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New Research on Humidity and its Impact on Electrostatic Discharge

Are Data Centers Drying Up?

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Valuable new data on the relationship between humidity and electrostatic discharge (ESD) in a data center environment has recently been published through ASHRAE Research Project RP-1499. The relationship between ESD and humidity has long been anecdotally known, but insufficiently quantified.

Everyone has had the experience of walking on a carpet and touching a metal surface soon afterwards – the result is an electrostatic shock.

The voltage of the shock ranges from a couple hundred volts to many thousand volts, and if the item being touched is sensitive electronics, there is a potential to damage that equipment. Likewise, these shocks tend to have much greater frequency (and magnitude) in the winter when the humidity is lower than in the summer when the humidity is higher.

Historical Trends in Data Center Humidification

IT equipment manufacturers have long known that electrostatic discharges occur at low relative humidity levels, and that these discharges can cause IT equipment failures. Legacy data centers were designed with a narrow relative humidity deadband: 45-55% RH.

When ASHRAE TC 9.9 first published *Thermal Guidelines for Data Processing Environments* in 2004, the recommended RH was a little more relaxed to the range of 40% to 55% RH, but introduced an Allowable Range that was set at a much broader 20% to 80%.

In the second edition of *Thermal Guidelines* (2008), the recommended humidity level was further relaxed to 5.5°C (42°F) dew point on the low side, and the lower of 60% RH and 15°C (59°F) dew point on the high side. *Figure 1* plots the 2004 and 2008 recommended envelopes on a psychrometric chart. The allowable range stayed the same between the first and second editions, at 20% to 80% RH and is plotted on a psychrometric chart in *Figure 2*.

In the latest (third) edition of the *Thermal Guidelines*, published in 2012, the recommended range has stayed the same, but two additional allowable ranges have been added: A3 and A4 (*Figure 3*). Both of these ranges allow for as little as 8% RH on the low side.

Justification for Additional Research

Humidification can have a significant impact on energy consumption that extends beyond the simple consumption of the humidification conditioning equipment itself. For instance, a high minimum humidity requirement in conjunction with an air-side economizer could result in blocking out a significant number of economizer hours and associated energy savings. Due to the significant impact of high minimum-humidity threshold requirements on energy consumption of data centers, ASHRAE TC 9.9 applied and received approval from ASHRAE for a research project to better understand the correlation between humidity levels and ESD.

The Research Project

While it may seem like a fairly straightforward research project, the actual implementation of a study to correlate ESD with humidity is complex. Part of the setup for the research involved obtaining a better understanding of exactly what mechanisms occur to create these discharges.

For instance, a person walking will definitely build up a charge (and the charging process was also studied in this report), but how will this be discharged? Will the person discharge by touching a piece of IT equipment with their hand, or will contact be made by first touching the equipment with something metallic, such as a flash drive? The magnitude and duration of these discharges will be different, and both instances were tested as part of the research.

The type of shoe worn by the occupant matters as does the type of flooring. At the least granular level, one can

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classify shoes as ESD dissipative or non-ESD dissipative, and the floor as ESD dissipative or non-ESD dissipative.

This study went into far more detail. For instance, 11 different shoe types were investigated and a total of 13 types of floors were also investigated (see *Table 1* for the full list).

Finally, a total of four relative humidity levels were examined: 60%, 35%, 15%, and (as an added requirement) 8%. While 8% RH may seem excessively low, as mentioned earlier, two new environmental classes of IT equipment (A3 and A4) were added as *Thermal Guidelines* environmental classes in the middle of this research project, and TC 9.9 was able to obtain ASHRAE approval for the scope of the research to be extended from 15% RH down to 8% RH.

ESD in Real Life vs. Research Simulation

In real life, ESD can cause:

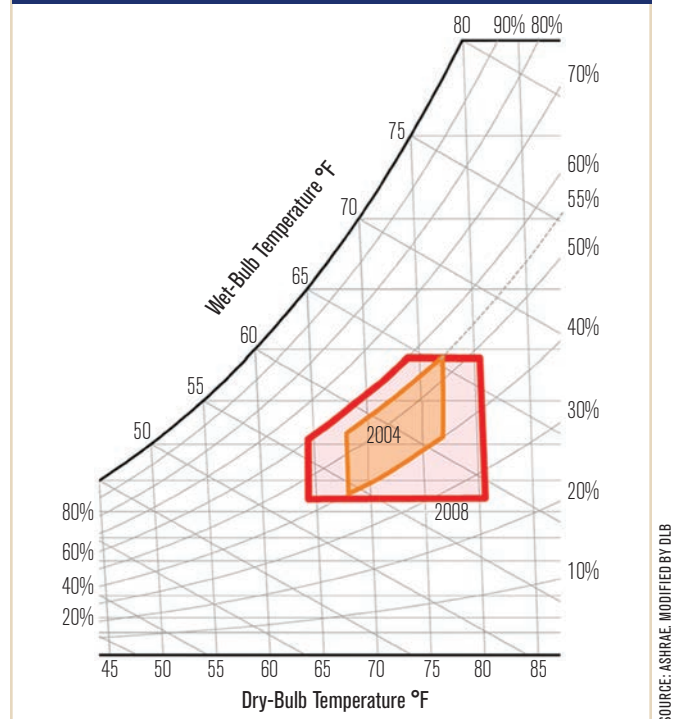
- Self-correcting errors (such as a lost package in LAN traffic);
- An upset that may need user intervention; or
- Actual physical damage to IT equipment.

For research purposes, measurements of these failure modes were not specifically documented, as the robustness of specific models of equipment varies so widely. Rather, voltages and durations were measured, and these were compared to the industry standard voltages (4kV and 8kV) defined in the International Electrotechnical Commission document IEC 61000-4-2.

Rather than absolute values, the report generally provides data in terms of relative probabilities of harmful events. This strategy is similar to the x-factor that is defined in *Thermal Guidelines*.

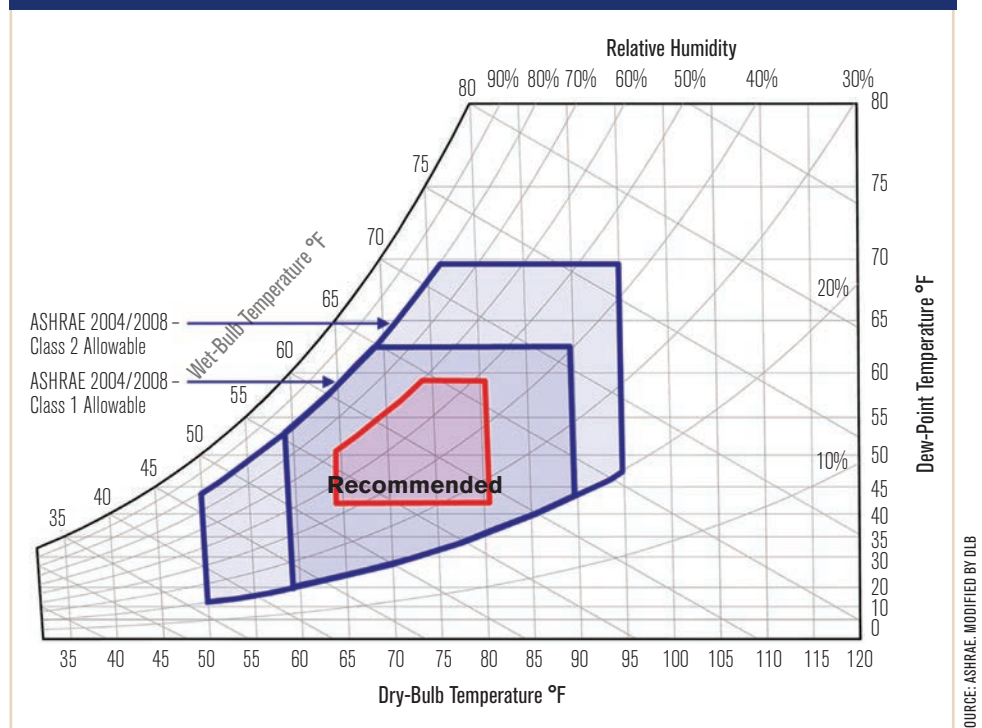
The value of the x-factor is a ratio, defined as the “Number of equipment failures under environmental condition A divided by Number of equipment failures

FIGURE 1 2004 and 2008 recommended ranges.



SOURCE: ASHRAE, MODIFIED BY DLB

FIGURE 2 2004 and 2008 allowable ranges.



SOURCE: ASHRAE, MODIFIED BY DLB

under environmental condition B.” If one has empirical data on the ESD failure rate at one relative humidity, the results of the study allow one to estimate the change in

ESD failure rate at another relative humidity level, all other factors being equal.

Generating the Charge

Before a potentially damaging discharge can occur, an electrostatic discharge first has to build up. A significant portion of the research was aimed at understanding these phenomena, since a significant discharge cannot be discharged if a charge has not built up in the first place. The testing procedures were generally in compliance with IEC 61000-4-2, as mentioned earlier.

For human charging experiments, another standard, ANSI/ESD STM97.2, defines a “well-defined pattern” (WDP) as shown in *Figure 4*, and a “random walking experiment” (Random). People, however, are not the only generators of electrostatic charge in data centers. Equipment carts are one additional source of charge, and cabling is another.

Results

The results of the study fall into several categories; this brief article cannot do justice to the results, but the following can be considered a summary.

For evaluating the combined impact of flooring and footwear in a data center, the six categories of data centers examined are shown in *Table 2*.

One takeaway from this data is that the probability of the 4000 Volt and 8000 Volt discharges vary by up to 18 orders of magnitude based on the type of floors and footwear. These construction and operations variables

can decrease ESD impact without any impact on energy consumption.

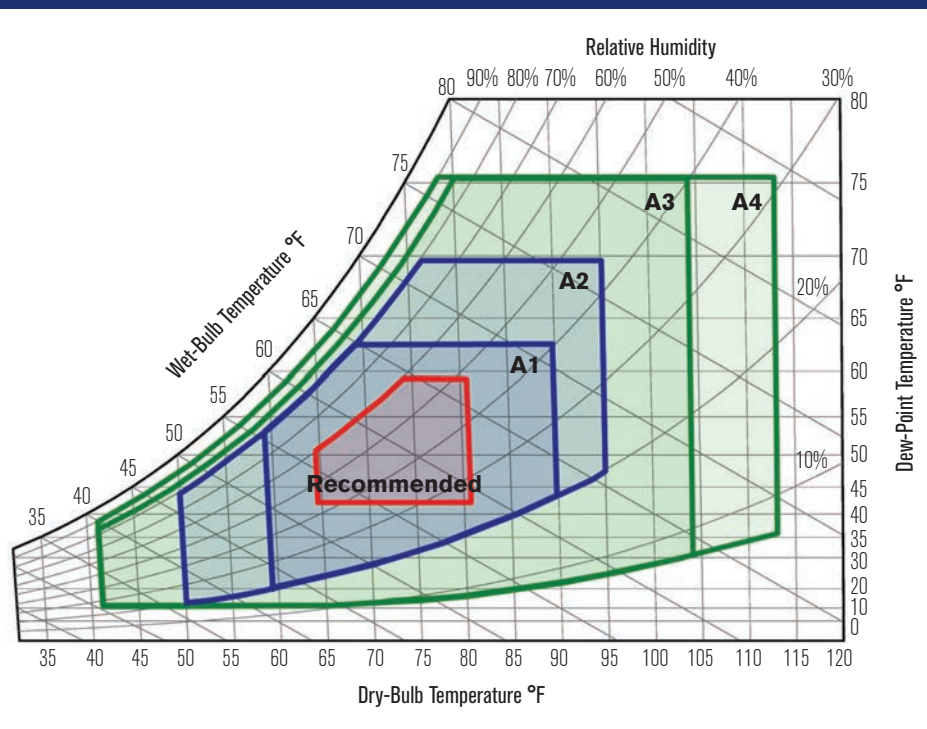
It should be noted that the experimental results listed in *Table 2* involved walking. Additional experiments, involving standing up from an office chair, and taking off a sweater, were able to generate higher voltages in humans.

Conclusions

The research provided several conclusions, including the following:

- Reducing the relative humidity in a space will increase the voltages of ESD.
- Reducing the absolute humidity (dew-point temperature) does not always lead to an increase in voltages, but the threshold at which a reversal may occur is low - in the range of -10°C to 0°C (14°F to 32°F).
- The chair and sweater events caused very high voltages.

FIGURE 3 2012 allowable ranges.



SOURCE: ASHRAE, MODIFIED BY DGB

TABLE 1 Floor and shoe test conditions. ©IBM

LOW RH EFFECTS ON DATA CENTER OPERATION	
TEST CONDITIONS	
FLOOR	SHOES
3M 4530 Asia	3M China Slip On
3M 6432 Cond	3M Full Sole
3M 8413	Running Shoe
3M Green Diss	DESCO 2 Meg Sole
3M Low Diss	DESCO Heel
3M Thin VPI	DESCO Full Sole 2 Meg
Epoxy 1A	Hush Puppy
Flexco Rubber	Red Wing
HPLF	Stata Rest
HPLN	Sperry
Korean Vinyl	Heel Strap
Standard Tile	
Wax	

- A factor called Relative Humidity Voltage (RHV) can be used to express the increase in the average voltages if the humidity is de-

creased. For a decrease in relative humidity from 45% to 8%, the RHV is approximately 3. For a decrease in relative humidity from 25% to 8%, the RHV is approximately 1.5.

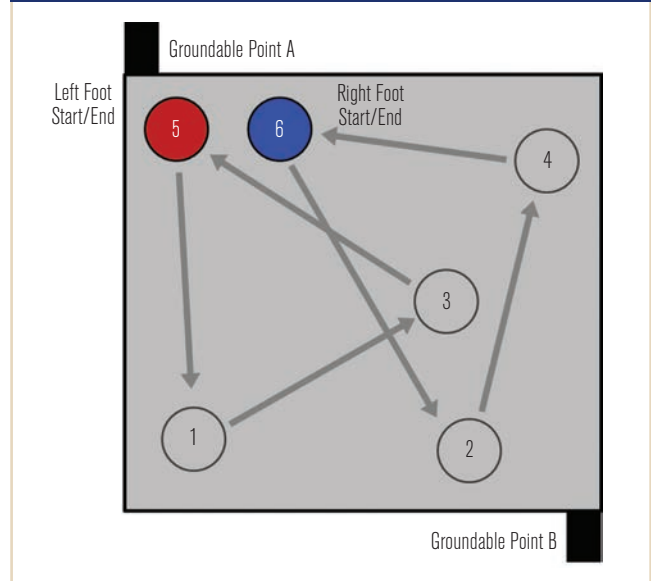
The RHV would need to be considered in combination with the relative scale of voltages commonly occurring in a given environment (based on the combinations of flooring, shoes, etc.) and the frequency that ESD events occur based on data center specific operations in order to determine the complete picture of ESD risks to electronic equipment failures.

Recommendations

The study provides general recommendations in a number of areas. These can probably best be categorized into the areas of relative humidity levels, flooring and footwear, grounding, chair and carts, grounding procedures, and cabling.

- For relative humidity levels, the results clearly show that the lower RH levels create higher discharge voltages and a higher frequency and potential for development

FIGURE 4 Well-defined pattern.



of higher voltages. In most cases, however, these voltages are less than the threshold voltages that IT equipment is

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TABLE 2 Summary data in probability for voltages greater than a threshold value (based on fitted lines).

TYPE OF DATA CENTER	500 VOLT DISCHARGE PROBABILITY		4,000 VOLT DISCHARGE PROBABILITY		8,000 VOLT DISCHARGE PROBABILITY	
	15% RH & 59°F	50% RH & 80°F	15% RH & 59°F	50% RH & 80°F	15% RH & 59°F	50% RH & 80°F
No Static Control	18%	0.2%	0.5%	$3.7 \times 10^{-6} \%$	0.1%	$3.2 \times 10^{-8} \%$
Dissipative Floors, Dissipative Footwear	16%	19%	0.016%	$1.0 \times 10^{-4} \%$	$5.5 \times 10^{-5} \%$	$2.2 \times 10^{-7} \%$
Dissipative Floors, Uncontrolled Footwear	34%	5.65%	0.9%	0.001%	0.09%	$2.3 \times 10^{-5} \%$
Conductive Floors, Dissipative Footwear	0.003%	$1.6 \times 10^{-7} \%$	$1.8 \times 10^{-7} \%$	$1.8 \times 10^{-11} \%$	$7.4 \times 10^{-9} \%$	$8.9 \times 10^{-13} \%$
Conductive Floors, Uncontrolled Footwear	8%	0.1%	0.004%	$4.7 \times 10^{-10} \%$	$4.1 \times 10^{-5} \%$	$7.5 \times 10^{-13} \%$
Conductive Rubber Floors, Uncontrolled Footwear	0.1%	$9.6 \times 10^{-13} \%$	$8.6 \times 10^{-7} \%$	$1.4 \times 10^{-20} \%$	$1.6 \times 10^{-8} \%$	$3.5 \times 10^{-23} \%$

designed to withstand, especially if ESD precautions are taken.

- Using ESD-mitigating flooring and footwear, the risk of ESD upset and damage can be reduced to an insignificant level, even if the humidity is allowed to drop to low values, such as 8%. Unfortunately, controlling the footwear in most data centers is very impractical.

- All office chairs and carts selected for use in data centers should have ESD-mitigating properties.

- Also grounding straps should be used when *before* making contact to any of the sensitive electronics.

- A standard set of ESD-mitigation procedures listed here will ensure a very low ESD incident rate at all humidity levels tested.

- For the new ASHRAE A3 and A4 environmental classes, the authors conclude that there is a greater chance for ESD events, but indicate that this can be mitigated with proper data center design and good ESD prevention with operating procedures. In general, the

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increased risk in migrating from 25% RH to 8% RH is about a 50% increase in the incidence of ESD risk.

Closing Comments

Lower relative humidity generally increases both the frequency and magnitude of ESD discharges. Whether these increases actually increase the risk damaging ESD events, however, is quite interdependent with other variables in the data center, such as floor conductance and operating procedures.

There are many industry “best practices” and risk mitigation methods that could be used to avoid damaging ESD on sensitive electronics. Oftentimes, these mitigation methods can be hard to implement and enforce, but especially in light of the data collected in this project, they are proven means to reducing the risks associated with ESD.

The new ESD research has helped to quantify the ESD risks associated with lower level humidity levels in the data center, and has concurrently shown other approaches to mitigating damage to IT equipment from ESD events. This research provides guidance for the operation of data centers in the new ASHRAE A3 and A4 environmental conditions. It also provides an excellent set of technical data that could form the basis for adjustments to ASHRAE’s recommended and allowable environmental ranges for IT equipment in the future.

For More Information

For those interested in the details of this study, the RP-1499 research project has spawned a wealth of Technical Papers, as well as a final report. An initial paper (DE-13-031) was published in 2013. The recent 2015 Winter Conference in Chicago

included three more papers, CH-15-005, CH-15-006, and CH-15-007. These papers can be obtained from the ASHRAE Bookstore.

References

1. IEC 6100-4-2 Electromagnetic Compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test. ■

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