ASHRAE Thermal Guidelines
Agenda

• ASHRAE and TC9.9
• Thermal Guidelines (Third Edition)
  • Air-cooling
  • Liquid-cooling
• Air-cooling thermal guidelines in practice
  • Performance
  • Reliability
ASHRAE and TC 9.9

**ASHRAE**
- American Society of Heating, Refrigeration and Air-Conditioning Engineers

**Technical Committee 9.9**
- Environment – thermal, structural, design, testing of data centers and technology spaces for IT equipment

**Committee Members**
- IT equipment manufacturers
- Environmental equipment manufacturers
- Data center designers
- End users
1. **Thermal Guidelines for Data Processing Environments 3rd Edition**
8. Particulate & Gaseous Contamination in Datacom Environments (2009)
10. Green Tips for Data Centers (2011)
Thermal Guidelines for Data Processing Environments

Chapter 1 – Introduction

Chapter 2 – Environmental Guidelines for Air-Cooled Equipment

Chapter 3 – Environmental Guidelines for Liquid-Cooled Equipment

Chapter 4 – Facility Temperature & Humidity Measurement

Chapter 5 – Equipment Placement & Airflow Patterns

Chapter 6 – Equipment Manufacturers Heat & Airflow Reporting
Air-Cooled IT Equipment Class Ranges

- **Allowable Range** – ITE designed to function within this range
- **Recommended Range** – Guidance from ITE manufacturers for high reliability, minimal power consumption (of ITE) and maximum performance
- **Operating Range** – Actual limits for an individual datacenter
  - Can begin with the recommended range
  - Dependent upon datacenter operator’s evaluation of ITE factors described in the whitepaper in combination with knowledge of the datacenter design
2011 ASHRAE Thermal Guidelines

These environmental envelopes pertain to air entering the IT equipment

Conditions at SEA LEVEL

A1

A2

A3

A4

Recommended
Operating Envelope

- ITE Allowable Envelope
- ITE Corrosion
- ITE Acoustical Noise
- ITE Cost
- ITE Airflow
- Datacenter operational knowledge
- ITE Performance
- ITE Power
- ITE Reliability
Liquid-Cooling Environments

Atmosphere ← Building ← Room ← Aisle ← Rack ← System ← Board ← Chip
### 2011 ASHRAE Liquid-Cooled Guidelines

<table>
<thead>
<tr>
<th>Classes</th>
<th>Main Cooling Equipment</th>
<th>Supplemental Cooling Equipment</th>
<th>Facility Supply Water Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>Chiller/Cooling Tower</td>
<td>Water-side Economizer (w/ drycooler or cooling tower)</td>
<td>2 – 17</td>
</tr>
<tr>
<td>W2</td>
<td></td>
<td></td>
<td>2 – 27</td>
</tr>
<tr>
<td>W3</td>
<td>Cooling Tower</td>
<td>Chiller</td>
<td>2 – 32</td>
</tr>
<tr>
<td>W4</td>
<td>Water-side Economizer (w/ drycooler or cooling tower)</td>
<td>N/A</td>
<td>2 – 45</td>
</tr>
<tr>
<td>W5</td>
<td>Building heating system</td>
<td>Cooling tower</td>
<td>&gt; 45</td>
</tr>
</tbody>
</table>
ITE Thermal Design

- Damage Limit
  - Shutdown

- Functional Limit
  - Performance and Power Management

- Reliability Limit
  - Manage Cooling

Optimize Performance, Power, Acoustics
CPU Performance – Light Load

• Power Saving, Lower Frequency
• Design
• Turbo

21°C
- A2 server
- A4 Workload-tuned
- A4 server

35°C
- A2 server
- A4 Workload-tuned
- A4 server

45°C
- A2 server
- A4 Workload-tuned
- A4 server

Damage Protection

Unpredictable performance, memory follows a similar trend although throttling mechanism is different
Performance – dependent on adequacy of thermal design
## Reliability ‘X-Factor’

### Server Reliability Trend vs. Ambient Temperature – Relative Failure Rates

<table>
<thead>
<tr>
<th>Dry Bulb Temp. (°F)</th>
<th>Hardware Failure Rate for Volume Servers (X-Factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>59</td>
<td>0.72</td>
</tr>
<tr>
<td>63.5</td>
<td>0.87</td>
</tr>
<tr>
<td>68</td>
<td>1.00 (Baseline)</td>
</tr>
<tr>
<td>72.5</td>
<td>1.13</td>
</tr>
<tr>
<td>77</td>
<td>1.24</td>
</tr>
<tr>
<td>81.5</td>
<td>1.34</td>
</tr>
<tr>
<td>86</td>
<td>1.42</td>
</tr>
<tr>
<td>95</td>
<td>1.55</td>
</tr>
<tr>
<td>104</td>
<td>1.66</td>
</tr>
<tr>
<td>113</td>
<td>1.76</td>
</tr>
</tbody>
</table>

© ASHRAE Table reformatted by DLB Associates

Assumes continuous (7 x 24 x 365) operation with Dry Bulb Temp. at ITE inlet.
Server Reliability Trend vs. Ambient Temperature (cont.)

- 2010 dry bulb temp for Chicago with air mixing to maintain 59°F min. temp.
Application of X-Factor (Chicago example)
• Cross referencing the hardware failure rates with the dry bulb data for Chicago, we can establish the Net X-Factor across the whole year.

<table>
<thead>
<tr>
<th>Location</th>
<th>59-68°F % hours</th>
<th>Avg. X-Factor</th>
<th>68-77°F % hours</th>
<th>Avg. X-Factor</th>
<th>77-86°F % hours</th>
<th>Avg. X-Factor</th>
<th>86-95°F % hours</th>
<th>Avg. X-Factor</th>
<th>Net X-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago</td>
<td>67.6</td>
<td>0.865</td>
<td>17.2</td>
<td>1.13</td>
<td>10.6</td>
<td>1.335</td>
<td>4.6</td>
<td>1.482</td>
<td>0.99</td>
</tr>
</tbody>
</table>

The Net X-Factor for in Chicago IT hardware failure with compressor-less cooling and a variable data center temperature is almost exactly the SAME as if the data center was operating at a tightly controlled temp. of 68°F.
City Comparison: Reliability

- Average Net Failure Rate Comparison for Air-side Economization (US Cities)
City Comparison: Chiller Hours

- Chiller Hours Per Year for Air-side Economization (US Cities)
Backup
Values outside this field have a probability of occurrence of less than 10% (see IEC 60721-3-0).

--- Exceptional climatic limits.

--- Normal climatic limits: Values outside these limits have a probability of occurrence of less than 1%.

NOTE: Exceptional conditions may occur following the failure of the temperature controlling system. This is described as 3.1E in the tables but it should be noted that there is no separate class 3.1E.
<table>
<thead>
<tr>
<th>ASHRAE Environmental Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applications</strong></td>
</tr>
<tr>
<td><strong>A1 2011</strong></td>
</tr>
<tr>
<td><strong>A2 2008</strong></td>
</tr>
<tr>
<td><strong>B</strong></td>
</tr>
<tr>
<td><strong>C</strong></td>
</tr>
<tr>
<td><strong>Datacenter</strong></td>
</tr>
<tr>
<td><strong>A3</strong></td>
</tr>
<tr>
<td><strong>A4</strong></td>
</tr>
</tbody>
</table>
2011 Thermal Guidelines – Power and Airflow

- Power – ITE thermal management drives air movers to cool components
  - Air movers, some silicon devices consume more power with elevated temperature
  - Airflow required not linear with temperature