Humidity Control in Data Centers

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I. Executive Summary

Humidity control has been applied to data centers since the early days of data center construction. For a long time, the industry developed standards based on the belief that humidity control follows a special need of the IT equipment located inside these facilities, and as a result of this perceived need, the data center humidity was controlled to a very narrow range.

Industry-wide experience and research on this issue has shown that IT equipment can actually tolerate a much wider humidity range than previously believed. Following these developments, several organizations have written guidelines that expand the temperature and humidity ranges of IT equipment. Additionally, some data center owner/operators have developed their own aggressive guidelines, which they use for their data center applications. Some of the more aggressive applications include data centers with minimal or no humidification control.

One example of the changing industry practice is the "Thermal Guidelines for Data Processing Environments," written by the American Society of Heating, Refrigerating, and Air Conditioning Engineers' (ASHRAE) Technical Committee 9.9. Since its inception in 2004, the guidelines have significantly widened the recommended range, from an initially restrictive one of 40% relative humidity (RH) to 55% RH in 2004 to today's much wider recommended range of from 15.8 °F DP to 60% RH (while also being restricted to a dew point (DP) of no more than 59 °F DP).

The industry now recognizes that by allowing a wider range of RH, and given proper controls, a great deal of energy and water can be saved while maintaining acceptable IT performance.

II. Introduction

Why Data Centers Have Been Humidity Controlled

1. *Paper (fan-fold printouts, statements, punch cards) and magnetic media*

Initially, humidity was tightly controlled in data centers, but NOT for the benefit of the computers. Rather, it was controlled to prevent misfeeds of the paper products used by high-speed printers and card readers, which were known to malfunction with very slight changes in relative humidity (such as +/- 5% RH). To maintain production in environments that used these paper products, close humidity control was a must.

Similarly, magnetic media used for long-term data storage, such as tape or disk, were also sensitive to changes in room temperature and relative humidity.

Over time, the industry began to address these very narrow operating environmental conditions by segregating these operations into rooms or containment devices dedicated exclusively to these functions. Printer rooms and storage silos became more commonplace, though these have been largely phased out in today's data center.

2. *Electrostatic Discharge and Corrosion*

Removing printers and storage devices from the data center opened a new avenue of discussion. With the need for the narrow environmental conditions eliminated, a newer, wider envelope of recommended temperature and humidity became the norm. Temperature issues aside, the following humidity-related questions arose:

1. What is the recommended low-end humidity for IT equipment, and is the IT equipment at risk of damage from electrostatic discharge (ESD), a known yet not well understood factor, when the space becomes too dry?
2. What is the recommended high-end humidity for IT equipment, and is the IT equipment at risk of corrosion and hygroscopic dust failures when moisture in the air combines with gaseous and/or particulate contamination?

How Data Centers Are Humidified

1. *Types of Humidification*

Multiple types of humidifiers were used to put moisture into the room air. These were typically steam boilers, infrared heaters, or electronic steam generators. Though these devices may be good at producing steam, they are energy intensive. The heat added to the water to produce the steam that enters the data center amounts to an additional cooling load to the room, which in turn requires additional air conditioning capacity to remove that heat.

2. *Simultaneous Dehumidification and Humidification*

As computer room air conditioning units (CRACs) were controlled to relatively low supply air temperatures, it was not uncommon for a CRAC unit to dehumidify the room air while at the same time a different CRAC unit could be in humidification mode.

Such a humidity-control strategy is like controlling a car's speed by balancing pressure on the brake and gas pedals at the same time—an obviously inefficient method of controlling humidity levels.

Current Humidification Issues

1. *Better Understanding of "Thermal Envelope"*

Thermal envelope, as used in the data center context, refers to ranges of temperature and humidity. There is a relatively tight range that is considered to be the "recommended range."

The industry also accepts a wider range of conditions, the "allowable range," which refers to an acceptable amount of humidity level drift, on a temporary basis, through which IT equipment will continue to function. For the sake of this discussion, it is better to keep the "recommended range" as the "design" condition (i.e., the amount of capacity required by the building mechanical system to maintain temperature and humidity control within specified environmental conditions). See Section III, ASHRAE Guidelines, for more discussion on the use of these ranges.

Temperature is well understood. We intrinsically understand what it means (that we may be comfortable at 75 °F and uncomfortable at 40 °F) and how it is measured. We encounter thermometers and/or temperature sensors every day.

Humidity is more complex to understand, because there are various ways to measure it. One way is to measure relative humidity (RH), which represents the amount of moisture the air holds relative to the amount of moisture the air could hold at that same temperature.

Hot air can hold more water than cold air. For example, air at 80 °F and 50% RH has a moisture content almost twice that of 60 °F air at the same 50% relative humidity. This describes one of the more obvious problems in measuring RH in any data center: The temperature across the data center can vary widely, so there is no clear indication of where the RH should be measured. We understand that high humidify would be uncomfortable (or "muggy") and low humidity may be comfortable but would lead to dry skin, but few people are able to conceptualize the difference between 80 °F/30% RH and 80 °F/50% RH.

Dew point (DP) is another way of measuring humidity. Physically, it relates to the temperature to which the air needs to be cooled for the moisture to condense out. It also relates to the *absolute humidity* of the air, which is defined as the amount of moisture per pound of air. This is a harder value to measure, and though it can be measured directly with some fairly expensive equipment, it is usually more cost effective to measure RH and temperature with a combination sensor at a fixed point, and convert it to dew point.

Understanding dew point is even more complex than RH. Most people are not able to conceptualize what a particular dew point feels like. For example, most people, hearing a weather forecast of 80 °F and 80% RH, would think it is going to be a muggy day. The same conditions can be expressed as 80 °F and 73 °F DP, yet most people are not able to process these two values as "muggy." This difficulty in relating to a dew point is a problem because dew point is ultimately the better way to characterize moisture content of air. Controlling the humidification or dehumidification process based on dew point in a data center is ultimately the most reliable method of achieving stable and efficient control.

The properly designed data center should have two basic properties associated with its mechanical system. First, the cooling coil surface temperature should be higher than the room dew point. This ensures that no moisture is removed from the data center via the cooling system. Second, no moisture should be added to the room. In most occupied spaces, people are the primary source of moisture. However, data centers normally have very few people in them, so the amount of moisture added to the space by people is negligible.

With these two conditions holding true, the data center's dew point is almost uniform throughout the room, regardless of where measurements are taken. A temperature/humidity sensor combination in the hot aisle will measure a different temperature and RH compared to another sensor combo in the cold aisle, but the dew points calculated for both sets should be the same (within a margin of error).

The only factor that can then affect the data center dew point is the introduction of outside air, even if that constitutes a small quantity. (With minimum outside air, the data center dew point will eventually approach the dew point of the air being introduced into the room, assuming the cooling coils run dry and no internal humidification is added to the space, as noted above.) Hence, in summer, the outside air should be dehumidified to a target zone of dew point; likewise, in winter, the outside air should be humidified to that same target zone of dew point.

Unfortunately, the thermal envelope is not easily described by a neat rectangle bound by high and low temperature and high and low dew point. This is because corrosion and ESD do not clearly follow dew point and temperature limits; they do not necessarily follow RH limits, either. The intent of defining the thermal envelope is to set an industry standard to minimize the impact associated with environmental conditions. Just as important, it also gives designers a target for the appropriate sizing of air conditioning and humidification equipment that serve the data centers.

2. *Newer Applications of Adiabatic Humidifiers*

New technologies have been developed to provide humidification without a significant outlay of energy. In some cases, especially for wetted media and spray/misting systems, these are not new technologies per se, but rather new applications of technologies that have been around for many years.

An important distinction with this family of humidifiers is that the humidification process occurs adiabatically—meaning that the air mixing with the water causes the water to evaporate. By using very small particles of water, which effectively increases the effective surface area of the water in the air stream, the water evaporates directly into the air in contact with the water. The heat that causes this evaporation comes from the air itself, which causes the air temperature to drop. The theoretical maximum amount of cooling occurs when the water saturates the air to 100% RH, and the air is cooled to its wet bulb temperature. (Effectively, this is the definition of wet bulb temperature.) Because of this cooling process, the term *adiabatic humidifier* is used interchangeably with the term *direct evaporative cooler.*

Though there are many types of adiabatic humidifiers available, the three main technologies that have been used in data centers are as follows:

a. Wetted media

A wetted media humidifier uses water that is percolated through a specially formulated media that allows air to pass through it while also dispersing water along a very large surface area using capillary action (like a sponge). This type of adiabatic humidification is passive in that no energy is consumed to evaporate the water. However, the media does have some resistance to airflow (as would air filters), and a small circulating pump is used to percolate the water across the media. The associated increase in fan energy plus the additional pump energy are not significant factors in the data center energy consumption.

b. Ultrasonic

Ultrasonic humidifiers use high frequency sound to break up the water into fine particles, which become entrained in the air flow. These particles are so small that they quickly evaporate into the air stream. The energy associated with the ultrasonic humidifiers is small compared to the more traditional boiler or steam type of systems.

One distinct advantage of ultrasonic humidifiers over the wetted humidifiers is that ultrasonic can be modulated to deliver the exact amount of moisture required while also responding to loads quickly.

One distinct disadvantage is that they require deionized water. *Deionized water* (DI) is ultra pure, demineralized water. Deionized water should be used for ultrasonic humidifiers for two reasons. First, it prevents the possibility of microscopic impurities (dissolved minerals) that are typically present in potable water from being dissipated throughout the space; in the data center environment, of particular concern would be the settlement of these impurities on IT equipment circuitry, which could eventually lead to equipment failure. Second, DI water leaves no deposits or scale in the humidification equipment, thereby extending the life of the equipment.

c. Spray or misting systems

Spray systems pump water at high pressure through small nozzles. These nozzles introduce atomized particles of water into an air stream, and as with ultrasonic humidifiers, the particles quickly evaporate into the air stream.

Spray systems can be cost effective when large quantities of moisture are required in data centers, but they do require specially designed piping systems, pumps, and deionized water. However, in today's current data center market, the need for large quantities of moisture can be value engineered out of most projects, as may become more clear below.

3. *Questionable Whether Humidification is Even Needed*

Two distinct IT equipment thermal envelopes have been developed over the last couple of decades. The Telcordia/NEBS Generic Requirements GR-3028-CORE (2001) targeted the recommended operational conditions for electronic equipment, and those requirements were applied mostly to telecommunications central offices. GR-3028 had no lower humidity requirement, mainly because the industry considered it a non-issue.

Later, in 2004, the ASHRAE Technical Committee 9.9 developed a different guideline intended for data center operation ("Thermal Guidelines for Data Processing Environments"), and it does have a recommended lower humidity limit.

Today, both guidelines have, for the most part, conformed fairly closely in terms of the high and low temperature limits, as well as the high humidity limit. However, these two similar standards did not agree on how to treat the low humidity condition, and that raised the question of why the ASHRAE Guidelines would provide a low humidity limit at all. To put the ensuing history in the proper perspective, some discussion of the ASHRAE Guidelines is appropriate.

III. ASHRAE Guidelines

ASHRAE Thermal Guidelines for Data Processing Environments

The first edition of the "Guidelines" (or "Thermal Envelope," as the document is often referenced) was released in 2004. The Guidelines are best described in terms of the "psychrometric chart," which is a graphical representation of the thermodynamic properties of air. The chart may intimidate some readers, but it is actually quite straightforward; more important, all heating, cooling, humidification, and dehumidification processes for air at a specified elevation can easily be represented on this chart. Given any two properties of air—e.g., dry bulb temperature, wet bulb temperature, relative humidity, absolute humidity (dew point temperature, moisture content), etc.—the other properties can be determined and can be readily calculated or obtained from the chart.

The Guidelines refer ONLY to the condition of the air *entering* the IT equipment. Any measurement that could be made in another location in the data center, such as inside the IT equipment, at the discharge of the IT equipment, in the hot aisle, in the return air plenum, in the supply air plenum, etc., is irrelevant with respect to IT equipment functioning and reliability.

Further, the "Thermal Envelope" makes a distinction between a "recommended range" and an "allowable range."

The *recommended range* is the range of air temperature and humidity within which the IT equipment will operate as designed, when the air is measured at the point where it enters the IT equipment. It is a statement of reliability.

The *allowable range* is a statement of functionality. The IT equipment manufacturers have tested their equipment at expanded ranges of temperature and humidity, and they state that their equipment will work at these given ranges, albeit not necessarily at the same level of reliability. Occasional excursions from the recommended range into the allowable range are not anything that most users should be concerned about. A few such excursions would have an insignificant effect on equipment reliability and life. On the other hand, long-term operation in the allowable range could affect IT equipment life. As such, today's best practices assume that the data center cooling systems are sized, selected, and designed to deliver an environment conforming to the recommended range.

The initial definition of the recommended range from the 2004 edition is summarized in Table 1, below. Note that there are different classes of data center IT equipment, classified as A1 through A4. The A1 equipment is known to continue to function at up to 90 °F; A4 equipment is known to function up to 113 °F. Yet, all classes have the same recommended range.

	2004 Edition	2008 Edition
Low-End Temperature	68 °F	64.4 °F
High-End Temperature	77 °F	80.6 °F
Low-End Moisture	40% RH	41.9 °F DP
High-End Moisture	55% RH	59 °F DP AND 60% RH

Table 1: Comparison of 2004 and 2008 Versions of Recommended Envelopes

ASHRAE Thermal Guidelines – Updated

Though the ASHRAE Guidelines have been in place since 2004, the recommended range has widened considerably over the years. The 2008 edition included a lowering of the lower recommended humidity level to a dew point of 41.9 °F DP. More important, it was the first time that the lower limit was set at a dew point rather than at a relative humidity (see Table 1).

In that edition, the upper limit of the recommended range was bound to a dew point of 59 °F, with the extra restriction that the humidity range was also bound to a maximum RH of 60%. The recommended range was virtually unchanged in the 2011 edition (see Figure 1). For the sake of simplicity, Figure 1 only shows Class A1 Allowable. Figure 2 shows all: A1 through A4.

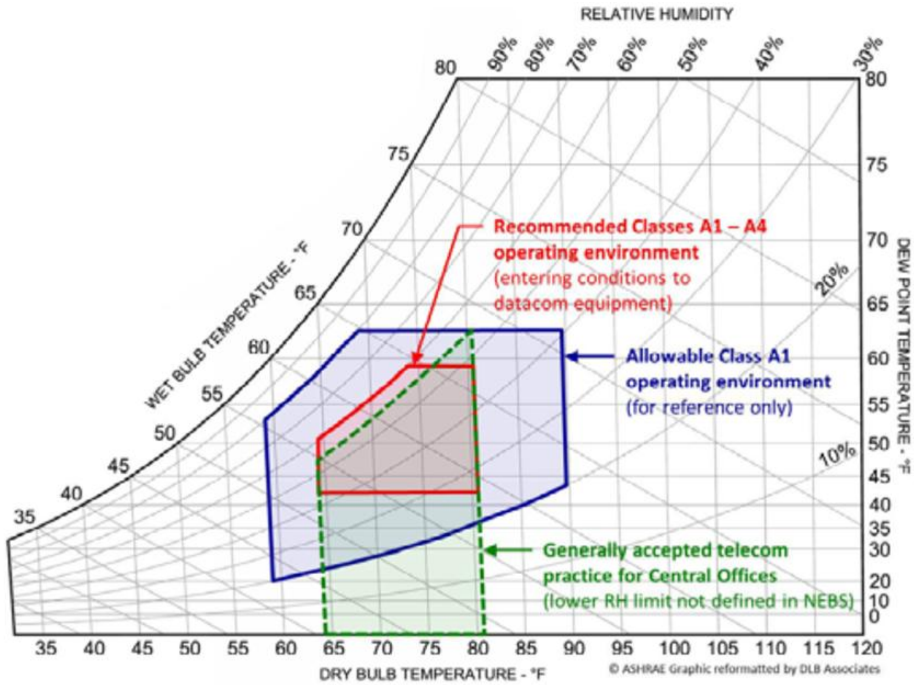

Figure 1: ASHRAE Recommended and Allowable Class A1 Operating Conditions (2008 and 2011)

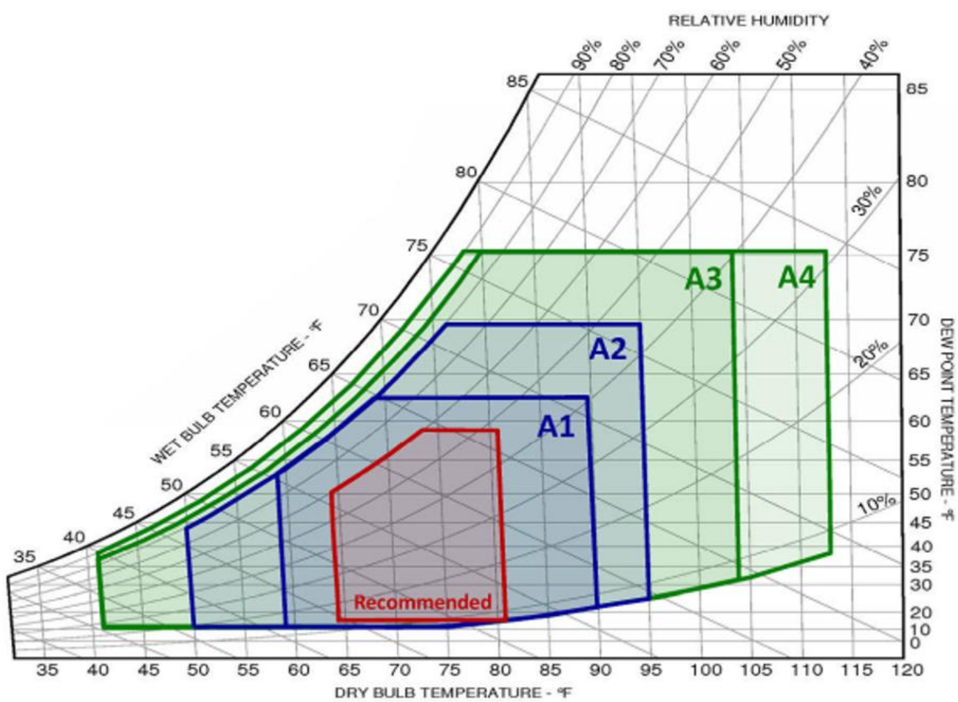

Figure 2: ASHRAE Recommended and Allowable Class A1-A4 Operating Conditions (2015)

It is important to understand the implication of this spread of minimum and maximum dew point. Many practitioners often miss that this range represents a fairly wide dead band of moisture level. *Dead band* in this context means that no humidification or dehumidification is required as long as the room humidity fits anywhere inside of that range.

Many designers often made the mistake of over-provisioning the capacity to humidify. Providing more capacity than needed increases the humidification system's cost, and may unnecessarily increase the amount of water consumed by the facility. Likewise, there is no reason to dehumidify a data center to a dew point value lower than the high end of the humidity range. Provisioning capacity for both processes that could allow a crossover would make inefficient operation and unstable control more likely.

The 2015 edition of the Thermal Guidelines lowered the lower limit of the recommended humidity range, and in doing so, came closer to what Telcordia/NEBS had set as the telecom guideline more than 20 years earlier (see Figure 2). Interestingly, the new lower humidity limit of 15.8 °F DP (which corresponds approximately to the 8% RH noted earlier) is not 0% RH, as it is for the Telcordia/NEBS document. However, in practice they are close to equivalent, since it is a rare occasion in which humidity of a space drops to such a low value.

This newer lower limit of the recommended range is a value that was reached by consensus by the IT equipment manufacturers. In coming to this agreement on this value, it is a representation that the IT equipment will not be damaged by continuous operation at this lower humidity level. As noted previously with the definition of the recommended range, it is a statement of reliability. It is also supported by research funded by ASHRAE that shows no significant increase in ESD or equipment failure at these lower humidity values.

Why Humidify at All?

This trend of lowering the lower humidity limit of the recommended range pushes the thermal envelope to a condition that could be considered desert-like. But why would there be a lower limit at all? The telecommunications industry, with its Telcordia/NEBS generic requirements, has not had a humidity lower limit in a long time. Should ASHRAE change theirs so they do not have a lower limit, too? Actually, this point should be moot because the lower end of the ASHRAE recommended range is so dry that most data centers could not get to that level of dryness, given the environment in which those data centers are built.

If a data center were to take in large quantities of outside air during the coldest months (when the air is at its driest), and if no moisture were added to that outside air, then it would be possible to achieve those extreme dry conditions. However, this approach misses the bigger point—one should not have to take in large quantities of outside air when it is so cold out. The colder it gets outside, the less outside air would need to be mixed with the data center return air to achieve free cooling. This is the essence of the airside economizer, which is discussed in more detail later.

From the standpoint of controlling humidity in a data center, there is a simpler approach: provide only the minimum outside air quantity needed to satisfy ventilation and pressurization control requirements, and add just enough moisture to that outside air to raise the incoming air to the desired dew point. This approach minimizes the amount of moisture that needs to be added to the room, but it does remove the possibility of achieving free cooling with outside air.

What it comes down to is that the owner must choose between two options that are mutually exclusive: (1) free cooling using outside air with a substantial moisture load, or (2) minimal moisture load with no free cooling—at least not from the use of outside air.

Waterside economizers are usually used when minimum outside air is provided. In principal, a waterside economizer cannot be as efficient as an airside economizer due to the extra pumps and cooling tower fans required, but it minimizes the issue of adding moisture to the data center, and it can be a very energy efficient solution in its own right.

The conditions discussed above apply when one very important design concept—the use of the highest supply air temperature possible—is implemented. To use a high supply air temperature, it is necessary to apply other best practices to improve air management (refer to ASHRAE's "Thermal Guidelines for Data Processing Environments," 4th edition, and "2015 HVAC Application Handbook" for these best practices).

High supply air temperature is an important feature because it supports the use of a high cooling coil surface temperature. How high should that supply air temperature go? That depends very much on how effectively the data center's airflow management strategy is implemented. The better the air flow management, the closer that supply air temperature can get to the high temperature limit of the recommended range.

Understanding this concept is critical when considering the multiple control strategies discussed in the sections below.

IV. Control Strategies

There are two reasons to provide humidification to any data center: (1) to provide at least the minimum moisture level desired in a data center (for whichever limit is selected by the end user), and (2) to provide free cooling through the use of direct evaporative cooling. Both reasons are discussed in more detail, below:

To Maintain a Minimum Moisture Level in a Data Center

1. This reason is very end-user dependent. Although both ASHRAE and NEBS are now in relatively close agreement that a minimum humidity level is not an issue of concern, a higher minimum humidity level may be imposed on the facility by certain best practices, as perceived by internal or external clients.

2. The designer, owner, and IT procurement teams should have detailed discussions before proceeding with a design to understand what lower humidity levels are desired. The selected lower limit should address what industry guidelines recommend, and then balance that with a level of ESD mitigation best practices, if any.

3. Once a minimum humidity level is selected, the designer can calculate the amount of moisture that needs to be added to reach the target humidity level.

4. The moisture can be added to the data center directly by the various types of humidifiers described earlier. However, risk of condensation in the center could put the operations at risk. The better approach is to add the humidifier to a dedicated outside air system (DOAS). With this approach, a single system, usually an order of magnitude or two smaller than the main data center air handling units, can control not only the humidification processes for the data center but also the dehumidification. (The humidification and heating process is shown in Figure 3A; the dehumidification process through mechanical cooling is shown in Figure 4C.) With the single point of control, the chances of simultaneously humidifying and dehumidifying are significantly reduced.

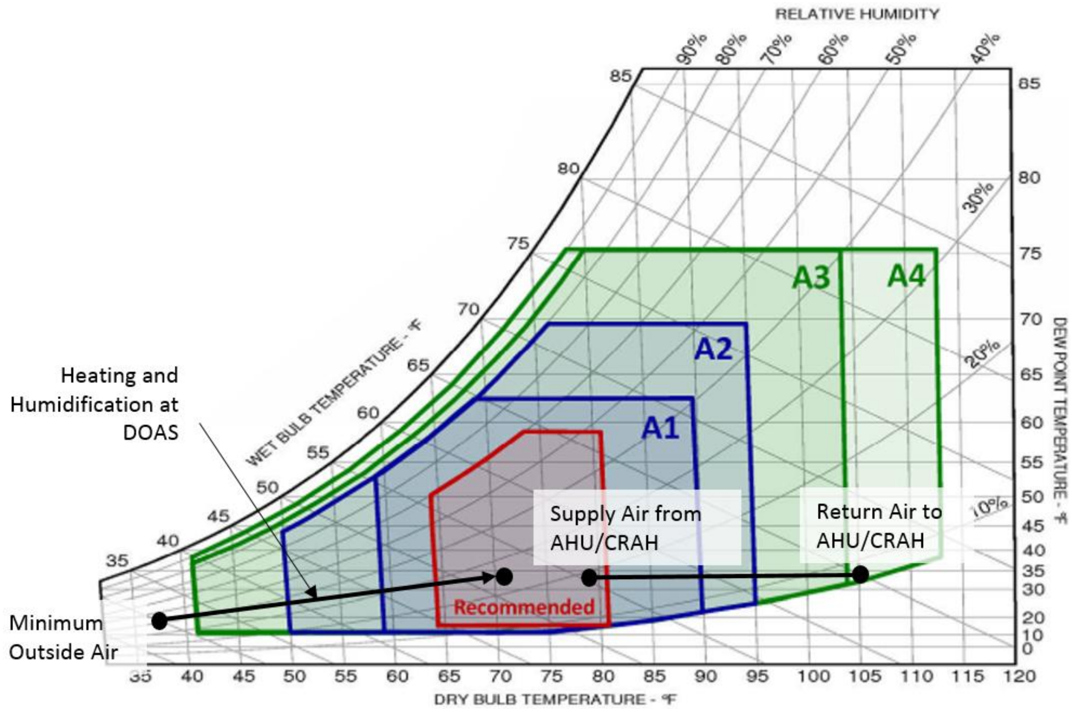

Figure 3A: No Economizer, Minimum Outside Air - Cold Outdoors

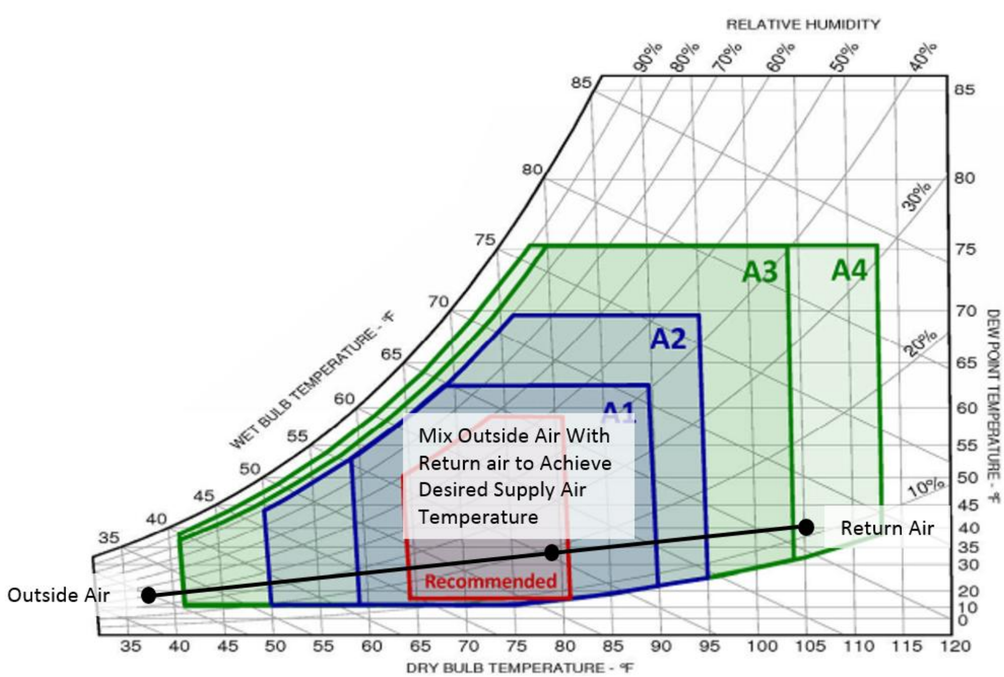

Figure 3B: Airside Economizer Process, Cold Outdoors

To Provide Free Cooling

1. Owners sometimes forget that a humidification system need not necessarily be provided just to maintain a minimum moisture level in a data center; rather, on a larger scale, it can be provided to deliver free cooling. As described previously, adiabatic humidification cools the air when moisture is added to the air. This means that as outdoor conditions become warmer, there may be a benefit in using 100% outside air, humidifying it, and introducing it to the data center to cool it without mechanical (compressor-based) cooling. (This is the definition of airside economizer and/or direct evaporative cooling.) When moisture is added for this purpose, the upper end of the humidity range should become the target so that evaporative cooling can be utilized before there is any need to apply mechanical cooling. (See Figure 4A.)

2. Compared to providing the minimum ventilation air with the minimum amount of moisture, a significant amount of water may need to be used for this evaporative cooling process. The payoff is that it avoids mechanical cooling, and thus can dramatically reduce data center energy consumption. If evaporative cooling is not able to provide 100% of the cooling, a second phase of cooling, provided by the mechanical plant, can provide the trim to bring the supply air into the recommended range (see Figure 4B).

3. Evaporative cooling can provide much of (or all of) the cooling needs in many climates. Though this may use more water than would be used just for straight humidification with minimum outside air, the benefits of NOT using mechanical cooling energy can be huge.

   Some users do not use direct evaporative cooling, with the justification that it uses too much water. This logic is flawed. Consider two scenarios:

   a. Scenario 1: Avoid direct evaporative cooling (due to the water use), and use a water-cooled chiller plant due to the relatively good system efficiency.

      This logic does not work because the water-cooled chiller plant has to use cooling towers to reject the heat to the outdoors. In doing so, they will use ~25% MORE water than would be needed to simply cool the space with direct evaporative cooling. (The extra 25% is the heat of compression from the refrigeration cycle, which has to be rejected too.)

      To put this into simple terms, consider a 1 megawatt (MW) data center. The heat that needs to be rejected is 1 MW. Using direct evaporative cooling in an airside economizer, one can evaporate 1 MW worth of water directly into the incoming air stream. Water, when it evaporates at typical atmospheric conditions, removes 970 Btu per pound. The 1 MW heat load will consume approximately 3,500 pounds of water per hour (421 gallons per hour). Keep in mind that depending on how cool it is outside, it is possible that significantly less water, or possibly no water, may need to be evaporated to remove that heat. However, the cooling tower must always evaporate 1 MW worth of water PLUS whatever heat is associated with running the refrigeration cycle, i.e. the chillers and pumps. This value is usually in the range of 0.25 MW of additional heat. In other words, when the chiller plant is in free cooling mode, i.e., waterside economizer, it must evaporate approximately 3,500 pounds of water per hour. When it is running the chiller, the amount of water to be evaporated is approximately 4,400 pounds of water per hour. Note that the water consumption numbers given here do not include blowdown, which typically adds 10%–20%.

b. Scenario 2: Avoid direct evaporative cooling and use air-cooled chillers or direct expansion (DX) cooling to avoid the water consumption. This logic would appear to make sense, but it does not hold up.

   It is true that no water is consumed on site, so that site may be relatively water efficient. But there is an embedded amount of water consumption in every unit of energy consumed. That water consumption may be in the form of river water consumed to cool a power plant, or evaporation from a reservoir used for hydropower. This amount of water can be substantial and it does vary by city, by state, and by utility provider. The cost of the water is embedded in the price the user pays for the delivered kWh of energy.

   That same 1 MW data center that would reject 1.25 MW worth of water by the use of a water cooled chiller plant may actually consume significantly more energy, and therefore more water, if an air-cooled chiller plant or DX coolers would be used. The air-cooled plant or CRAC makes disaster resilience easier, since a source of cooling water does not need to be secured in the event the normal water supply fails.

   "There is no such thing as a free lunch." When considering regional water and energy usage, the use of water cannot be avoided. The best that can be done is to understand the control strategies for humidity and cooling so that the wasteful use of water and energy are minimized. To achieve this, the control strategy should always be to control temperature and humidity to the nearest limit of the recommended range. For example, if the upper end of the recommended range is 59 °F DP, dehumidify to 59 °F DP (less a degree or two for good measure). If the lower end of the recommended range is 16 °F DP, humidify to 16 °F DP (plus a degree or two). Allow a wide dead-band range of

16 °F DP to 59 °F DP, meaning that neither energy nor water is consumed for humidity control while the room dew point is within that dead band.

Use Dew Point Control

As noted above, dew point is uniform throughout the data center when there is no addition or removal of moisture from the space. This is the case regardless of where the temperature and humidity sensors are placed, provided they both sense the same air stream. Since the thermal envelope's humidity range is specified in terms of dew point, it makes sense to measure AND control to room dew point. Dew point sensors are expensive and difficult to calibrate. Most dew point measurements are actually taken using a combination of temperature and RH sensors, which are inexpensive, and the controller paired with the sensor calculates the dew point from the temperature and the measured relative humidity. These pairs are not very accurate, so to get a good reading of room dew point, it is important to follow a few guidelines:

1. *Measure temperature and RH using sensors that are grouped together. (They must be physically in the same air stream.)*
2. *Convert temperature and RH to dew point through the appropriate algorithms.*
3. *Install at least three sensor pairs within a data center (preferably more). It is important that at least three sensor pairs are used so that when a reading drifts outside of an acceptable range, it is easy to tell which sensor is out of range.*
4. *Verify that all sensor pairs report more or less the same dew point (given a reasonable margin of error.)*
5. *Use the average dew point as read from all sensor pairs known to be within calibration. Do not control to a single sensor pair. Doing so could expose the control loops to perturbations in the readings or airflow, and this will cause instability in the control response. Using an average value as the measured quantity makes for a more stable control point. Additionally, using a single calculated control point will assure that all units are coordinated in their response.*

Whether a system uses a DOAS (which provides the minimum ventilation air required by code) or an airside economizer (which can modulate up to a full 100% outside air), different approaches must be taken for the control sequences. The following are applicable for DOAS systems only:

6. *Select all the data center computer room air handling (CRAH) or computer room air conditioning (CRAC) units for as high a supply air temperature as possible, up to the high end of the recommended range. (CRAH units are chilled water-based systems,*

CRAC units are DX-cooled systems.) Doing so guaranties that the main units that provide the cooling carry no humidification or dehumidification load.

7. *All room humidity controls are relinquished to the DOAS. As such, the DOAS is the only unit that has the capabilities to humidify or dehumidify. When high supply air temperatures are used for the main data center cooling, the CRAH or CRAC unit cooling coils operate at a temperature above the room dew point. No water can condense on the cooling coil, and no dehumidification can occur. Therefore, if the DOAS unit is to be able to dehumidify, its cooling coil may need to operate at a lower temperature to supply air at a lower dew point. For that reason, DX cooling coils are often used for the DOAS system.*

8. *It does not take much humidification or dehumidification to make a change in the data center dew point. In fact, using a small DOAS system to control room moisture is more controllable because the response to any change made at the DOAS unit produces slow changes. This assures that the system works in a more stable manner and is not as prone to overshoot its control point.*

9. *Using the measured room dew point, stage the cooling coil at the DOAS unit to dehumidify when the measured dew point exceeds the room dehumidification set point. It is recommended to define a throttling range, a range of measured values through which the response varies from 0% to 100%. Usually, the high limit of dew point set point can reside in the middle of that throttling range. For example, if the dehumidification set point is 59 °F DP, coordinate the throttling range across a 4° range of dew point. At 61°F DP, the dehumidification response should be at 100%. At 57 °F DP, the dehumidification response should be at 0%.*

10. *Using the measured room dew point, stage the humidification equipment in the DOAS to humidify when the measured dew point drops below the target humidification set point. This lower humidification set point is a little trickier to define, given the information provided in the previous discussion of industry trends. The owner, along with the IT group that will own the data center equipment, should agree to a reasonable lower limit of dew point or RH. When that is selected, say 35 °F DP, the same process should be followed for staging humidification equipment. The throttling range can be 4 °F DP, meaning that the humidification equipment may be at 100% when the room dew point is at 33 °F DP, and at 0% when the room dew point is at 37 °F.*

The following are applicable for airside economizer systems only:

11. *When outdoor conditions are cold, blend in just enough outside air to mix with return air until the resulting mixed air is at the set point dry-bulb temperature. If that mixed condition is below the lowest dew point limit, humidify until the dew point of the*

mixed air rises to just above that lower limit. Figure 3B shows this process overlaid on the expanded recommended range. If a higher room dew point were desired, moisture would be added to the mixed air condition until that dew point set point is achieved.

12. *As conditions warm up, start using more outside air to maintain the supply air temperature set point. When the system gets to 100% outside air, the mechanical cooling plant should be OFF. Humidify, as needed, to achieve the temperature desired, preferably as close as possible to the high end of the recommended range (see Figure 4A).*

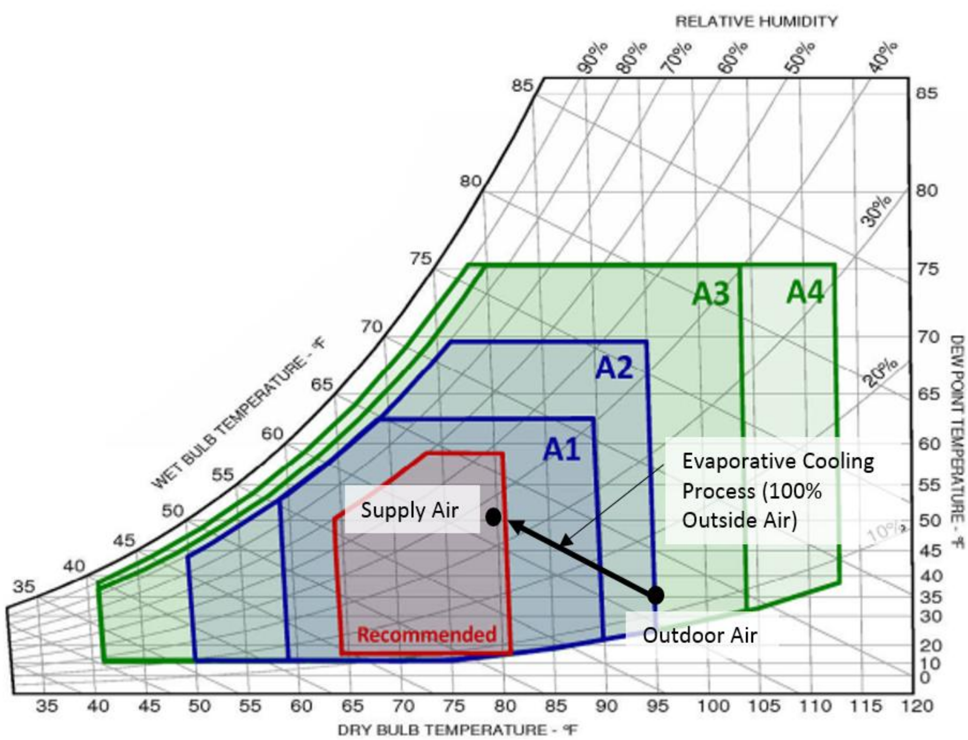

Figure 4A: Airside Economizer Processes, Warm and Dry Outdoors

13. *As outdoor temperatures continue to rise, monitor the resulting room dew point. If the room dew point is below the maximum value of the recommended range, start adding moisture through the evaporative cooling system until the room dew point reaches that maximum value. As long as the resulting supply air (dry-bulb) temperature is below the maximum value of the recommended range, provide no mechanical cooling (Figure 4A still applies).*

14. *Turn on mechanical (refrigeration) cooling when the supply air temperature exceeds the maximum value (see Figure 4B).*

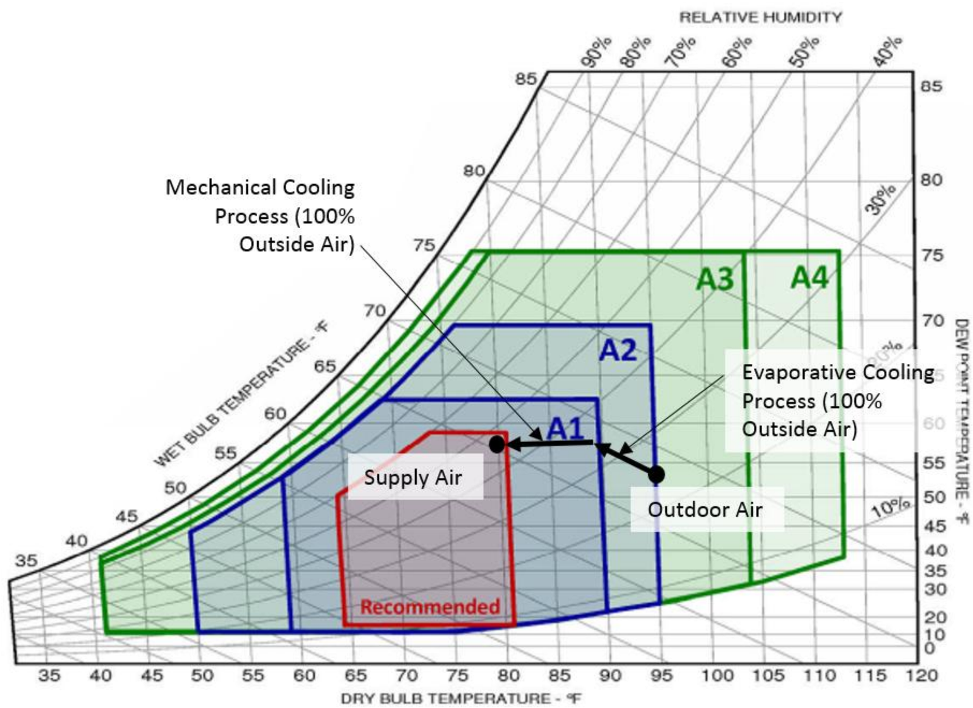

Figure 4B: Airside Economizer Processes, Warm and Less Dry Outdoors (Evaporative + Mechanical Cooling = Partial Economizer)

15. *Turn OFF the evaporative cooling if the outdoor dew point is greater than 59 °F DP (the maximum value of the recommended range), and return to minimum outside air (see Figure 4C). Any moisture added to the room will increase the room conditions above the higher limit of the recommended range. The main system should be 100% mechanically cooled at that condition. The minimum outside air, as provided through the DOAS, is dehumidified to the desired room dew point. This air flow, small as it may be, determines the room dew point.*

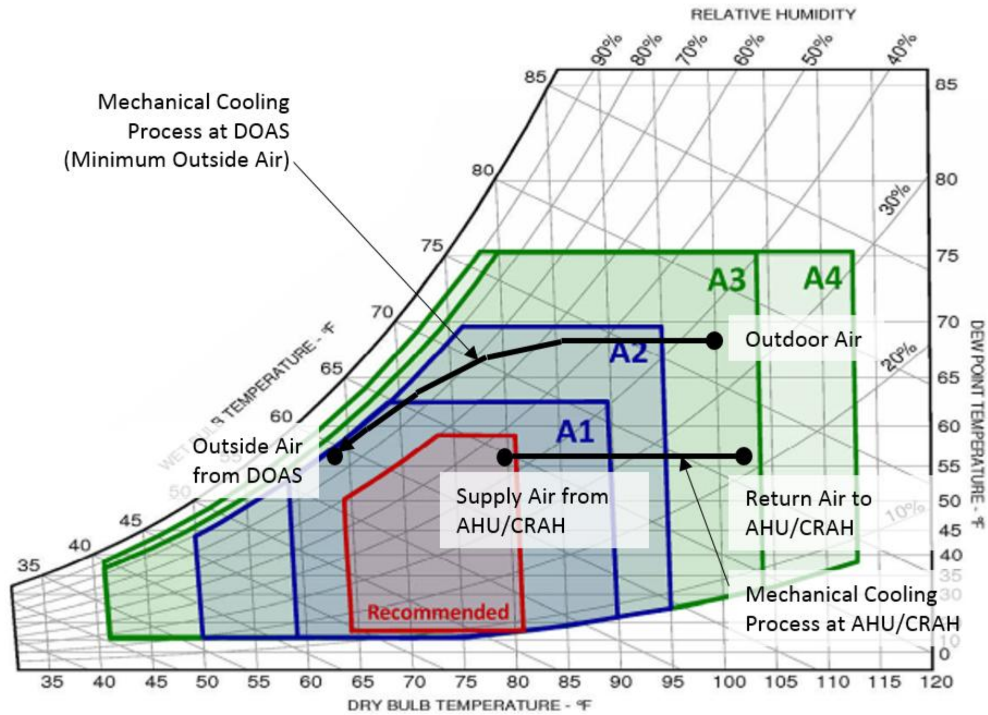

Figure 4C: No Economizer Available, Warm and Humid Outdoors (>59° F Dew Point)

V. Benefits of a wider humidity range

Allowing the wide range of room dew point has multiple benefits. The wide dead band allows the humidification and dehumidification systems to remain mostly OFF. The wider the dead band, the more hours of the year that water and energy can be conserved.

One of the more wasteful features of legacy systems is that the humidification and dehumidification equipment are oversized. When equipment is oversized, the room response is quick—the targeted room condition may be overshot, meaning that the system must switch from humidification to dehumidification in a short time, sometimes even performing both operations simultaneously. Other times, the equipment may simply switch on and off frequently, short cycling the equipment and providing poor control. Having a narrow dead band, or worse, not having a dead band at all, assures that the unnecessary use of energy and water continues. When a data center is cooled by CRAC or CRAH systems, and each unit is independently controlled with humidification and dehumidification enabled, often some units are humidifying while others are dehumidifying. This situation is a variant of simultaneous heating and cooling, wasting both energy and water and decreasing the power and cooling systems' ability to meet IT loads.

Widening the range of humidity control, and widening the dead band of no control assures a more stable room environment. ASHRAE's Guidelines have a restriction of the rate of change of temperature and humidity, but most users do not pay much attention to it. Most would think that the range of temperature and humidity are more important; yet, a high rate of change can lead to IT equipment failures, even when the temperature or humidity limits are not exceeded. The steps to slow the response, as described above, assure that the risk of damage from frequent changes in the room environment is mitigated.

An important aspect that is often overlooked is that reducing the size of the humidification equipment reduces the size of the electrical infrastructure that supports it. Adiabatic humidifiers (or evaporative coolers), when used in lieu of the older style boilers or heating elements to produce steam, lead to large reductions in the energy used by the data center. Just as important, they also reduce the kilowatt demand required of the system. This means more of the electrical capacity to the site can be dedicated to IT equipment, and less generator capacity may be required to support the unnecessary additional loads associated with the older-style humidifiers. Likewise, active dehumidification for CRACs and CRAHs typically involves running the cooling at full capacity to remove moisture, then reheating the over-cooled air so that the humidity and temperature set points can both be reached. The re-heaters are an unnecessary load, creating extra load on the cooling system and increasing the electrical load. Typically the inadvertent dehumidification provided by the cooling coil (since it operates below 50 degrees) in normal cooling operation is more than adequate to bring the humidity below the high end of the recommended range.

VI. Summary

There is not anything inherently wrong with using water in a data center, and that is true whether it is used for humidification or for cooling. The important concern is that water, a consumable and sometimes scarce resource, should not be used to over-humidify beyond what would be considered best practice; likewise, there is no value in using more water than is needed to overcool data centers to a lower temperature than what the industry recommends as being appropriate.

Using water for passive or evaporative cooling may actually save water and energy. But it is important to understand the bigger picture of how energy and water are interrelated. Understanding the concept of embedded water usage when it applies to the purchase of electricity can provide a better framework for truly saving both resources.

The "Thermal Envelope," as shown in the ASHRAE book "Thermal Guidelines for Data Processing Environments" is a work in progress that improves over time as more research is completed. It demonstrates to what extent the industry can push the envelope in terms of cooling and/or controlling humidity for IT equipment. The important issue is that the thermal envelope is used as a tool to guide the industry to cool just enough, but no more; to humidify or dehumidify just enough, and no more. In today's world, large savings can be achieved when the data center is designed to operate near the limits of the recommended range of the thermal envelope.

Relying on excursions into the allowable range of the thermal envelope can reduce the size of the mechanical equipment and the amount of energy and water consumed at the site. In many cases, such as in dry or cool climates, this may be completely acceptable; in other cases, a risk analysis may be required to fully document the impact on the IT equipment.

VII. References

ASHRAE Thermal Guidelines for Data Processing Environments, 1st Edition, 2004

ASHRAE Thermal Guidelines for Data Processing Environments, 2nd Edition, 2008

ASHRAE Thermal Guidelines for Data Processing Environments, 3rd Edition, 2011

ASHRAE Thermal Guidelines for Data Processing Environments, 4th Edition, 2015

ASHRAE HVAC Applications Handbook, Chapter 19, 2015

Telcordia/NEBS Guidelines GR-3028-CORE, 2001

VIII. Abbreviations

AHU: Air Handling Unit (chilled water based)

ASHRAE: American Society of Heating, Refrigerating, and Air-Conditioning Engineers

CRAC: Computer Room Air Conditioning unit (DX based)

CRAH: Computer Room Air Handling unit (chilled water based)

DI: Deionized (Water)

DOAS: Dedicated Outside Air System

DP: Dew Point

DX: Direct Expansion cooling, in which the refrigerant coil is in the room's supply air flow

ESD: Electrostatic Discharge

IT: Information Technology