal conditions. Those will be discussed later. Generally, people are comfortable in the relative humidity range 25-60%.

A related term is dew point. Dew point is the temperature at which water vapor starts to condense out of the air, the temperature at which air becomes completely saturated. Above this temperature the moisture will stay in the air. On a psychrometric chart this temperature can be read by following a horizontal line from the state-point to the saturation line. Dew point is represented along the 100% relative humidity line in a psychrometric chart.

Table 1 shows the changes in relative humidity as a function of temperature for a fixed absolute humidity. Our baseline will be the typical data center space conditions of 72°F db and 45% RH. The specific humidity at this condition is 0.077 lb_{water} / $lb_{dry\text{-}air}$, (54 grains/ $lb_{dry\text{-}air}$). The dew point at these conditions is 50°F.

Table 1: Relative Humidity vs. Temperature @ 54 grains/ $lb_{dry\text{-}air}$

Temperature db	RH %
92°F	24%
82°F	33%
72°F	45%
62°F	65%
52°F	95%

Consequences of Low Humidity

By definition, static electricity is an electrical charge at rest. The discharge of this built-up energy can cause numerous problems. When the humidity is low, static electricity is high. How much static electricity is too much? A charge of 3500-4000 volts sounds like a lot, but it is actually the minimum a person can feel. (Remember high school physics? Static voltage isn't life threatening because the amperage is tiny. It's amps, not volts, which are dangerous.). According to industry sources, a static charge as low as 400 volts can cause non-catastrophic damage to integrated circuits. Table 2 shows how much static electricity can be generated by various activities at different humidity levels.

Table 2: Static Electricity Generation

Activity	Static Charge at 65-90% RH	Static Charge at 10-20% RH
Walking over vinyl flooring	250 Volts	12,000 Volts
Walking Across Carpet	1500 Volts	35,000 Volts
Worker at bench	100 Volts	6,000 Volts
Vinyl envelopes for work instructions	600 Volts	7,000 Volts
Common poly bag picked up from bench	1,200 Volts	20,000 Volts
Work chair padded with urethane foam	1,500 Volts	18,000 Volts

Conditions that can result in static charge build-up are ungrounded raised floor pedestals, carpeted tiles with low natural fiber counts (specify static electricity build-up should not exceed 2000V at 40% RH), using chairs with plastic or vinyl seats, chairs or equipment carts with casters, and failure to use wrist straps when working on equipment. Today's electronic equipment has a dense geometry, and is composed of thin, easily damaged, materials. Damage caused by ESD can take the form of catastrophic failures, but is more often low-grade damage that may not show up during initial setup, but can make equipment more susceptible to a later failure. Cumulative degradation of the components can also occur as the result of repeated, low voltage exposures. These types of problems are very subtle, and extremely difficult to detect. One complication with assessing static damage is that the results are not always immediately obvious because the resulting failure often destroys the evidence of damage. It is often problematical to state categorically that a failure was caused by static damage.

While humidification does increase the surface conductivity of the material, the charge will dissipate only if there is a conductive path to ground. Surface resistivity of many materials can be controlled by the humidity of the surroundings. At a humidity of 40 percent and higher, the surface of most materials will adsorb enough moisture to ensure a surface conductivity that is sufficient to prevent accumulation of static electricity. When humidity falls below about 30 percent, these same materials could become good insulators, in which case accumulation of charge would increase. Control of humidity is the easiest and surest way of mitigating build-up of static electricity.

Consequences of High Humidity

In the electronic industry, printed wirings get corroded due to presence of high humidity. Transistors may break down or suffer a decrease in longevity.

When the air temperature is lowered below the dew point temperature then water condensation is formed. An ideal condition for condensation to occur would be in a data center where the air is maintained at 72°F, but the outside environmental conditions are 90°F with a relative humidity of about 90% RH (hot and humid). Introduction of this unconditioned air can produce condensation. The results of condensation inside an electronics unit can be degraded equipment performance, specifically:

- Changes in surface resistivity that alter timing circuits, change the frequency of oscillator circuits, change the current level in a constant current source, result in loss of sensitivity or reduce the input impedance on high impedance amplifiers.
- Electrical shorts
- Swelling and binding of mechanical moving parts
- Localized corrosion
- Delamination of printed circuit board (PCB) materials
- For facilities with older raised floor tiles where galvanic coatings were used, high humidity can cause the formation of a zinc solute, which can lead to the growth of zinc whiskers (filamentary growth on metallic materials) on PCBs. Whiskers can grow long enough to short out circuitry.

Controlling Humidity

By now the need for humidity control is clear. The commissioning authority should be able to make a good case for why control of humidification is necessary. Our next decision is from where to control humidity. There are pros and cons to both local and remote control of humidification. Many engineers, owners and operators have experience with various configurations and systems and have strong opinions for and against.

Local vs. Remote

If a facility has a dedicated make-up air / pressurization unit with a redundant back-up, the incremental cost for adding humidification and reheat (for dehumidification) is marginal. Remote control of humidification offers the advantages of running city water piping to one or two locations as opposed to computer room air conditioning (CRAC) units throughout the raised floor. Additionally, there is a significant cost savings for running smaller power circuits to each

CRAC unit (no humidifier or reheat). These two items are particularly important considering the increases in the cost of copper in the past year.

For facilities where CRAC units are DX and no water is allowed on the floor, the choice is obvious; humidity must be added remotely. For small facilities, facilities where there are no dedicated make-up air / pressurization units, the choice is also clear. Add humidifiers and reheat to the CRAC units. For facilities served from central station air handlers (no local CRAC units), humidification should be installed in the units.

Types of Humidifiers

Several types of humidifiers have been in common use in critical environments over the years. Table 3 shows a comparison of various systems.

Table 3: Humidification Method Comparison

Comparison Criteria	Spray Pad	Electric Steam	Ultrasonic	Infrared
Effect on Temperature	Substantial drop	Some increase	Substantial drop	Some increase
System Size	Medium to large	Small to medium	Small to large	Small
Vapor Quality	Poor	Excellent	Excellent	Excellent
Control Response	Slow / Imprecise	Slow	Fast / Precise	Fast / Precise
Sanitation / Corrosion	Medium	Excellent	Excellent	Medium
Maintenance Attention	High	Medium	Medium	High
Relative Costs				
Capital	Low	Lo—Med	High	Lo—Med
Operating	Low	High	Low	High
Maintenance	High	Medium	High	Medium

Spray pads are used on large air handling systems and have developed a poor reputation for several reasons. The nozzles require periodic replacement and the water often sprays other than where intended. The spray pads need frequent replacement. The collection basin is a potential sanitation problem and the water spray is often wasteful and excess, unvaporized water and resultant scale and sediment are sources of corrosion and potentially encourages organic growth. Close control of humidity is difficult. Some systems, such as the wet deck type can be configured in multi-bank arrangements with face and bypass dampers, and can provide closer control. The systems are still slow to start operation.

Ultrasonic humidifiers use a piezoelectric transducer that converts a high frequency electronic signal into high frequency mechanical oscillation, which ultimately converts water into vapor at low temperature and pressure. They generate a mist with a particle size one fiftieth the size from a spray nozzle. They generate no waste water. Operating costs are on the order of one tenth the cost of operating an electric steam unit. They can be installed in make-up air handling units, in the supply ductwork keeping the wet bulb above 58°F on a cooling coil (they work well on the return side, too), or in individual CRAC units. Ultrasonic humidifiers should only be used with de-ionized water and a reverse osmosis (RO) water treatment system is recommended for most installations. The high maintenance attention rating is due to the care RO system needs and the 3-5 year life of the ultrasonic transducers. Training must cover the need to periodically circulate water through the system in the off months to protect the membrane. Additionally, the humidifiers must be drained (manually or automatically) after 3 days of inactivity to prevent sanitation problems. Furthermore, the RO piping must be stainless steel (plastic may be an option—check local codes). Both spray pads and ultrasonic humidifiers drop the supply air temperature because the vaporization of the droplets draws heat.

Electric steam humidifiers, sometimes called electrode humidifiers boil water in a canister to generate steam that is delivered through a perforated tube. The tubes are installed in supply ducts or in CRAC units. They can also be installed in air handlers. It takes time for the canister to boil and response to changing conditions interior environmental conditions can be slow. Local water should have a conductivity of 200 -500 micromhos for reliable operation; deionized water will not work. Challenge the designer that he investigates the water quality before selecting the appropriate humidification system. Steam canisters require regular replacement and should not all be replaced at once or during times of high demand, since the canisters need to run about 24 hours before they produce at full output (the addition of salt speeds the process).

Infrared or quartz humidifiers use high intensity quartz infrared lamps over a stainless steel humidifier pan. They are active in about 6 seconds and are typically installed inside CRAC units and sometimes in smaller central air handling units. Lamps on infrared humidifiers need to be replaced regularly (if pan maintenance is mediocre) and the pans need to be de-scaled monthly to remove mineral deposits. Also, the sockets occasionally require replacement. Infrared and steam systems add some heat to the air stream.

Electric and infrared may be good choices where electricity costs are low and keeping first cost down is important. Though not listed, direct steam may be a good choice, if available. These setups require a very high end controller doe to the difficulty in controlling raw steam dispersion. When evaluating humidification systems, investigate local utilities for rebates for installing the lower energy consuming ultrasonic systems in lieu of the electric steam or infrared systems.

Discussions of the relative merits and costs of the various humidification systems should include the facility operations and maintenance staff. Equipment selection (and later training) should be geared towards the skill levels of technicians, with consideration as to whether they will be performing maintenance, or if it will be contracted out.

Safeties

Two critical safeties should be part of the humidification system. One is a high limit cutout to prevent over-humidification. The other is the most important and that is the air flow proving switch. It is critically important that the humidifier be disabled if there is no air flow (ie: the supply fan is off). Otherwise, the duct or air handler can fill with water as the vapor condenses—it has nowhere else to go. In the worst case, the water will run down the duct and leak out the seams. If ductwork is run over critical electrical equipment, the results could be catastrophic. . The ultrasonic humidifiers are especially prone to overheating in the event of a scale build up, necessitating the use of a high temperature thermostat.

Other Design Considerations

Correct system sizing is important, particularly on make-up air and units with return air. Compare 100% air OA conditions on a clear, dry 55°F day with mixed air conditions at minimum OA on winter design day to determine maximum humidification requirements. Also consider the cooling effects of ultrasonic systems when determining the highest humidification requirement (humidification system size can be reduced on mixed air units). Also, adjust the discharge temperature on a ratio ramp with a rise in the humidifier output PID for units that are for pressurization, not cooling; the air can hold more moisture. With entrainment the increased air temperature is insignificant as concerns the data floor temperature.

Computer room air handling units are typically sensible coolers and are selected for little or no latent cooling. In this case a rule of thumb is to provide 25% of the units with humidifiers. This will work if a vapor barrier is installed, however, if the facility operators change the temperature and humidity set points (or lower the chilled water supply temperature), the CRAC unit coils may be doing more dehumidification than the design allowed for, and more humidifiers may be required to meet demand. The commissioning authority is the one who can solicit input from the operators as to how they intend to operate the facility, and assure the designers accommodate their needs and intentions. All too often the rule of less is more seems to get lost after the design and commissioning professionals leave the site.

Proper installation per manufacturer's instructions, particularly with regards to velocity and straight runs if installed in ductwork, are essential to success. Ultrasonic systems require 300-600 fpm velocity, with 500 fpm providing the best misting. Steam electrode systems and infrared systems installed in CRAC units generally perform reliably. Ultrasonic systems in CRAC units have had some difficulties due to placement and are less common. Again, it is up to the CxA to find these issues and address them before they are built.

Another problem condition occurs when the critical space is provided with a smoke purge system. Activating the smoke purge system brings a lot of unconditioned air into the space. Presumably this only happens after a fire and there will be far greater concerns than space humidity, however, discussion of the consequences of activating or testing the system should take place with the owner and designers. If outside air conditions are cold and dry, then that is the air the smoke purge system introduces into the space. The cooling functions of the air conditioning system stop; the systems may go into reheat mode. If the humidity control system is absolute, the humidifiers may crank up to full output. When purge is completed, the humidifiers may not back down quickly enough, resulting in over-humidification. Over-humidification leads to the previously addressed electronic malfunctions. This is a not acceptable for a data center. If the outside air conditions are hot and humid, the cooling system will drive to full capacity, but sensible coolers will do little to remove moisture and again the space will be over-humidified (Unless the operators lowered the chilled water supply temperature setpoint after the CxA left).

One more item that is often missed is drains. Make sure that every room with a humidifier has a floor drain or slop sink. Verify that everything that needs to be drained can be drained.

Dehumidification

Dehumidification is a simpler issue, but is given far less attention. Dehumidification is simply subcooling the air to remove moisture and then reheating it as required to maintain space temperature. In a central system, provide a reheat coil and program a dehumidification sequence into the control logic. If the choice to control humidity is at the CRAC unit, then add a reheat coil, enable the dehumidification cycle and control for absolute humidity. For chilled water units, the chilled water temperature must be low enough to allow dehumidification. Reheat coils are necessary to prevent overcooling the floor, particularly at low load conditions. For make-up air units the summer discharge temperature should be 55°F and reheat is not required.

Vapor Barriers

Here is a place where the commissioning authority connects the HVAC design with the Architecture. The first thing to understand is that pressurization has no impact on humidity control. It is a common misunderstanding to believe that moisture will flow from a positively pressurized space to a lower pressure space, and that pressurization can take the place of a vapor barrier. Moisture flows from higher humidity spaces to lower humidity spaces. In short, humidity WILL migrate from a low air pressure to high. Pressurization is more functional for keeping unwanted particulates out of the space than any other considerations. The installation of a vapor barrier is necessary to mitigate moisture migration so that the humidity control system can function properly.

A vapor barrier is any material, usually a plastic or foil sheet, that resists passage of both air and moisture through walls, ceilings, and floors. They are usually made out of plastic, such as polyethylene. Whatever material is used, it must have a permeability rating of 1 or lower. Aluminum foil is virtually impervious to water, with a permeability of 0.0001. Polyethylene plastic sheet, 6 mil or greater in thickness has a permeability of 0.06. Additionally, some paint manufacturers are producing a vapor barrier primer suitable for new or previously painted gypsum wall board with a permeability claim of 0.5.

In the Data Center

Insulation and a vapor barrier should be applied to both interior partitions and exterior walls if there is a temperature or humidity difference between these areas. The commissioning authority should verify this is included in the architectural design, even if architecture is not included in the CxA scope of work. If you catch that there was no design intent to install a vapor barrier, you will prevent a serious omission and you will be a hero. A vapor barrier must be continuous to work properly. During construction inspections, verify seams are sealed. There should be no tears, and electrical receptacles and switches, and locations where walls meet ceilings and floors should all be sealed.

The A/E should analyze the conditions of adjacent spaces; he may find a need to apply a vapor barrier at the ceiling as well. In existing facilities it may be more cost effective to apply a vapor barrier paint than new insulation with a vapor barrier and new gypsum wall board. Careful analysis of the existing wall construction and outside conditions will determine where the dew point will occur and what the consequences may be. What is suitable for a 12” concrete wall in a moderate climate may result in wet fiberglass in other construction types and climates. Another recent alternative, particularly useful for interior walls, is foil-backed gypsum wall board. Again, pay attention to sealing joints. Taping a 12” wide polyethylene sheet at each joint has proven successful.

Doors are always a source of leakage. The best solution is weather-stripping. Typically, a data center does not have windows. If there are windows, and they are to be blocked off, certain precautions must be taken. Airflow must be allowed to circulate around the interior side of the window; otherwise the glass is subject to thermal stress cracking and the interstitial space between the glazing and block-off barrier will develop condensation. Drilling holes in the covering board at the top and bottom of the window allows air to circulate and ameliorates the situation. These items may not strictly fall within the CxA scope of work, but again, a big save can make you a hero.

Functional Testing

Functional testing of humidity control systems must include safeties and alarms. Improper setting of an air flow cutout can allow vapor to condense inside ductwork when the fan is off, but the humidifier is still running. If the duct is pitched towards the outlets, water can drip onto sensitive electronic equipment with predictably catastrophic results. Note that if the control system is programmed correctly, fan status enables all loops. The other flow safety essentially becomes a back up.

Before start-up, all setpoints and alarm values should be documented and verified with the owner and his O&M staff. For commissioning the humidifiers installed in CRAC units, first verify that humidification is enabled and that the control method; absolute or relative is selected; then check the sensitivity or dead band, typically 3 or 5%. The humidifier pan size (large or small for infrared or steam, respectively) and IR fill rate (for infrared humidifiers) should also be confirmed. Then test the high and low humidity alarms by alternately setting the alarm values above and below the current setpoint (by more than the dead band). To test the humidifier operation, change the humidification setpoint 10% above the current return air humidity. Infrared lamps will light and steam will quickly be produced. Verify all lamps light and take an amp reading for comparison to catalog value. Steam cans take longer to boil, so take an amp reading when full boil is reached. Remember that steam cans should be run for 24 hours before testing; otherwise they may not boil well; the same minerals that can cause the steam canister to fail are also helpful in making it work.

For testing the dehumidification cycle on CRAC units, first make sure dehumidification is enabled and the stages are correct. Change the humidity and temperature setpoints to engage the dehumidification cycle and verify one compressor is running (or chilled water valve is open) and that the appropriate stages of heating are energized. This has to be done assuring the chilled water is at design temperature, or the reheats may not be able to overcome the cooling affect, and the result will be a sub cooled floor that can reach dew point.

Testing of electrode steam canister humidifiers installed within ductwork or central station air handling units should follow the manufacturer's instructions and any sequences particular to your project. Using a packaged steam canister system as an example, first verify that the drain valve is open and the make-up valve is closed when the AHU is OFF. When the AHU is ON and the humidifier is commanded ON, the drain valve closes and the make-up valve opens. When the AHU is ON and the humidifier is commanded OFF, the drain valve opens and the make-up valve closes. Force demand to 100% and the tank fills. While filling, trip the air proving switch and verify the fill stops. Tripping the limit stat will have the same effect. After allowing the tank to fill to its full height (mark the level on the canister with a Sharpie), verify operation of the manual drain switch. Simulate a high humidity condition at the humidistat and verify the demand goes to zero. Verify the demand meter climbs as the humidistat dries out.

Testing of ultrasonic humidifiers is similar; test the units run when called and don't run if the AHU is off. They should also drain down when not in use. Test the high humidity limit cut out. And remember that testing must include the RO water treatment system. There are alarms and cutouts for high conductivity that require testing. There are also flush and backwash cycles to test.

Testing of spray pad systems is also similar with the addition of a recirculating pump. The pump should be ON when the humidifier is ON and OFF when the humidifier is OFF. The sump should fill as the canister filled in the description above. Test the sump level controls including the timed drain cycle.

Integrated System testing must include recording and observation of humidity in the critical space. For the data center example, Integrated System testing typically involves providing resistive load banks to simulate a full design heat load. The performance of the humidification system at full load should be monitored. During various power failure and recovery tests the space temperature will rapidly rise above design conditions and then fall back to design conditions as the mechanical plant recovers. This is where the control of absolute humidity versus relative humidity comes into play. Relative humidity will be all over the place depending on the temperature in any given area, especially in areas where high density loads are being applied. If control is based on absolute humidity, the relative humidity will drop as the temperature rises. Relative humidity may drop to the point where IT personnel must exercise extreme caution during contact with sensitive equipment and they should be made aware of this possibility. However, as the mechanical plant recovers, the relative humidity recovers rapidly and there is no over humidification. If the control is relative, then the humidifiers will increase output as the space temperature rises. The effect is positive for IT personnel, if the relative humidity is maintained, however, as the mechanical plant and space temperatures recover, the relative humidity rises rapidly, perhaps faster than the humidification system can accommodate. With high humidity outside air conditions, this could make it very difficult to dry out the space. Remember, CRAC units are sensible coolers and do very little dehumidification. If reheat coils and the dehumidification cycle are not provided, there may be enough water in the air to cause problems. I have experienced an over-humidified room where the CRAC units were overwhelmed and flooded the underfloor area. Test what you can, within the limits of outside air conditions at the time of testing and return for seasonal testing if warranted.

Another problem condition occurs when the space is provided with a smoke purge system as mentioned earlier. Incorporate testing of the smoke purge system under design load conditions at the outside air conditions available at the time of testing. Trend humidity as well as temperature. Return for seasonal testing if warranted, although testing the smoke purge system may not be permitted in a live data center.

The Solution

Proper control of data center humidity will improve reliability, availability and up-time. Ignore humidity and the facility remains at risk. It’s that simple. As the CxA make your case for humidification, verify the design, installation and operation. Your work can make the difference in system performance for the facility and in job retention for the operators.