

Creating a Perfect Storm

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In ASHRAE Technical Committee 9.9's *Thermal Guidelines for Data Processing Environments*, the environmental guidelines for IT equipment inlet conditions extended the allowable range up to 85% and 90% relative humidity (RH) and 75°F (24°C) dew point. However, in an unconnected parallel move, international regulators banned the use of lead-based solders within the manufacturing of electronic equipment. The lead-based solder has been replaced with silver-based solder. Unfortunately, silver, unlike lead, is more susceptible to effects of corrosion when exposed to certain environmental conditions.

As a result, operating data centers at the higher humidity levels defined in the allowable ranges in *Thermal Guidelines* can have detrimental effects on electronic equipment reliability. This is particularly true when the location has elevated levels of certain particulate and gaseous pollutants caused by today's industrial and manufacturing activities.

The gaseous contaminants can act alone, in the presence of humidity, or in synergy with dust or each other to corrode metallic materials. They can cause irreversible damage of circuit boards, connectors, integrated circuits and various other electronic components.

The result is a perfect storm caused by the pursuit of energy savings and environment-friendly materials in the design and construction of data centers.

Background

The Restriction of Hazardous Substances (RoHS) Directive 2002/95/EC was adopted in February 2003 by the European Union and went into effect in 2006. The directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment.

Prior to this, electronic equipment was primarily manufactured with lead-based solder. In short, this directive has restricted the use of lead in electronics and replaced it by silver-based solders instead.

Silver is reactive when in the presence of elevated humidity and certain gaseous contaminations including the following: Sulfur dioxide (SO₂); hydrogen sulfide (H₂S); chlorine (Cl₂); hydrogen chloride (HCl); nitrogen oxides (NO, NO₂); and ozone (O₃).

In recognition of these potential IT hardware failures, TC 9.9 published a book entitled *Gaseous and Particulate Contamination Guidelines for Data Centers* in 2011. This book sought to introduce and warn the industry about the potential for problems.

It also sought to establish collaboration between related industry organizations to solve this problem through research and information exchange. Those industry groups include: ASHRAE; The International Electronics Manufacturing Initiative (iNEMI); The International Society of Automation (ISA); The China Electronics; and Engineering Design Institute (CEEDI).

Energy Efficiency

During the development of the *Contamination Guidelines*, there was aggressive industry activity focused on reduction of data center energy consumption.

The DOE had released its report to Congress indicating the exponential rise in data center energy consumption. This report was picked up by ASHRAE and The Green Grid, who had published several white papers on the PUE metric. This widely adopted industry metric had resulted in a heightened awareness of the importance of energy consumption data centers and was leading to aggressive measures to reduce it.

One of the primary methods to improve PUE was the adoption and deployment of economizers in data centers, including airside economizers.

By 2010, ASHRAE approved a significant change in the Title, Purpose, and Scope of Standard 90.1 to include

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data centers (computer rooms) in the standard. In doing so, they introduced prescriptive requirements for economizers, including airside economizers, despite fierce opposition from the data center industry members.

Thermal Guidelines

With the global push on energy efficient operation at this point, the third edition of ASHRAE's *Thermal Guidelines for Data Processing Environments* sought to solve this problem with wider envelopes (Figure 1).

Energy efficient operation, through expanded allowable environmental envelopes, was previously tempered by the unknown impacts that higher temperatures would have on the failure rates of the IT equipment. To quantify this unknown, a conglomerate of the major IT OEM equipment manufacturers published consensus relative failure rates of IT equipment for different inlet temperature conditions (as described in detail in last month's column). The information was included in the third edition of *Thermal Guidelines* along with practical examples of how to apply the information.

At the time, only higher temperatures were considered an impact on hardware reliability. More recent industry experience has demonstrated a very real problem associated with elevated humidity conditions when in the presence of gaseous contamination.

Effect of Moisture and Particulate Contamination

The Allowable Classes (A-1 through A-4) permit elevated humidity levels greater than 80% RH. At 80% to 85% relative humidity, most dust will get wet and support high levels of leakage currents between adjacent features on printed circuit boards (PCBs).

In addition, high relative humidity tends to aggravate the following: creep corrosion; ion migration in/on PCBs; component corrosion; connector corrosion;

and moisture absorption by PCB laminates, which may degrade machine performance and reliability.

Deliquescent relative humidity of dust occurs when particulate contamination absorbs humidity. Airborne dust in data centers can be divided into two size ranges: coarse dust with particle size greater than 2.5 mm; and fine dust with particle size less than or equal to 2.5 mm (PM2.5).

Fine dust is of particular concern because of its ability to absorb water. Fine particle filtration requires a MERV rating of 13 or higher to effectively filter out PM2.5 particles from a data center.

Reliability & Failure Modes

Particulate and gaseous corrosion can lead to electronic equipment failures. Those failure modes can consist of the following:

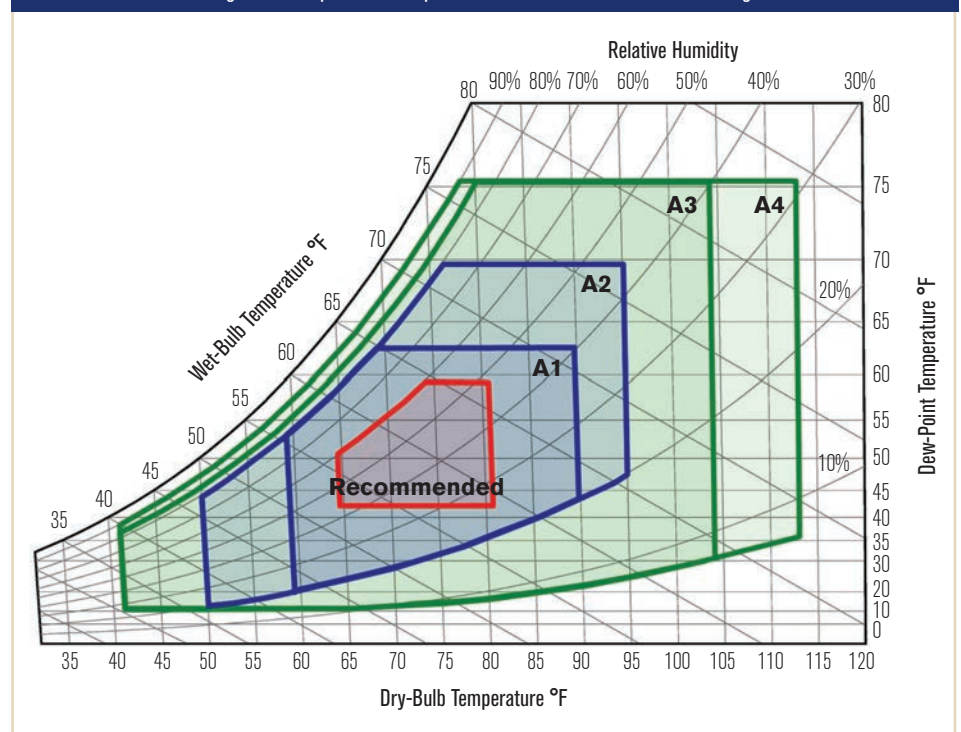
- Copper creep corrosion on circuit boards (Figure 2);
- Corrosion of silver metallization in components; and
- Formation of copper sulfide on ITE printed circuit board (PCB) assemblies.

Sulfur-bearing gases are mainly responsible for corrosion-related hardware failures when silver is present.

Research: Past and Proposed

Several studies aimed to address the role of humidity

FIGURE 1 ASHRAE thermal guidelines expanded envelopes for recommended and allowable entering air conditions.



SOURCE: ASHRAE, MODIFIED BY DLB

along with temperature and gaseous and particulate contamination on corrosion of copper and silver. However, most of these efforts have been based on very high concentration of gaseous contamination (far beyond practical applications). Typical ranges of outdoor pollutants are in *Table 1*.

The results of those studies can be summed up as follows:

- Copper corrosion rate was sensitive to relative humidity; however, silver corrosion rate was quite insensitive to relative humidity.
- Copper and silver corrosion rates are influenced by SO₂, H₂S, Cl₂, HCl, NO, NO₂, and O₃ concentrations.
- The relationship between relative humidity and IT equipment failure rates is probably of a step function nature: the failures rates being low below 50% relative humidity range and rising sharply above 50% relative humidity range.

There is a recent increase in the number of data centers using free air cooling using an expansion of the allowable temperature and humidity limits as per *Thermal Guidelines*. As a result, the need has been recognized to study the impact of elevated and dynamic humidity conditions on the performance and reliability of IT equipment.

Recent studies suggest that it appears that humidity plays a very important role in facilitating an electrochemical interaction. Most recently, TC 9.9, *Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment*, and TC 2.3, *Gaseous Air Contaminates and Gas Contaminates Removal Equipment*, are seeking approval of a work statement “Impact of High Humidity and Gaseous Contamination on the Reliable Operation of Information Technology Equipment in Data Centers” to further the understanding in this field.

This research program seeks to characterize the impact that high humidity and gaseous contamination have on IT equipment reliability. Furthermore, it is anticipated that guidelines will be prepared for the acceptable operating environment in data centers globally. The publication of this information is expected to increase the adoption of *Thermal Guidelines* in data centers worldwide continuing the energy conservation movement.

Closing Comments

Corrosion-induced failures of copper and silver-based electronics has emerged as a new problem in data center electronic equipment.

The combination of the following has combined to

FIGURE 2 Examples of copper and silver corrosion on electronics.

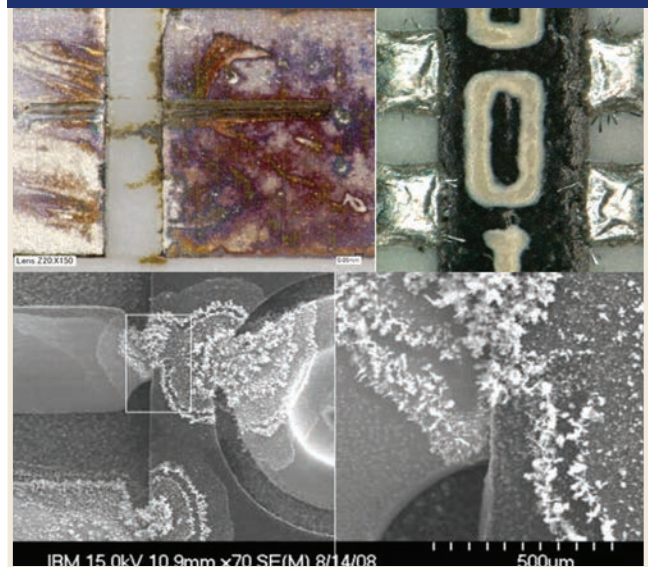


TABLE 1 Typical range of outdoor pollutants worldwide.

POLLUTANT TYPE	OUTDOOR RANGES IN PPB	
	MINIMUM	MAXIMUM
Hydrogen Sulfide (H ₂ S)	4.0	1,400
Nitrogen Dioxide (NO ₂)	5.0	80.0
Sulfur Dioxide (SO ₂)	4.0	40.0
Chlorine (Cl ₂)	1.0	10.0
Ozone (O ₃)	5.0	60.0

TABLE 2 ISA classification of reactive environments (ANSI/ISA 71.04 2013).

		G1 (MILD)	G2 (MODERATE)	G3 (HARSH)	G4 (SEVERE)
		<300	<1,000	<2,000	2,000
COPPER REACTIVITY LEVELS (Å/MONTH)					
GROUP	GAS	GAS CONCENTRATION (IN PPB)			
A	Hydrogen Sulfide (H ₂ S)	<3	<10	<50	50
	Sulfur Dioxide (SO ₂)	<10	<100	<300	300
	Sulfur Trioxide (SO ₃)	<10	<100	<300	300
	Chlorine (Cl ₂)	<1	<2	<10	10
	Nitrogen Oxides (NO _x)	<50	<125	<1,250	1,250
B	Hydrogen Fluoride (HF)	<1	<2	<10	10
	Ammonia (NH ₃)	<500	<10,000	<25,000	25,000
	Ozone (O ₃)	<2	<25	<100	100

create the perfect storm in the data center:

- New industry regulations have imposed restrictions on the materials used in electronic equipment solder;
- Wider allowable humidity ranges published in *Thermal Guidelines*; and
- The introduction of airside economizers. ■