New ASHRAE Thermal Guidelines for Air and Water Cooling

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ASHRAE Technical Committee 9.9

Title: Mission Critical Facilities, Technology Spaces, & Electronic Equipment

Overview:

 Concerned with the design, operations, maintenance, and efficient energy usage of modern data centers and technology spaces.

 The committee is comprised of a wide range of industry representatives including but not limited to equipment manufacturers, consulting engineers, data center operators, academia, testing laboratories, government, etc. who are all committed to increasing and sharing the body of knowledge related to data centers.

 The ASHRAE TC 9.9 Datacom* Series, a series of nine publications, provides a comprehensive treatment of datacom cooling and related subjects.

* - datacom: data processing and telecommunications equipment

- Chapter 1 – Introduction
- Chapter 2 – Equipment Environmental Specifications
- Chapter 3 – Facility Temperature & Humidity Measurement
- Chapter 4 – Equipment Placement & Airflow Patterns
- Chapter 5 – Equipment Manufacturers Heat & Airflow Reporting
- Appendix A – Psychrometric Charts
- Appendix B – Temperature & Altitude Charts

Can obtain book @ http://tc99.ashraetcs.org/
ASHRAE IT Equipment Environment - Class Definition

- Recommended & Allowable Environmental Conditions vary depending on the application, scale & type of electronic equipment that is being cooled.

**Class 1 – Data Center**
- Enterprise and Volume Servers
- Storage products

**Class 2 – Office Space**

**Class 3 – Home Office**

**Class 4 – Point of Sale**

- Expanded recommended range
- Increased opportunity to use compressor-less cooling solutions

<table>
<thead>
<tr>
<th>Class</th>
<th>Dry-Bulb Temperature</th>
<th>Relative Humidity (%)</th>
<th>Max Dew Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 to 32 °C (59 to 89.6 °F)</td>
<td>See table below</td>
<td>17 °C (62.6 °F)</td>
</tr>
<tr>
<td>2</td>
<td>10 to 35 °C (50 to 95 °F)</td>
<td>20 to 80</td>
<td>21 °C (69.8 °F)</td>
</tr>
<tr>
<td>3</td>
<td>5 to 35 °C (41 to 95 °F)</td>
<td>N/A</td>
<td>28 °C (82.4 °F)</td>
</tr>
<tr>
<td>4</td>
<td>5 to 40 °C (41 to 104 °F)</td>
<td>N/A</td>
<td>28 °C (82.4 °F)</td>
</tr>
</tbody>
</table>

2004 Version 2008 Version

- Low End Temperature 20 °C (68 °F) 18 °C (64.4 °F)
- High End Temperature 25 °C (77 °F) 27 °C (80.6 °F)
- Low End Moisture 40% RH 5.5 °C (41.9 °F) DP
- High End Moisture 55% RH 60% RH & 15 °C (59 °F) DP
IT Equipment Environment - Envelope Definitions

**Recommended** – The purpose of the recommended envelope is to give guidance to data center operators on maintaining high IT reliability while still achieving reasonably energy-efficient data center operation.

**Allowable** – The allowable envelope is where the IT manufacturers test their equipment in order to verify that the equipment will function within those environmental boundaries.

**Prolonged Exposure** – Prolonged exposure of operating IT equipment to conditions outside its recommended range, especially approaching the extremes of the allowable operating environment, can result in decreased equipment reliability and longevity. **It is acceptable to operate outside the recommended envelope for occasional, short periods of time without affecting the overall reliability and operation of the IT equipment.**
## Thermal Guidelines – 2011 Whitepaper

<table>
<thead>
<tr>
<th>Class</th>
<th>Product Operation (Powered On)</th>
<th>Dry-Bulb Temperature</th>
<th>Relative Humidity (%)</th>
<th>Max Dew Point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Allowable</td>
<td>Recommended</td>
<td>Allowable</td>
</tr>
<tr>
<td>A1</td>
<td></td>
<td>15 to 32 °C (59 to 89.6 °F)</td>
<td>20 to 80</td>
<td>17 °C (62.6 °F)</td>
</tr>
<tr>
<td>A2</td>
<td></td>
<td>10 to 35 °C (50 to 95 °F)</td>
<td>20 to 80</td>
<td>5.5 °C (41.9 °F) DP</td>
</tr>
<tr>
<td>A3</td>
<td></td>
<td>5 to 40 °C (41 to 104 °F)</td>
<td>-12 °C (10.4 °F) DP and 8% RH to 85% RH</td>
<td>60% RH and 15 °C (59 °F) DP</td>
</tr>
<tr>
<td>A4</td>
<td></td>
<td>5 to 45 °C (41 to 113 °F)</td>
<td>-12 °C (10.4 °F) DP and 8% RH to 90% RH</td>
<td>24 °C (75.2 °F)</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>5 to 35 °C (41 to 95 °F)</td>
<td>N/A</td>
<td>8 to 80</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>5 to 40 °C (41 to 104 °F)</td>
<td>N/A</td>
<td>8 to 80</td>
</tr>
</tbody>
</table>

- **2011 Classes**: 2008 Classes
- **Application**: Datacenter, Office, home, trans-portable equipment, etc.
- **IT Equipment**: Enterprise servers, storage products, Volume servers, storage products, personal computers, workstations, Personal computers, workstations, laptops, and printers, Point-of-sale, industrial factory, etc.
- **Environmental Control**: Tightly controlled, Some Control, Minimal Control, No Control

- Creating 2 additional environmental classes to enable improved PUE capability
- Provide guidance on the usage of the existing and new classes
- Clients are wanting to further minimize the use of chillers throughout the year (results in large energy savings)
- European Union Code of Conduct for Data Centers Group is made up of users who are pushing to widen the IT environmental guidelines to reduce the number of hours required for chillers

Thermal Guidelines - 2011 Whitepaper
Guide for the Use and Application of the ASHRAE Data Center Classes

Operation outside the recommended region should be a balance between energy savings and the deleterious effects that may be created in reliability, acoustics, or performance.
Server Power Trend vs. Ambient Temperature

Class A2

Class A3

- Increase component power (leakage current)
- Increased fan power (increased air flow)
- Decreased power conversion efficiency
Server Reliability Trend vs Ambient Temperature

<table>
<thead>
<tr>
<th>Dry Bulb Temperature (°C)</th>
<th>Average Failure Rate X-Factor</th>
<th>Lower Bound of Failure Rate X-Factor</th>
<th>Upper Bound of Failure Rate X-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>17.5</td>
<td>0.87</td>
<td>0.80</td>
<td>0.95</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
<td>0.88</td>
<td>1.14</td>
</tr>
<tr>
<td>22.5</td>
<td>1.13</td>
<td>0.96</td>
<td>1.31</td>
</tr>
<tr>
<td>25</td>
<td>1.24</td>
<td>1.04</td>
<td>1.43</td>
</tr>
<tr>
<td>27.5</td>
<td>1.34</td>
<td>1.12</td>
<td>1.54</td>
</tr>
<tr>
<td>30</td>
<td>1.42</td>
<td>1.19</td>
<td>1.63</td>
</tr>
<tr>
<td>32.5</td>
<td>1.48</td>
<td>1.27</td>
<td>1.69</td>
</tr>
<tr>
<td>35</td>
<td>1.55</td>
<td>1.35</td>
<td>1.74</td>
</tr>
<tr>
<td>37.5</td>
<td>1.61</td>
<td>1.43</td>
<td>1.78</td>
</tr>
<tr>
<td>40</td>
<td>1.66</td>
<td>1.51</td>
<td>1.81</td>
</tr>
<tr>
<td>42.5</td>
<td>1.71</td>
<td>1.59</td>
<td>1.83</td>
</tr>
<tr>
<td>45</td>
<td>1.76</td>
<td>1.67</td>
<td>1.84</td>
</tr>
</tbody>
</table>

Table C-1. Relative hardware failure rate x-factor for volume servers as a function of continuous (7 days x 24 hours x 365 days) operation air inlet temperature (indexed to 20°C).

Figure 5. Histogram of dry bulb temperatures for the city of Chicago for the year 2010.

Figure 7. Failure rate projections for air side economizer and water-side economizer for selected US cities. Note that it is assumed that both forms of economizer will result in data center supply air 1.5°C above the outdoor dry bulb.

- **Chapter 1** – Introduction
- **Chapter 2** – Facilities Cooling Systems
- **Chapter 3** – Facility Piping Design
- **Chapter 4** – Liquid Cooling Implementation for Datacom Equipment
- **Chapter 5** – Liquid Cooling Infrastructure Requirements for Chilled Water Systems
- **Chapter 6** – Liquid Cooling Infrastructure Requirements for Technology Cooling Systems

Can obtain book @ http://tc99.ashraetcs.org/
Typical Liquid Cooling Architecture for a Data Center

Facilities Water System (FWS)
Chilled Water System (CHWS)

Condenser Water System (CWS)

Cold Site

Defined Interface Requirements

CDU: Coolant Distribution Unit
Establishes liquid cooling (W) classes analogous to the air cooled classes

- Reduce number of chiller hours per year

- Design data center w/o chillers

- Very similar to Air Cooling Guidelines where customers wanted wider temperature and humidity guidelines

- US National Labs wanted to run all their HPC data centers w/o chillers being required for entire year as an option
Liquid Cooling Class W1, W2, & W3

Cooling Tower ➔ Frame Heat Exchanger ➔ Chiller ➔ CDU ➔ IT Equipment

Facilities Water Supply Temperature

<table>
<thead>
<tr>
<th>Class</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>2 to 17 °C (35.6 to 62.6 °F)</td>
</tr>
<tr>
<td>W2</td>
<td>2 to 27 °C (35.6 to 80.6 °F)</td>
</tr>
<tr>
<td>W3</td>
<td>2 to 32 °C (35.6 to 89.6 °F)</td>
</tr>
</tbody>
</table>

Examples

- **W1**
  - SGI Altix ICE
  - HP MCU
  - IBM p6 Power 575
  - 7 to 15.5 °C
  - 7 to 15 °C
  - 6 to 16 °C

- **W2**
  - IBM p7 Power 775
  - IBM BlueGene
  - 2 to 20 °C
  - 16 to 27 °C
Liquid Cooling Class W4

Cooling Tower or Dry Cooler → Frame Heat Exchanger → CDU → IT Equipment

Facilities Water Supply Temperature

W4: 2 to 45 °C (35.6 to 113 °F)

Examples

LRZ SuperMUC: 25 to 45 °C
Eurotech Aurora (IBM QPACE): 30 to 40 °C
Liquid Cooling Class W5

Cooling Tower or Dry Cooler

Frame Heat Exchanger

Heat Recovery Systems

- Under-Floor Heating (30-40 °C)
- Radiant Heating (60-70 °C)
- Absorption Chillers (60-70 °C)

CDU ➔ IT Equipment

Facilities Water Supply Temperature

W5

> 45 °C

(> 113 °F)

Examples

IBM Aquasar (ETH Zurich) 65 °C
IBM iDataCool (U. of Regensburg) 65 °C
### Liquid Cooling Guidelines - Summary

<table>
<thead>
<tr>
<th>Liquid Cooling Class</th>
<th>Typical Infrastructure Design</th>
<th>Facility Water Supply Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary Facilities Cooling Equipment</td>
<td>Secondary / Supplemental Cooling Equipment</td>
</tr>
<tr>
<td>W1</td>
<td>Cooling Tower / Chiller</td>
<td>Water Side Economizer</td>
</tr>
<tr>
<td>W2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>Cooling Tower</td>
<td>Chiller</td>
</tr>
<tr>
<td>W4</td>
<td>Water Side Economizer (with Dry Cooler or Cooling Tower)</td>
<td>N/A</td>
</tr>
<tr>
<td>W5</td>
<td>Building Heating System</td>
<td>Cooling Tower or Dry Cooler</td>
</tr>
</tbody>
</table>

**Class W1/W2:** Typically a data center that is traditionally cooled using chillers and a cooling tower but with an optional water side economizer to improve on energy efficiency depending on the location of the data center.

**Class W3:** For most locations these data centers may be operated without chillers. Some locations will still require chillers.

**Class W4:** To take advantage of energy efficiency and reduce capital expense, these data centers are operated without chillers.

**Class W5:** To take advantage of energy efficiency, reduce capital expense with chiller-less operation and also make use of the waste energy, the water temperature is high enough to make use of the water exiting the IT equipment for heating local buildings.
Conclusion / Summary

- Datacenter operational environmental envelopes have been expanded to further minimize the use of chillers throughout the year (results in large energy savings).

- Operation outside the recommended region should be a balance between energy savings and the deleterious effects that may be created in reliability, acoustics, or performance.

- Recommended environmental envelope will continue to be the most used environmental envelope for operating data centers.
Thank You for your Attention

Questions ?