

Fifth Edition Highlights

ASHRAE's Data Center Thermal Guidelines

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Thermal Guidelines for Data Processing Environments, Fifth Edition, has some important updates for both air-cooled and liquid-cooled environments. Our column in May's *ASHRAE Journal* focused on changes to the air-cooled classes defined by ASHRAE's *Thermal Guidelines for Data Processing Environments* and the history of changes during the 18 years since the original *Thermal Guidelines* was published in 2004. The focus of this month's column is to look in detail at the changes between the fourth and fifth editions, published in 2015 and 2021, respectively.

The update was driven by both an ASHRAE research project and a need to adjust to recent information technology (IT) industry equipment trends.

The primary changes between the *Fourth Edition* and the *Fifth Edition* were:

- A change to the recommended temperature/humidity envelope because of research into the concurrent impact of relative humidity (RH) and gaseous pollutants on information technology equipment (ITE) corrosion;
- The addition of a new high-density air-cooled environmental envelope (Class H1); and
- A change in the nomenclature of liquid-cooling classes to reflect each class's maximum liquid inlet temperature.

These changes will be described in more detail in the remainder of this column.

Change in Air-Cooled Recommended Envelope Based on Corrosion Research

For most U.S. locations, gaseous pollutants are not typically a major problem for the ITE found in data centers, except possibly during upset conditions, such as an external fire. Worldwide, however, gaseous air pollution can be more of an issue. The increased failure rates seen for data center ITE in polluted cities was observed by the ITE manufacturers, and created the impetus for an ASHRAE research project (RP-1755) to study the issue.

For RP-1755, *Impact of Gaseous Contamination and High Humidity on the Reliable Operation of Information Technology Equipment in Data Centers*, from 2015 to 2018 ASHRAE funded Syracuse University Mechanical and Aerospace Engineering Department to

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FIGURE 1 Test results for copper: 21°C and 50%, 70% and 80% RH.¹

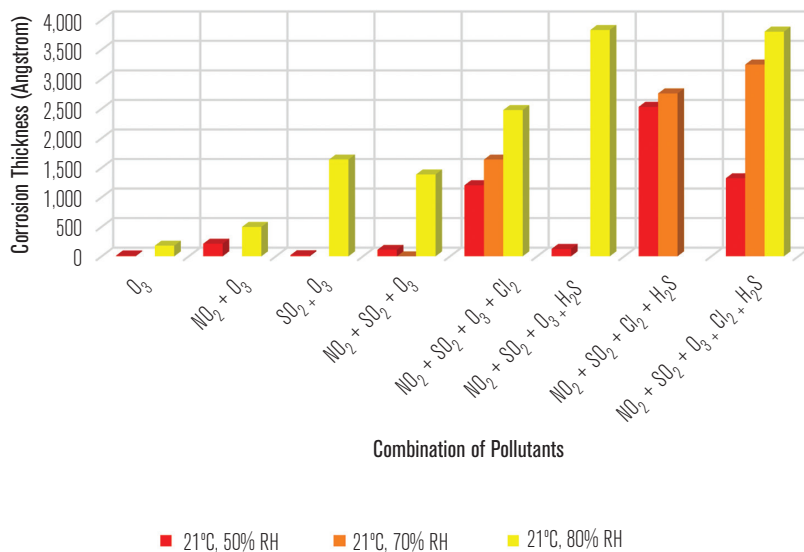


FIGURE 2 Example of copper and silver corrosion coupons.



investigate the risk of operating at higher levels of moisture when high levels of gaseous pollutants exist. The objective was to evaluate the ability of increasing the recommended moisture level in support of reducing energy required by data centers.

Five gaseous pollutants were tested under a variety of temperature and relative humidity (RH) conditions—three pollutants that are pervasive throughout the planet (SO₂, NO₂ and O₃) and two catalyst pollutants (H₂S and Cl₂). Pollutant levels tested were at or near the maximum common concentration levels existing around the world.

The data collected as part of this research led to a finding that relative humidity levels in the range of 50% to 70% RH can contribute to an increased risk of corrosion when catalyst pollutants are concurrently present. Figure 1 provides an example of some of the study's results. In this case, corrosion rates on copper were measured with eight combinations of five pollutants and at three different relative humidity levels at a typical ITE inlet temperature of 69.8°F (21°C). The preponderance of the data showed increasing corrosion with higher relative humidity. It also showed significantly higher corrosion rates when the two catalyst pollutants (H₂S and Cl₂) were present.

The *Fourth Edition of Thermal Guidelines* had a recommended maximum relative humidity of 60%, without any qualifications as to the corrosivity of the air. The *Fifth*

Edition, relying on the research from RP-1755, now has two different maximum recommended RH levels (50% and 70%), depending on the corrosivity of the environment as measured empirically using both copper and silver coupons. Figure 2 shows one of the currently available corrosion coupons.

For data center environments tested with silver and copper coupons that are shown to have corrosion levels less than 300 Å/month for copper and 200 Å/month for silver, suggesting that only the pervasive pollutants (SO₂, NO₂ and O₃) may be present, the recommended moisture limit is raised from 60% to 70% RH. The upper moisture limit is now 70% RH or 59°F (15°C) dew-point temperature, whichever has the lowest absolute moisture content.

For data center environments tested with silver and copper coupons that are shown to have levels of corrosion greater than 300 Å/month for copper and/or 200 Å/month for silver, suggesting that Cl₂, H₂S, and/or other corrosive catalysts may be present, the recommended maximum moisture level has been reduced. The recommended upper moisture limit listed in the *Fifth Edition of Thermal Guidelines* is 50% RH or 59°F (15°C) dew point, whichever has the lowest absolute content. Chemical filtration should also be considered to reduce levels of corrosive gases.

For reference, Figure 3 shows the Recommended Envelope for Classes A1 to A4 in the *Fourth Edition*. Figure 4

then shows the two Recommended Envelopes for the same classes in the *Fifth Edition*. The single envelope from the *Fourth Edition*, with the 60% RH upper limit, is replaced with two envelopes in the *Fifth Edition*, with 50% and 70% RH upper limits, for the different corrosion conditions (as described in the previous paragraphs).

The Addition of a New High-Density Air-Cooled Environmental Envelope (H1) Based on IT Technology

The decision to add a new environmental class to *Thermal Guidelines* was based on new high-density IT products. These high-density products use high-powered components such as CPUs, GPUs and memory. These components require increased cooling that could be provided with an increase in heat sink volume/fan performance. However, server volume limitations do not permit these performance enhancements within allowable server sizes using Class A1 cooling temperatures. For this reason, the new Class H1 was added. The new Class H1 has more restrictive (lower) recommended and allowable temperature ranges than the existing classes A1 through A4. *Figure 5* shows the recommended and allowable ranges for Class H1 for operating environments with both low and high gaseous pollution levels.

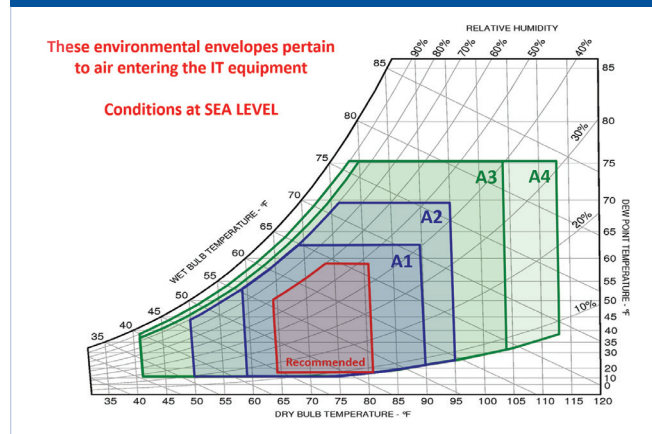
Most of the environmental envelopes shown in the *Thermal Guidelines*, including those shown in *Figures 4* and *5*, are applicable to sea level conditions. At higher elevations, heat transfer is reduced due to lower air density, and the temperatures need to be correspondingly reduced. *Figure 6* provides data on the required deratings, which are significant for all classes. Note that the guideline threshold is an elevation of 9,840 ft (3,000 m). Additional information can be found in Appendix G of the *Thermal Guidelines*.

Since Class H1 has the most restrictive envelope of all *Thermal Guidelines* classes, the addition of this class of equipment to existing data centers designed for less restrictive classes requires careful engineering of both cooling and humidity control systems. Partitioning of this equipment—with independent cooling systems—may be needed. The requirement for independent cooling will likely also be required for new data centers to maintain as low a PUE as possible.

Liquid-Cooled Class Nomenclature Changes

For liquid cooling, the decision was made to change the nomenclature for Liquid Cooling Classes, first

FIGURE 3 Class A1 to A4 Recommended Envelopes, *Fourth Edition of Thermal Guidelines*.²



introduced in the *3rd Edition*, to reflect the water supply temperature to the ITE. The old classes were W1 through W5, and the new classes are W17, W27, W32, W40, W45 and W+. The number after the “W” represents the maximum expected liquid design temperature in degrees Celsius at the inlet to the ITE. The minimum allowable temperature for all classes is 35.6°F (2°C).

Care must be taken to ensure compatibility between the facility’s liquid cooling system and the ITE served regarding working pressures, flow rates, differential pressure and temperature rates of change. Knowledge of the air temperature range in the data center is also needed. For all liquid cooling classes, it is essential that the dew-point temperature of the space be below the coldest temperature of the recirculating liquid to avoid localized high relative humidity and/or condensation issues. Also, the discharge temperature from the ITE will be higher than the inlet temperature, and heat rejection equipment must account for this higher temperature and the appropriate temperature range of the cooling system.

One of the long-term advantages of liquid cooling is that there is a greater opportunity for higher water temperatures than air temperatures due to closer heat transfer approach temperatures. This increases the percentage of the year that the facility can be operated in economizer mode. At the higher temperatures, district heating is also an opportunity, though provision must also be made for back-up heat rejection equipment if the minimum annual district heating demand is less than the data center’s heat rejection requirements. Liquid cooling is well suited to district heating (relative to an air-cooled data center) due to the ease and efficiency

FIGURE 4 Class A1 to A4 Recommended Envelopes, *Fifth Edition of Thermal Guidelines*.³ Left figure is for spaces with low levels of gaseous pollutants; right figure is for spaces with high levels of gaseous pollutants.

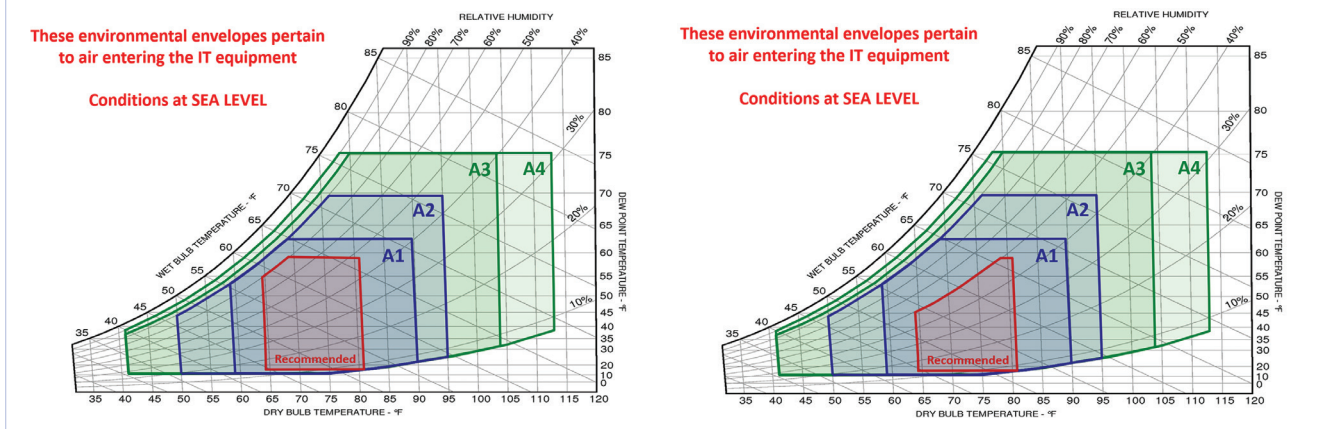
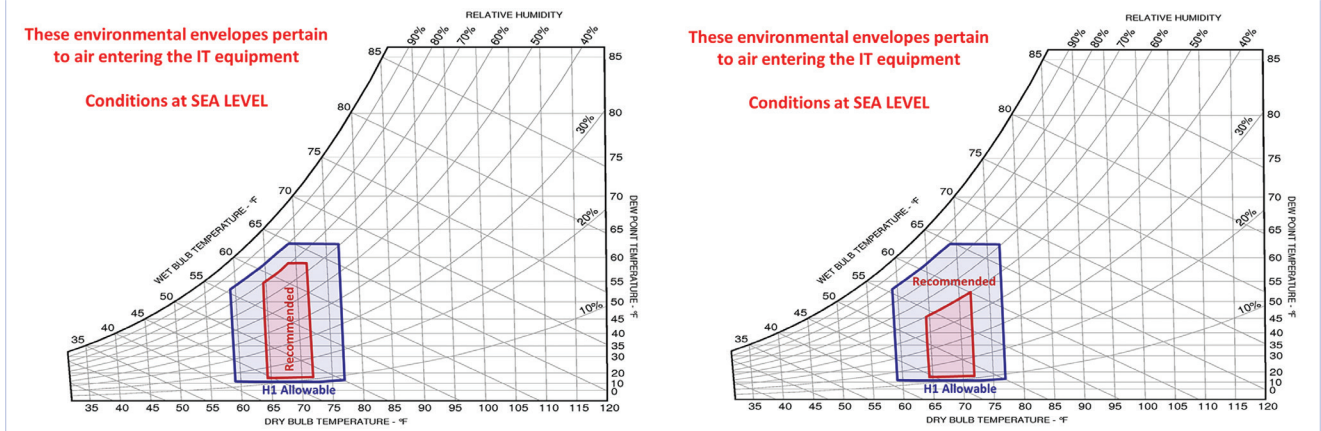


FIGURE 5 New Class H1 Recommended and Allowable Envelopes, *Fifth Edition of Thermal Guidelines*.³ Left figure is for spaces with low levels of gaseous pollutants; right figure is for spaces with high levels of gaseous pollutants.)

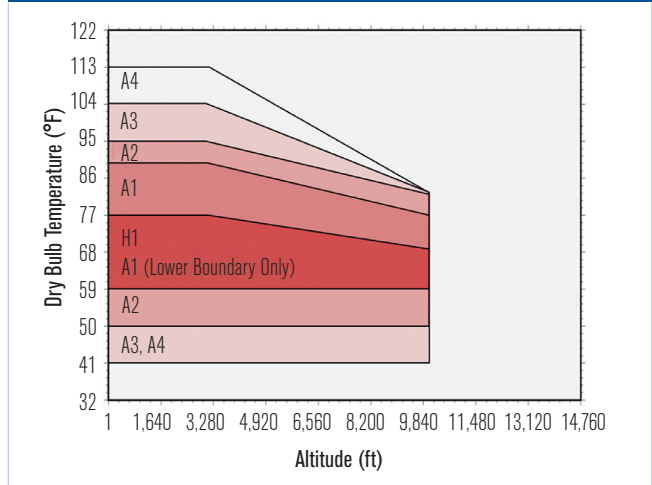


with which liquids can transport heat relative to air. One note: for IT designs that meet the higher supply temperatures as referenced in Table 3.1 of the *Fifth Edition* guidelines, enhanced ITE thermal designs are required to maintain liquid-cooled components within the desired temperature limits.

The environmental classes for liquid-cooled ITE listed in the guideline are:

- Class W17/W27 (62.6°F to 80.6°F [17°C to 27°C]): These are typically data centers that are traditionally cooled using chillers and a cooling tower, but with an optional waterside economizer to improve energy efficiency, depending on the location of the data center.
- Class W32/W40 (89.6°F to 104°F [32°C to 40°C]): For most locations these data centers may be operated without chillers. Some locations may still require chillers, but they may not need to be sized for the full cooling load.

FIGURE 6 Allowable temperature derating for Classes A1 to A4 and H1 as a function of altitude.³



- Class W45/W+ (113°F+ [45°C]): These data centers are operated without chillers to take advantage of energy efficiency and reduce capital expense. The temperature

FIGURE 7 Alignment of liquid cooling classes between the *Third* (left) and *Fifth* Editions (right) of *Thermal Guidelines*.^{3,4}

TABLE 3.1 2012 ASHRAE LIQUID-COOLED GUIDELINES			
Equipment Environment Specifications for Liquid Cooling			
Liquid Cooling Class	Typical Infrastructure Design		Facility Water Supply Temperature, °C (°F)
	Primary Facilities Cooling Equipment	Secondary/Supplemental Cooling Equipment	
W1	Chiller/cooling tower	Water-side economizer	2 to 17 (35.6 to 62.6)
W2			2 to 27 (35.6 to 80.6)
W3	Cooling tower	Chiller	2 to 32 (35.6 to 89.6)
W4	Water-side economizer (with dry-cooler or cooling tower)	N/A	2 to 45 (35.6 to 113)
W5	Building heating system	Cooling tower or dry-cooler	>45 (>113)

Table 3.1 2021 Thermal Guidelines for Liquid Cooling			
Equipment Environment Specifications for Liquid Cooling			
Liquid Cooling Class	Typical Infrastructure Design		Facility Water Supply Temperature, °C (°F) ^a
	Primary Facilities	Secondary/Supplemental Facilities	
W17	Chiller/cooling tower	Water-side economizer (cooling tower)	17 (62.6)
W27			27 (80.6)
W32	Cooling tower	Chiller or district heating system	32 (89.6)
W40			40 (104)
W45	Cooling tower	District heating system	45 (113)
W+			>45 (>113)

a. Minimum water temperature for all classes is 2°C (35.6°F).

is also sufficiently warm that it could help feed a district water heating system.

Figure 7 shows the alignment between the liquid cooling classes defined in the *Third Edition* of *Thermal Guidelines* and the classes defined in the *Fifth Edition*.

Data centers have only recently come on-line with significant use of waste heat from liquid-cooled servers. Most often, the data center needs to be proximate to a facility that can use relatively low-temperature water for heating purposes. Reference 5 provides an example.

Closing Comments

With the publication of the fifth edition of ASHRAE's *Thermal Guidelines for Data Processing Environments*, ASHRAE has kept pace with both the IT industry requirement for higher-density ITE and with its own research on the impact of relative humidity and gaseous pollutants on ITE corrosion. In consideration of the expected increased role of liquid cooling over time, the nomenclature of the liquid cooling classes has also been revised to more intuitively reflect the liquid-cooling conditions of these classes.

References

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3. ASHRAE. 2021. *Thermal Guidelines for Data Processing Environments, Fifth Edition*. Peachtree Corners: ASHRAE.

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5. NREL. Undated. "High-Performance Computing Data Center Waste Heat Reuse." National Renewable Energy Laboratory. <https://tinyurl.com/2p8aa32t>

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