Humidity Controls For Data Centers

Are They Necessary?

By Mark Hydeman, P.E., Fellow ASHRAE; and **David E. Swenson**

ASHRAE's Special Publication *Thermal Guidelines for Data Processing Environments*[1] recommends humidity control in data centers in all climates. The same is true for ANSI/TIA-942-1 2005, *Telecommunications Infrastructure Standard for Data Centers*[2] developed by the Telecommunication Industry Association (TIA). In contrast, telecommunications facilities covered by Telcordia's Network Equipment Building Systems (NEBS) requirements have no lower humidity limit.[1] This article examines the background of these guidelines, the issues they try to address, and the practical impacts of controlling humidity in data centers.

The background discussed in this article was discovered in the development of TC 9.9's Research Work Statement 1499, *The Effect of Humidity on the Reliability of ICT Equipment in Data Centers*. The research proposal investigates the relationship between humidity and the severity of electrostatic discharge (ESD) events in datacom environments over a range of thermal conditions and grounding of the floor and personnel.

The Current State of Practice

Table 1 shows the current published recommendations for humidity control in ASHRAE, NEBS and TIA. As shown in this table, only ASHRAE and TIA have lower humidity limits. NEBS has no lower humidity limit but has recommended personnel grounding practices to prevent electrostatic discharge events. All three documents have upper humidity limits. In

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response to concerns about energy use in data centers, in 2008 an ad-hoc working group revised the previously published thermal and humidity guidelines.[3] The revised guidelines were published as a white paper[3] for immediate release and subsequently updated in the existing Datacom Series Guides, which are ASHRAE Special Publications.[1] The changes will be reflected in the next version of *ASHRAE Handbook—HVAC Applications*.

The authors of this article were involved with ASHRAE Technical Committee (TC) 9.9's (Mission Critical Facilities, Technology Spaces and Electronic Equipment) Research Work Statement 1499. We researched the background of the standards and guidelines in *Table 1*, and interviewed participants in their development. From these investigations, we learned that the lower humidity limits were provided primarily to reduce the potential of ESD events. The interviewees identified two areas of concern: personnel handling IT equipment; and communication cables being pulled across floors and subsequently plugged into IT equipment.[4]

In support of the high humidity limit, the white paper on the revised guidelines raised concerns about the growth of conductive anodic filament (CAF) on circuit boards and the potential for equipment failure from these filaments bridging the circuits.[3] However, published research on CAF growth establishes that it does not occur below 80% RH, and then only if specific environmental conditions are present.[5] The white paper also mentions the increased risk of corrosion from gaseous contaminants and the potential for increased wear on tape drives due to moisture-induced friction.[3] Although these issues are plausible, they do not appear to be widespread concerns in the published literature on data center design and operation. Within TC 9.9, the risk from gaseous contaminants has been an issue of much debate.

Source	Low	High
ASHRAE[1,3]	41.9°F (5.5°C) t_{dp}	60% RH & 59°F (15°C) t_{dp}
NEBS[1,3]	None	55% RH
TIA-942[2]	40% RH	55% RH

***Table 1:** Recommended humidity limits for data centers and telecom facilities from ASHRAE Telcordia and TIA.*

No formal review of equipment failure has been provided or published to support the humidity limits, and no research substantiating limits is referenced in either the TIA Guideline or ASHRAE's Datacom Series Guides. Manufacturers' published specifications for IT equipment generally have a much broader range of humidity. Manufacturers' published server and disk drive specifications typically range from 10% to 80% RH.[6]

The Electrostatic Discharge Association (ESDA) in its standard ANSI/ESD S20.20-2007[7] eliminated humidification as a primary control for prevention of ESD events in manufacturing and processing facilities. The threshold charges that can destroy electronic components on circuit boards during handling are so low that humidification alone cannot prevent the destructive ESD events. Similar to NEBS, ANSI/ESD S20.20 relies on personnel practices and a grounded workplace to prevent ESD events.

The Green Grid commissioned a white paper in 2008 from two past presidents of the ESD (one of whom works for an IT equipment manufacturer) to review the need for humidification of data centers for prevention of ESD events.[8] The white paper details how all IT equipment shipped to the European Union that bears the CE Mark must be tested for ESD immunity following the procedures in Standard IEC61000-4-2.[9]

In this procedure each piece of IT equipment is tested using a calibrated probe that generates up to 8,000 V in contact discharge and 15,000 V in air discharge. Under this standard, the enclosure and all connectors that are user accessible must be tested for ESD immunity. This white paper had two conclusions:

1. The charge levels from personnel under normal conditions of data center grounding are unlikely to exceed those already tested for in IEC61000-4-2 for the CE Mark, under any condition of relative humidity.

2. If personnel are handling circuit boards or components, the threshold levels for ESD damage are so low (<100 V) that humidification has no beneficial effect.

Controlling Humidity

Lower humidity limits are typically maintained using one or more humidifiers. The most common practice is to have these humidifiers distributed throughout the data center in the computer room air conditioning (CRAC) or computer room air-handling (CRAH) units. Another approach is to place the humidifiers in the unit or ductwork serving to ventilate the data center.

Humidity control is typically provided using one of four technologies:

- Steam humidifiers with steam that is generated either by gas or electric heaters;
- Infrared humidifiers that generate steam by electric heaters;
- Ultrasonic humidifiers that generate vapor by mechanically pulsing the water; and
- Direct evaporative humidifiers using a wetted media.

Upper humidity limits are typically controlled by the cooling coils in CRAC, CRAH or air-handling units (AHUs) that serve the data center. In many data centers, the upper limit is not directly controlled; it simply results from the inherent dehumidification that occurs with mechanical cooling. However, some CRACs and CRAHs include reheat coils (usually electric resistance) controlled by humidity sensors and controllers.

Humidification and dehumidification is typically controlled using relative humidity sensors and controllers located in CRACs and CRAHs. Ideally, humidity controls are configured to control absolute humidity (humidity ratio or dew point), rather than relative humidity, since relative humidity is temperature dependent and temperatures can vary significantly from one location to another in data centers (e.g., hot aisles versus cold aisles).

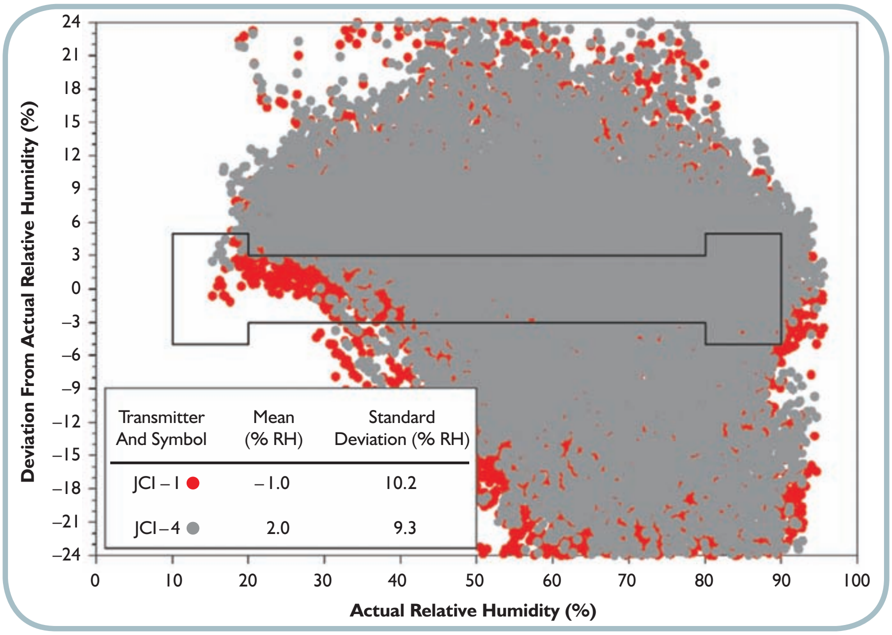

Figure 1: Results of NBCIP field tests for a humidity transmitter.[10]

Issues with Humidity Controls

HVAC System and Operating Costs

Humidity controls and systems cost money and use energy and water. In addition to the cost of the humidifier, there is the cost of the infrastructure including: makeup water piping; drainage piping; the electrical or steam infrastructure to run the humidifier; a deionization or reverse osmosis filtration system (if you have an ultrasonic humidifier); and the humidity system controls.

The energy implications vary with the humidifier technology. The least efficient humidification systems are infrared and

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	Reference Probe			CRAC Unit Panel			
	Dry Bulb °F (°C)	RH	Dew Point °F (°C)	Dry Bulb °F (°C)	RH	Dew Point °F (°C)	Mode
AC 005	84.0 (28.9)	27.5	47.0 (8.3)	76.0 (24.4)	32.0	44.1 (6.7)	Cooling
AC 006	81.8 (27.7)	28.5	46.1 (7.8)	55.0 (12.8)	51.0	37.2 (2.9)	Cooling & Dehumidification
AC 007	72.8 (22.7)	38.5	46.1 (7.9)	70.0 (21.1)	47.0	48.9 (9.4)	Cooling
AC 008	80.0 (26.7)	31.5	47.2 (8.4)	74.0 (23.3)	43.0	50.2 (10.1)	Cooling & Humidification
AC 010	77.5 (25.3)	32.8	46.1 (7.8)	68.0 (20.0)	45.0	45.9 (7.7)	Cooling
AC 011	78.9 (26.0)	31.4	46.1 (7.8)	70.0 (21.1)	43.0	46.6 (8.1)	Cooling & Humidification
Minimum	72.8 (22.7)	27.5	46.1 (7.8)	55.0 (12.8)	32.0	37.2 (2.9)	
Maximum	84.0 (28.9)	38.5	47.2 (8.4)	76.0 (24.4)	51.0	50.2 (10.1)	
Average	79.2 (26.2)	31.7	46.4 (8.0)	68.8 (20.5)	43.5	45.5 (7.5)	

Table 2: Field survey of CRAC units with reference temperature and humidity sensor.

steam, which not only use energy to evaporate the water but add heat to the data center that must be removed by the cooling units. The infrared technology is the most prevalent because it is provided with CRAC or CRAH units as a standard factory option. By contrast, ultrasonic humidifiers are adiabatic (they do not add heat to the data center). Ultrasonic humidifiers require treated water (typically using either deionization or reverse osmosis filtration systems) to remove the dissolved solids from the water. These minerals in the water, if uncontrolled, can turn into conductive dust that can be spread into the data center. Arguably, the most efficient of the humidification technologies is direct evaporative cooling. Unfortunately, this technology is rarely used in current practice.

Where humidification is provided by infrared or steam humidifiers in data centers with air-side economizers, the economizer should include a nonstandard low outdoor air dew-point switch to prevent cold dry air being introduced, which subsequently needs to be humidified. Without this low dew-point switch, the economizer can increase the facility energy use. With ultrasonic and direct evaporative humidifiers, this is not an energy issue as the water evaporation provides beneficial cooling. With all of the technologies, the economizer increases the amount of water used for humidification.

Dehumidification, if actively controlled, is only an issue if reheat coils are used to maintain warmer supply air temperatures. These were commonly used on older CRAC and CRAH units in low density data centers. Reheat coils add to the first cost of the units (both for the equipment and the increased electrical service) and increase energy use. They are almost never needed since the data center loads provide all the reheat necessary to maintain upper humidity limits.

Accuracy

The National Building Controls Information Program (NBCIP) performed laboratory and field tests on the most common commercially available humidity transmitters. In this study[10] they found that most of the transmitters could not meet the manufacturer's printed statements of accuracy. *Figure 1* is an example graph from this report. It shows two different transmitters from one manufacturer, comparing the deviation from the laboratory grade reference humidity transmitter in field tests over a wide range of humidity conditions. The box in the center of the graph is the manufacturer's published statement of accuracy for this transmitter. The deviations measured were in excess of 24% error over a significant portion of the test.

Similar results have been observed in the field. *Table 2* is a survey of six water-cooled CRAC units in a data center. The reference probe had just been recalibrated at the factory and the CRAC unit readings were taken from the front panel of each unit. For the reference probe and CRAC unit sensors, the temperature and relative humidity readings were converted to dew-point temperatures. As shown in *Table 2*, the reference sensor had ~1°F (0.55°C) variation in dew-point measurements, but the CRAC unit sensors (the ones being used for the controls) varied by as much as 8°F (4.4°C). Since this was an open space the vapor pressure (and dew-point temperature) should have been relatively constant across all of the units. As can be seen in this survey, two problems exist with the controls: the control sensors are inaccurate and unable to precisely control the humidity; and the units are fighting one another due to the inaccuracy of the control sensors and the use of relative humidity for control (the controllers in these older CRACs could not be configured for absolute humidity control). During this survey, CRAC unit 006 was actively in dehumidification mode while CRAC units 008 and 011 were actively humidifying the data center. Unfortunately, this behavior with distributed humidity controls is quite common.

Looking at *Table 2*, it is interesting to note that AC 006, the unit that was dehumidifying, ostensibly had the lowest dew-point temperature of all six CRAC units. This is because controls work on relative humidity not dew-point temperature. The 2008 update to the environmental guidelines[3] revised the previously published recommendations to use dew-point temperature, in part, to address this control issue. If humidity is to be controlled, it should be controlled using one or more high quality dew-point sensors. As can be seen from the measurements in *Table 2*, relative humidity varies across the data center but dew point is relatively constant.

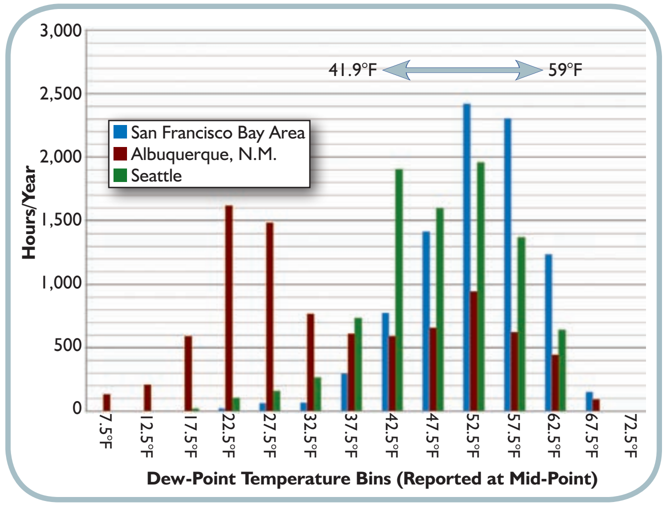

Figure 2: Bin data for dew-point temperature for case studies.

Reliability

In theory, the purpose of humidifying the data center is to improve the reliability of the IT equipment operations. In practice, humidifiers are often a source of problems that can reduce the reliability of data center operations. Issues include: the introduction of water into the data center (which increases exposure to water damage from leaks); inaccurate sensors, leading to over-humidification of the data center (a potential corrosion problem if you have gaseous contaminants or salts in the air); and fouling of smoke detectors (which can cause false fire alarms).

Do We Really Need Humidity Control?

A number of data centers currently operate without active humidity control. On the West Coast, the authors are aware of dozens of facilities including:

- A Fortune 500 bank (all facilities);
- The main data centers of a major health service provider;
- Several IT equipment manufacturers;
- Several software development firms;
- Several collocation facilities;
- A major chip manufacturer;
- Several major animation studios; and
- Several supercomputer facilities.

Recently, two major IT manufacturers published studies of IT equipment operating without any conditioning.

The first[11] was an experiment to run servers in a tent in Washington State from November 2007 to June 2008. Although a fence knocked into the tent during a storm, water dripped on the racks, and a leaf was sucked into a server, the authors of this study noted "zero failures, or 100% uptime."

The second experiment[12] was a side-by-side comparison of two data centers over a 10-month period in New Mexico. One was fully conditioned, and the other had an air-side economizer and filtration but no cooling. The authors of the study observed that, "servers in the economizer compartment were subjected to considerable variation in temperature and humidity, as well as poor air quality; however, there was no significant increase in server failures. If subsequent investigation confirms these promising results, we anticipate using this approach in future high-density data centers."

A third facility in the San Francisco Bay Area, which one of the authors of this article has been working with, has been operating for more than a year without active humidity controls. The facility experienced significant problems with the steam humidifier prior to shutting it off including: hot water backwash from the humidifier damaging the roof, water condensing in the ductwork and steam fouling the smoke detectors (ionization and photoelectric types). Turning the humidifier off increased the reliability of the data center. Since turning it off, no IT equipment failures in the facility have been attributed to low humidity.

Figure 2 shows the dew-point temperature bin for the climates from these three locations. The range from 41.9°F to 59°F (5.5°C to 15°C), indicated on this figure, is the recommended envelope in the revised ASHRAE guidelines. Although all three of these climates had few hours in excess of the upper humidity limit, they each had significant hours below the lower recommended humidity limit: 17% of the time in the California location; 70% of the time in Albuquerque, N.M.; and 40% of the time in Seattle. As noted previously, none experienced significant IT equipment failures from lack of humidity (and in two cases temperature) control.

In addition to these case studies, consider the thousands of telecom switching facilities covered by NEBS that have absolutely no humidity control in all climates of the country. And, hundreds of millions of computers worldwide are located in homes and offices without any humidity control (e.g., www.etforecasts.com/products/ES_cinusev2.htm). If humidification was really necessary to prevent IT equipment failures, and so many data centers are not humidity controlled, why aren't there published case studies of failures attributable to the lack of humidity control?

Conclusion

When the data and studies are reviewed, it is difficult to make a case for actively controlling humidity in data centers. The controls increase installed and operating costs; have been shown in the field to cause problems that reduce the reliability of data centers; and have no apparent benefits that are established through published research or comprehensive forensic analysis. However, there is evidence that ESD is a concern for data centers, particularly where components inside the servers are being handled. The question that remains is how to best address this risk from ESD. From our research, we conclude that the following practices are the most effective means to prevent ESD failures:

1. The IT equipment should be rated and tested for ESD conformance with IEC61000-4-2;
2. In facilities where electronic circuit boards and components are handled, personnel grounding and procedures should be used as the primary method of protection; and
3. With these measures in place, humidification appears not to be necessary.

Adding humidity to the data center might lower the potential severity of the ESD events, but as established in the development of ANSI/ESD S20.20, cannot fully protect against them. The research from TC 9.9's Research Work Statement 1499 should provide data to inform the industry on the role of humidification to mitigate ESD.

High humidity levels are seldom an issue in most data centers. The IT equipment temperatures are typically much warmer than the operating dew-point temperatures of the cooling coils. Furthermore, most IT equipment is rated for operation up to 80% RH. Although concerns have been raised about CAF and gaseous contaminants, little published evidence exists that these issues are a risk to most data centers.

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