IBM Systems

Effectively applying the expanded ASHRAE guidelines in your data center

Effects of temperature and humidity on resiliency, energy efficiency and IT reliability

Executive summary

Energy consumption by data centers continues to rise with each generation of IT equipment.[1] The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has created a set of environmental guidelines to help data center operators simplify the process of selecting IT equipment for their environment. This paper introduces the key environmental classes that apply to IBM Systems IT equipment.

The paper will highlight how data center operators can make the best use of ASHRAE operating classes and the effect each class has on total cost of ownership and IT equipment reliability. When properly applied, these guidelines can help reduce overall energy use and operational expense by improving energy efficiency and maximizing free-cooling from the outdoor environment. Understanding and correctly applying these principles can help data center operators add more capacity with less need for additional capital equipment or data center upgrades, reduce the initial capital cost for new data centers, and improve the data center's robustness and resiliency in the event of a cooling failure.

Defining the ASHRAE environmental classes

The key ASHRAE environmental classifications for product operation are shown in Figure 1. The recommended envelope (Rec) specifies a long-term operating environment that can result in greater IT equipment reliability. The 3rd Edition of the ASHRAE Thermal Guidelines[2] introduced new allowable envelopes that should be used only for short-term operation or in the case of a cooling malfunction. These allowable envelopes (A1, A2, A3) are defined envelopes where IT equipment manufacturers test their equipment to verify functionality. The three allowable envelope limits define how far the environment can stray from the recommended envelope and still expect the IT equipment to remain functional. However, due to the stresses that operating in the allowable envelopes can place on IT equipment, these modes should be used for short-term operation, not for continuous operation.

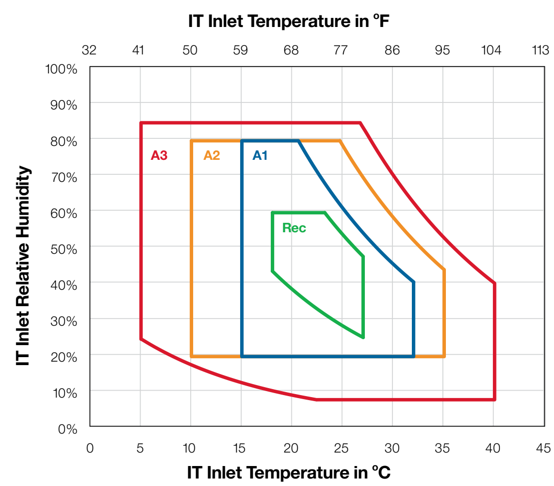

Figure 1. Recommended and allowable operating envelopes for ASHRAE Classes A1/A2/A3 during IT product operation.[3]

Potential trade-offs when operating outside the recommended range

There are numerous advantages to operating the data center at the upper boundary of the recommended envelope or, for short periods of time, within other allowable envelopes. But before discussing these, it is vital to understand the impact your choices can have on the overall data center and your total cost of ownership. Prolonged exposure to operating conditions outside of the recommended envelope, especially approaching the extremes of the allowable environment, can frequently result in decreased equipment reliability and longevity. Figure 2 shows the mechanisms that can negatively impact IT equipment and data center reliability when equipment is operated outside the recommended envelope.

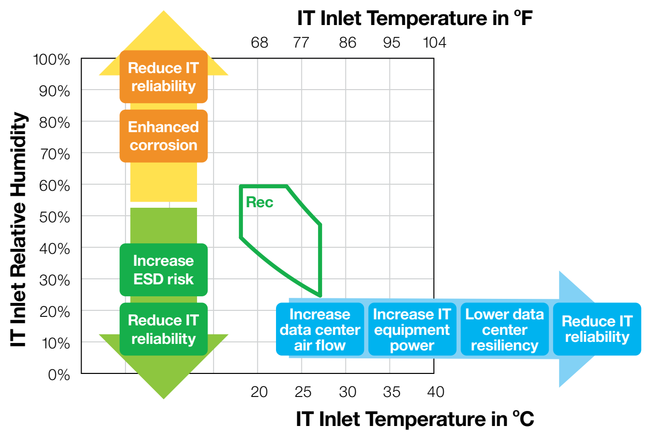

Figure 2. The impact to IT equipment and data centers by operating outside of the ASHRAE recommended envelope.

Risks of moving to a higher data center temperature

Many components within the IT equipment exhibit an Arrhenius-type failure rate, meaning that the failure of these components increases exponentially with temperature. ASHRAE characterized the expected failure rate of IT equipment with temperature using a so-called x-Factor.[4] The x-Factor defines a multiplier for the increase in failure rate expected when temperature is increased. Assuming that the base equipment failure rate at 20°C (68° F) was 10 per 1,000 servers, the ASHRAE x-Factor predicts that the new failure rate at a temperature of 30°C (86° F) is between 12 and 16 per 1,000 servers, and at 40°C (104° F) is between 15 and 18 per 1,000 servers. This means prolonged operation at these elevated temperatures can cause failure rates that are significantly higher than operating within the recommended envelope.

The second potential problem with higher data center temperatures is that air moving devices within the IT equipment will increase air flow to attempt to maintain operational IT device temperatures. This can result in greater energy consumption by air moving devices as well as a commensurate increase in air flow required to be delivered from the data center. With the current projected increase in power density of each new generation of IT equipment, the air flow required at high temperatures will eventually exceed the capabilities of traditional raised-floor data center cooling systems. Additionally, the IT electronics themselves consume more power as the data center temperature increases. Today's typical central processing units (CPUs) contain billions of transistors and are typically the highest power consuming components in a server. These transistors can experience undesirable leakage current at higher temperatures, resulting in an increase in the CPU's power consumption.

Perhaps most importantly, operating with higher data center temperatures means you are operating closer to the IT equipment's maximum allowable limits. Any extended operation at these levels can place the IT equipment at risk of performance throttling to maintain component temperature or complete shutdown to protect devices from permanent damage. In many data centers, cooling equipment is not connected to uninterruptible power. When cooling equipment fails, the data center temperature will rise until backup power can be brought online, which typically takes several minutes. In today's high density data center environments, the temperature entering the IT equipment can exceed the allowable envelope in minutes—or even seconds—depending on the type of cooling failure.

Figure 3 provides an example of the time it takes for the server inlet temperature to rise from the recommended range to an allowable range of A2 or A3 after the loss of a computer room air handler (CRAH) fan. Servers capable of operating in an ASHRAE A3 environment provide an additional thermal guard band during a cooling failure compared to those rated for an ASHRAE A1 or A2 environment. Data center operators should recognize this additional guard band to minimize the impact on their business during cooling failure events.

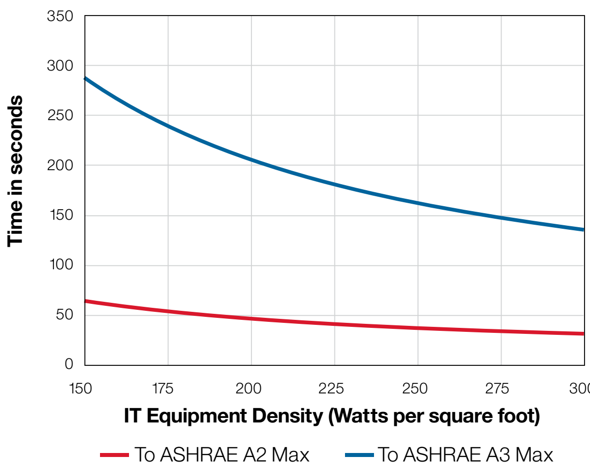

Figure 3. Length of time it takes for the IT equipment air inlet temperature to increase from the ASHRAE recommended envelope to the limit of the allowable envelopes after a CRAH failure.[5]

Potential problems of moving to a higher data center humidity

As shown in Figure 1, the allowable envelopes extend the relative humidity up to as high as 85 percent depending on operating temperature and IT equipment class. However, moving to a higher relative humidity within the data center is not conducive to high IT equipment reliability, especially in data centers that have conductive or corrosive airborne particulate contaminants, or corrosive gaseous contaminants. IT equipment reliability manifests itself in several ways when contamination is present in the data center. When particulate contamination contacts air with a high relative humidity, the particles can become wet and conductive. When these wet and conductive particles settle on circuit boards, they can create an electrical short circuit. Therefore, it is also recommended that, at a minimum, data center air handling units be filtered using a minimum-efficiency reporting value (MERV) 8-rated particulate filter and that make-up air be filtered using a MERV 13 - 15 final particulate filter.

Gaseous contamination can result in copper creep corrosion on circuit boards causing shorts as well as silver sulfide filaments growing on components causing open circuits. The rate of copper corrosion has been observed to increase with relative humidity. ASHRAE provides guidelines for the acceptable limit of gaseous contamination.

Impact of moving to a lower data center relative humidity

The ASHRAE environmental guidelines place lower limits on humidity within the data center to avoid the risk of electrostatic discharge (ESD) events. It is well known that lower humidity increases the charge voltage and leads to longer charge retention time, both of which can cause more damaging discharges. Recently, results of an ASHRAE-funded research program, led by the EMC Laboratory at the Missouri University of Science and Technology[6], showed that with appropriate ESD floors and ESD shoes in the data center, there is only minimal impact on IT equipment when extending the recommended relative humidity envelope from 20 percent to 8 percent. The ASHRAE Technical Committee 9.9, for Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment, has voted to approve extending both the current recommended and allowable envelopes for new IT equipment to allow for the lower relative humidity. These guidelines will be updated when the 4th Edition of the ASHRAE Thermal Guidelines publication is released.

Considerations when using the ASHRAE allowable envelopes

With a better understanding of the consequences of operating within the allowable envelopes, we now look at how your business should use the A1, A2 and A3 envelopes. Unfortunately, there is no one-size-fits-all solution to adopting the ASHRAE allowable envelopes. Every business must evaluate their particular situation including the pros, cons and impact on your business's total cost of ownership.

One major advantage of the expanded ASHRAE allowable envelopes is to enable the use of economizers. Economizers are used to provide free-cooling to the data center. Free-cooling uses low outside air temperatures to assist in chilling water or air which can then be used for indoor cooling. There is a common misconception that the data center must operate at the upper end of the allowable range for a large portion of the year if economizers are used. In fact, this is incorrect. Most locations throughout the world have a significant number of hours in the year where adequate cooling can be provided from an economizer while still remaining within the ASHRAE recommended range.

Table 1 highlights select cities and the average number of hours in a year where cooling can be provided by only a water-side economizer. For example, in Chicago, a water-side economizer can provide cooling within the recommended envelope nearly 83 percent of the year and nearly 97 percent of the year within the ASHRAE A1 allowable envelope. In many major cities, there are only a very few hours within the year that a data center relying on economizers would be required to operate at the extremes of the A3 allowable envelope. Hong Kong and Singapore are the notable exceptions.

City	**Average percentage of annual hours**			
	within Rec	**outside Rec, within A1**	**outside A1, within A2**	**outside A2, within A3**
Bangalore	29.9%	67.5%	2.6%	0.0%
Boston	86.0%	12.9%	1.1%	0.0%
Chicago	82.5%	14.7%	2.6%	0.2%
Dallas	59.0%	24.7%	15.5%	0.8%
Hong Kong	33.6%	23.2%	31.8%	11.4%
London	99.2%	0.8%	0.0%	0.0%
Miami	19.5%	41.5%	38.5%	0.5%
Rome	71.6%	25.1%	3.3%	0.0%
San Francisco	99.7%	0.3%	0.0%	0.0%
Sao Paulo	59.1%	40.6%	0.3%	0.0%
Seattle	99.2%	0.8%	0.0%	0.0%
Singapore	0.0%	1.5%	81.1%	17.4%
Sydney	78.8%	21.1%	0.1%	0.0%

Table 1. Percentage of the year data centers in select cities can operate within a given ASHRAE envelope using only a water-side economizer.[7]

When economizers are not installed or the ambient conditions are not conducive to economizer use, operating within the ASHRAE recommended range can be as energy efficient as operating outside of the recommended range but within the allowable range. Figure 4 shows the trend in data center power consumption as the IT equipment air inlet temperature is raised. The figure provides upper and lower bounds to accommodate the inherent differences in IT equipment configurations. It compares low-density IT which contains mostly low-power devices with high-density configurations that are filled with many high power consuming devices.

Your organization should understand the trade-offs that occur when the inlet air temperature is increased. This requires significant interaction between both facilities and IT personnel. Figure 4 also shows that for higher density IT equipment configurations, the initial savings on refrigeration power are quickly overcome by increases in IT equipment power as the data center temperature is increased. Simply raising the maximum allowable air supply temperature in an effort to realize energy savings does not always translate to overall minimum energy consumption for the data center. The exact optimum operating point should be carefully balanced because each piece of IT equipment and each data center is unique.

In general, data center air temperature should be cool enough to prevent the IT equipment fans from speeding up. If this happens, the total data center energy consumption will likely begin to either flatten out or even increase as IT equipment power consumption rises, often erasing any facility power savings. This point typically lies within the ASHRAE recommended envelope. Even when this point lies at the upper end of the recommended range, the savings achieved by further increasing the data center temperature is typically small. You should weigh these additional savings against the potential for reducing IT equipment reliability and compromising an adequate safety margin in the event of a cooling failure.

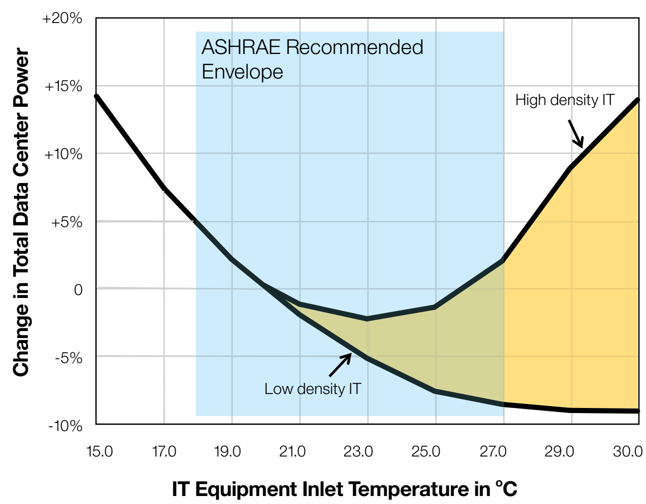

Figure 4. The trend in IT equipment and data center cooling power consumption as the data center air temperature is raised from a reference point of 20°C (68° F).[8]

Conclusion

As you have seen, there are many variables to consider when choosing the proper temperature and humidity operating range for your data center. However, one fact is clear: operating outside the equipment's recommended envelope, whether continuously or for prolonged periods, can easily cancel out any energy savings that this type of environment may provide. Although operating in the allowable envelopes (depending on your IT equipment) can be necessary at times, it can also contribute to lower reliability, higher equipment replacement costs and even additional power expenses when continued for long periods of time.

How IBM Systems can help

The IBM® z13™ introduced numerous cooling innovations, design upgrades and protections that enable a wider range of data center designs. Recognizing that many customers prefer to operate outside the recommended envelope for brief periods in order to reduce the power required for data center temperature control, the z13 supports the ASHRAE class A2 environment. The ability to operate in allowable envelope environments translates to a more robust system design. Because of the increase in demand for cooling at higher temperatures, taken as a whole, the recommended envelope is often as energy efficient as the allowable envelope for the z13, while requiring significantly less air flow, generating many fewer decibels of noise and offering better component reliability. In fact, in all cases, the z13 will continue to operate even when pushed well above its maximum specified 35°C (95°F) temperature. As IBM continues to design upcoming generations of IBM z Systems™ equipment with innovative features, future models will likely be certified for class A3 operation.

Built with open technologies and designed for mission-critical applications, IBM Power Systems® offer servers designed to deliver superior cloud economics with secure and open choices through innovation from a growing ecosystem that can broaden application choice and enhance optimization. The IBM POWER8® processor-based Scale-out and Enterprise solutions introduced support for the ASHRAE A3 allowable environment, giving customers an expanded envelope of up to 40°C (104°F) for a more a resilient and energy efficient data center infrastructure.

With the ever increasing demand for computing resources, accelerated by cloud, analytics, mobile and social applications, it's more important than ever for organizations to understand the impact IT equipment selection can have on their data center facilities. IBM has the expertise and experience to guide you through the data center facilities design and equipment selection process using a holistic cooling approach. Each facility is unique and every company has a unique culture, value system, business plan and risk tolerance which can result in dramatically different design choices. IBM has capabilities from the silicon to the outdoors to help you feel confident you're making the right decisions for your specific situation.

For more information

To learn more about effectively applying the expanded ASHRAE guidelines in your data center, please contact your IBM representative or IBM Business Partner, or visit the following website: **ibm.com**/systems/services/labservices

For more information on IBM Systems, visit:

- **ibm.com**/systems/z
- **ibm.com**/systems/power

About the author

Dr. Dustin Demetriou is a member of the IBM Systems Advanced Thermal Energy Efficiency Lab. In his role, he focuses on the development of advanced cooling technologies for IBM server and storage products and helping clients with data center power and cooling solutions, with an emphasis on state-of-the-art green and energy efficient data center designs. Dustin is a voting member of the ASHRAE Technical Committee 9.9 on Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment. He can be reached at dwdemetr@us.ibm.com.

[6] Pommerenke, D., 2014, "The Effect of Humidity on Static Electricity Induced Reliability Issues of ICT Equipment in Data Center," ASHRAE Research Project Report 1499-RP, October 2014.

[7] The analysis in Table 1 is provided as an example and is not meant to be used in lieu of a detailed design, analysis and business case prepared by a licensed engineer. The analysis assumes a data center using an evaporative cooling system providing water to a close-coupled, rack-level cooling solution. The analysis assumes a 9°C (16.2°F) temperature rise between outdoor wet-bulb temperature and IT inlet air temperature.

[8] The analysis used to generate Figure 4 is documented in, Demetriou, D., "A Simple Method to Understand Trade-Offs in Data Center Cooling," Electronics Cooling, October 2015, http://www.electronics-cooling.com/2015/05/a-simple-method-to-understand-trade-offs-in-data-center-cooling/.

IBM®

IBM Systems
Route 100
Somers, NY 10589

Produced in the United States of America
November 2015

[1] ASHRAE, Datacom Equipment Power Trends and Cooling Applications, 2nd Edition, ASHRAE Datacom Series 2.

[2] ASHRAE, Thermal Guidelines for Data Processing Environments, 3rd Edition, ASHRAE Datacom Series 1.

[3] For ASHRAE A1 and A2, de-rate the maximum allowable dry-bulb temperature by 1°C/300 meters above 900 meters. For ASHRAE A3, de-rate the maximum allowable dry-bulb temperature 1°C per 175 meters above 900 meters.

[4] ASHRAE, Thermal Guidelines for Data Processing Environments, 3rd Edition, ASHRAE Datacom Series 1.

[5] Figure 3 was generated based on the work described in Erden, H., Khalifa, H.E., and Schmidt, R. (2014). "A hybrid lumped capacitance-CFD model for the simulation of data center transients," HVAC&R Research, Vol. 20 (6), pp. 688 – 702.

XBW03029-USEN-00