CHILLERLESS DATA CENTERS: ASHRAE ENVIRONMENTAL CLASSES

Presented by Don Beaty, P.E., ASHRAE Fellow,
President of DLB Associates Consulting Engineers

Opening Comments

There are TWO very different types of data centers:

1) **Data Center Type 1 – Internet Data Center**
   (e.g. Facebook, Google, Wikipedia, Amazon, Ebay)

2) **Data Center Type 2 – NOT an Internet Data Center**
   (e.g. Bank, Telephone or Electric Company, Hospital, Commercial, Retail, University, Research, Airline)

These data centers have very different requirements and applying ASHRAE Guidelines change based on the type of data centers even though there are similarities.

Opening Comments

My company has designed over 4 GWs (gigawatts) or 4,000 MWs (megawatts). What I have observed is:

1) Projects typically have hundreds of variables with 5 to 10 variables being really significant.

2) The industry in general tends to solve for a single variable or two such as PUE.

3) The difference in construction cost, operating cost, and future proofing is huge when considering 1 or 2 variables versus 5 to 10 significant variables

4) There are fundamental differences in the significant variables for an Internet Data Center versus all other data centers.

5) Computers are always changing and therefore design and construction needs to continually adapt.

Opening Comments

1) These are EXCITING times for the data center industry with LOTS of CHANGE.

2) Data Center Operations like to keep things CALM & LOW RISK by MINIMIZING CHANGE.

This is a CONFLICT and an UNCOMFORTABLE situation; the RIGHT problem to solve is:

HOW to CONTINUE to keep things CALM and MINIMIZE RISK while SAVING ENERGY

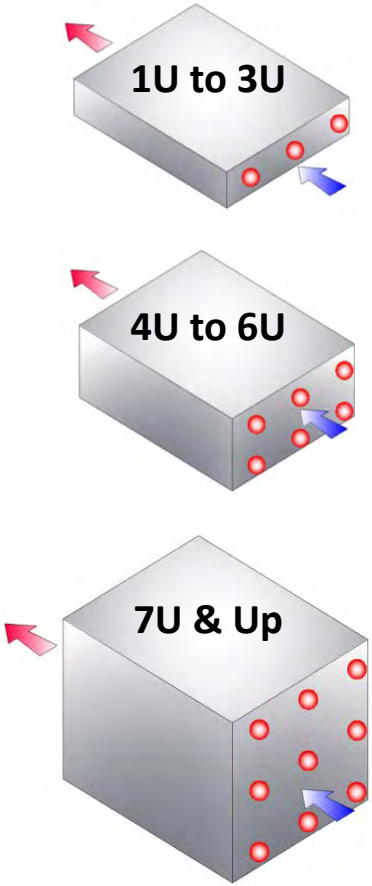
Reluctance to operate at higher temperature / humidity ranges include a perceived higher risks of outages, lower resilience, voiding IT equipment warranties, etc.

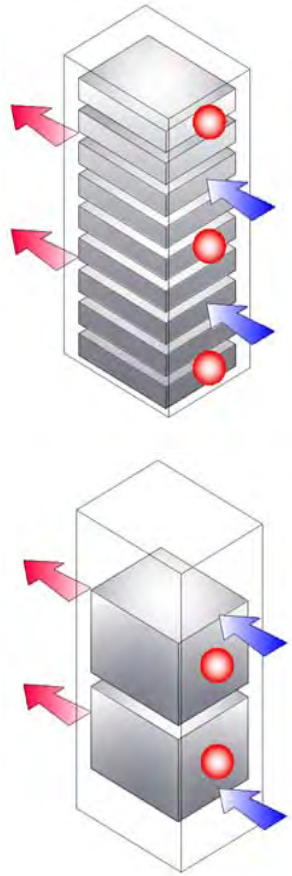
In 2004, IT OEMs from ASHRAE TC 9.9 published the first VENDOR NEUTRAL temperature and humidity ranges that did NOT void legacy IT equipment warranties.

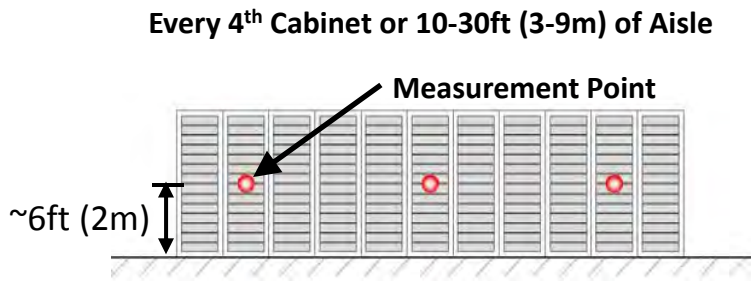
In 2008, the ranges were further expanded without voiding warranties and in 2011, new groundbreaking data was provided by IT OEMs to help guide greater energy efficiency.

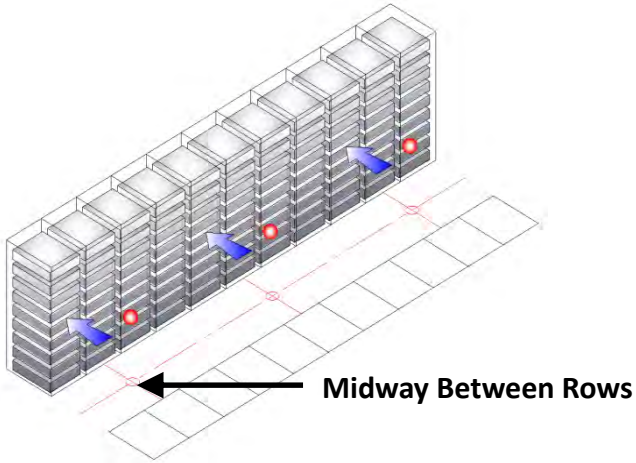
THE OPPORTUNITIES FOR COMPRESSORLESS COOLING (NO REFRIGERATION) ARE HIGH

ITE Environment – Measurement Points









Server Troubleshooting **Rack Troubleshooting** **Facility Health**

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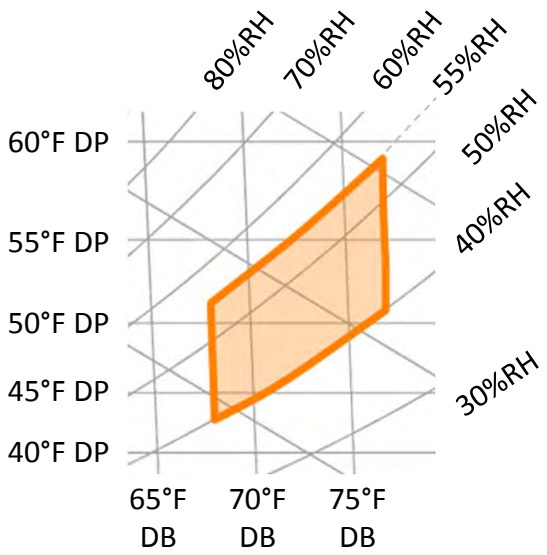
ITE Environment – Measurement Points

ITE Environment – Envelope

Recommended – The purpose of the Recommended Envelope is to give guidance to operators on the combination of maintaining high reliability and energy efficiency.

The recommended envelope is based on IT OEM's expert knowledge of server power consumption, reliability & performance vs. ambient temp.

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.



Envelope

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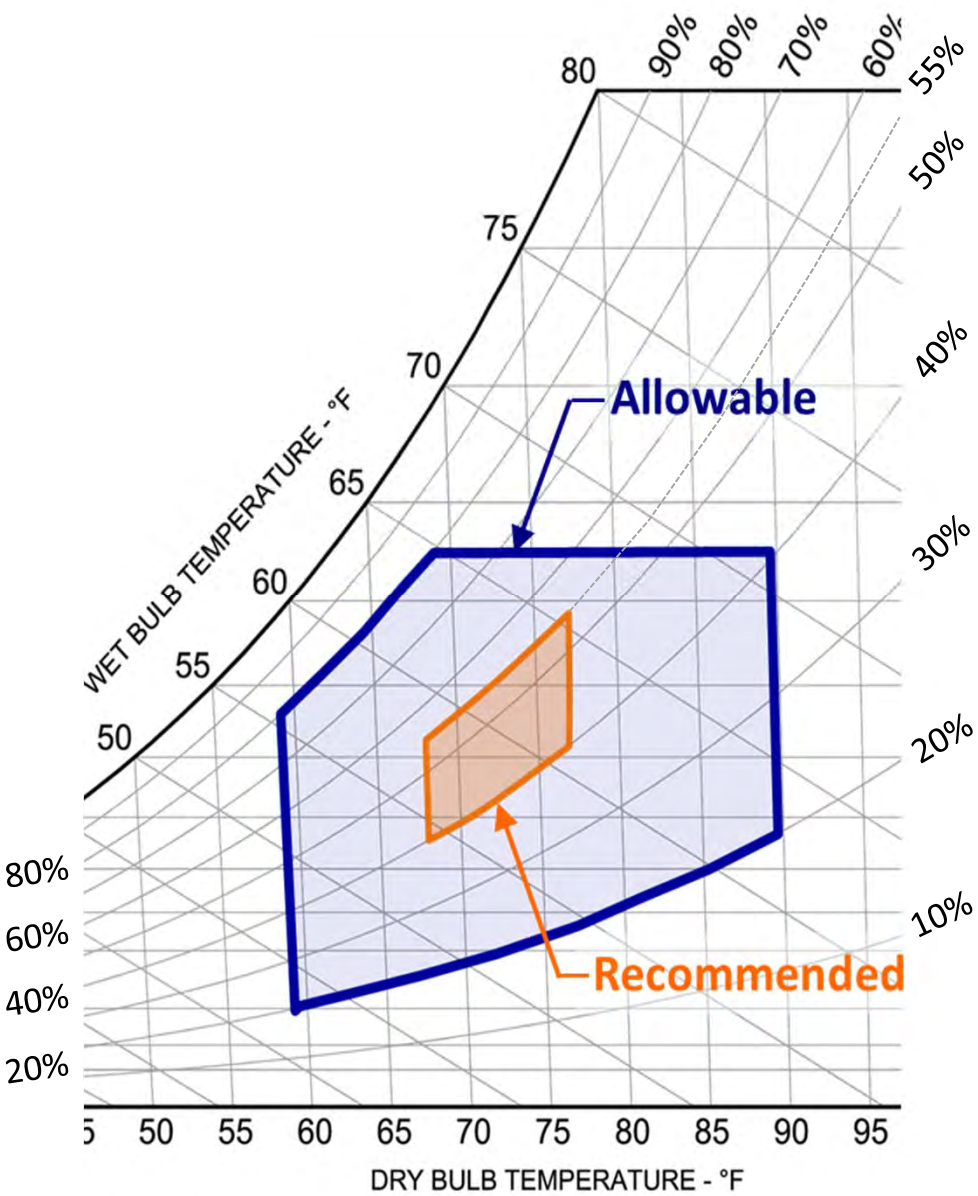
Prior to ASHRAE; single operating point, say 68°F, 50% RH

2004 Recommended Envelope – Many Operating Points (160)

Dry Bulb	% Relative Humidity																
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	
68	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
69	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
71	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
72	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
73	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
74	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
76	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
77	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=16
	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=10	=160

ITE Environment – ASHRAE Psychrometric Chart



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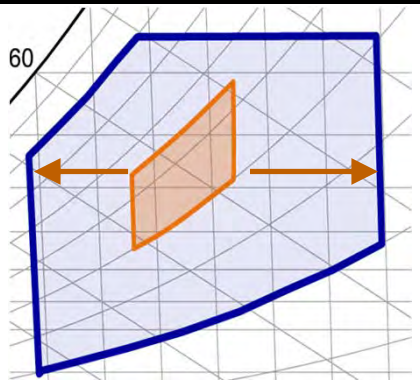
2004 Recommended & Allowable Envelope



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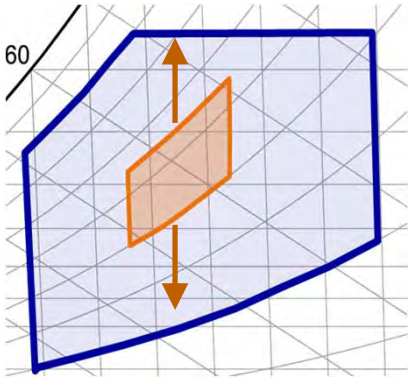
Temperature Excursion



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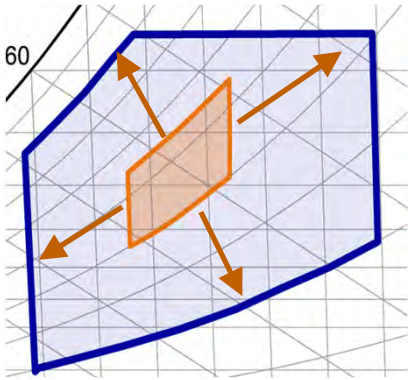
Humidity Excursion



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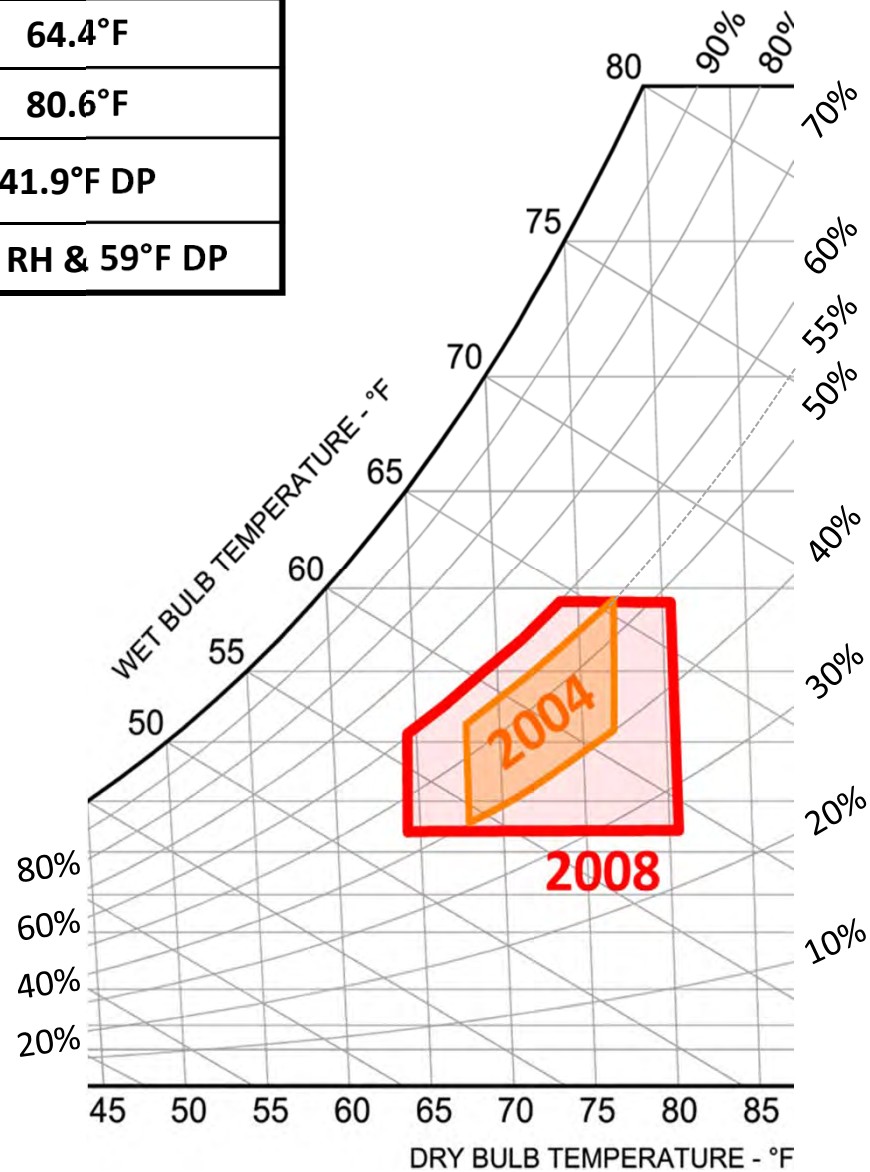
Temp. & Humidity Excursion

ITE Environment – ASHRAE Psychrometric Chart – 2004 / 2008 Recommended

Criteria	2004	2008
Low End Temp.	68°F	64.4°F
High End Temp.	77°F	80.6°F
Low End Moisture	40% RH	41.9°F DP
High End Moisture	55% RH	60% RH & 59°F DP



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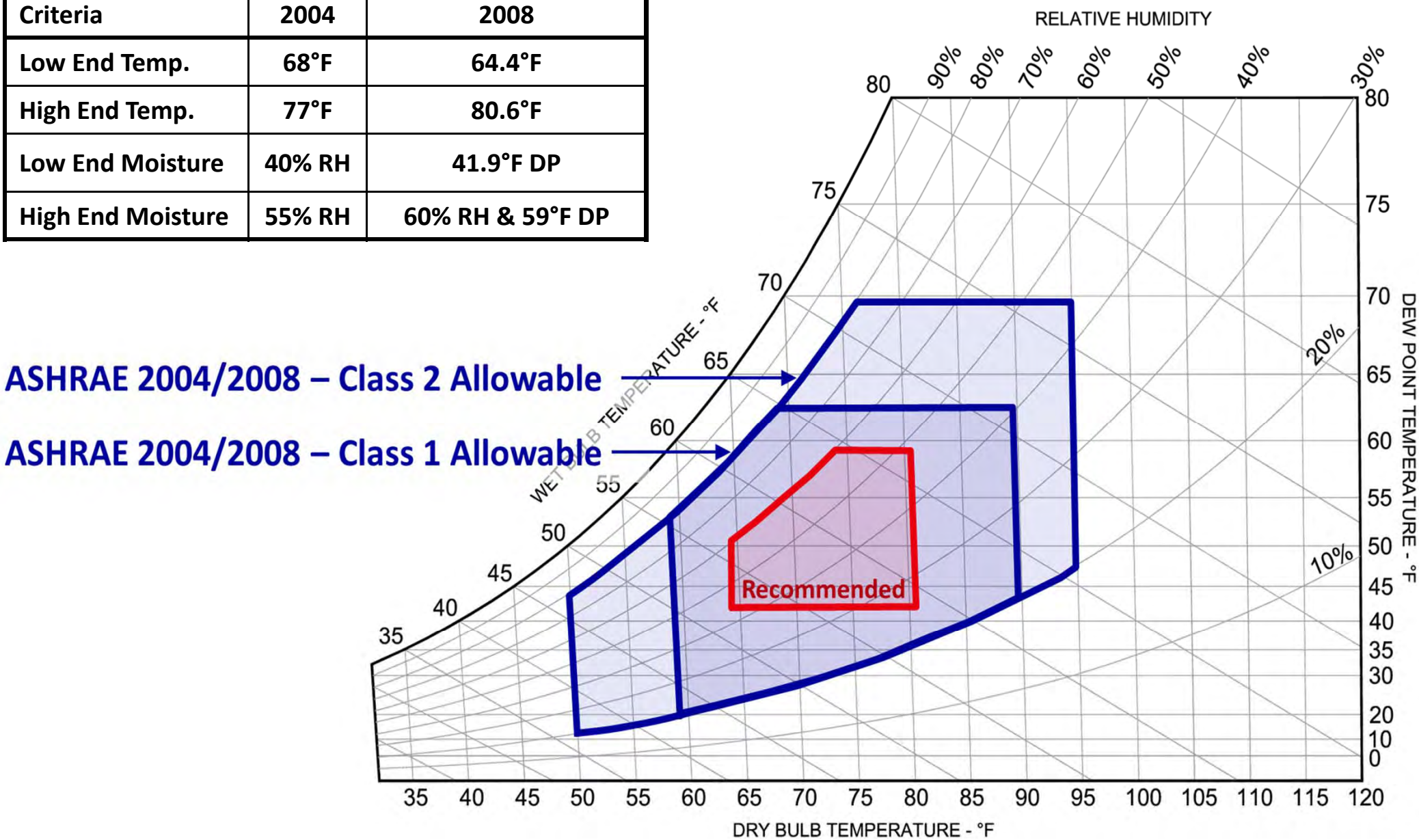
ITE Environment – 2008 Recommended Envelope Operating Points

2008 ASHRAE Thermal Guidelines Recommended Envelope – Many Operating Points (282)

Dry Bulb	% Relative Humidity																					
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	
64.4					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=17
66			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=19
67		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=20
68	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=21
69	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=21
70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=21
71	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=21
72	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=21
73	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	=21
74	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		=20
75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				=18
76	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						=16
77	1	1	1	1	1	1	1	1	1	1	1	1	1	1								=14
78	1	1	1	1	1	1	1	1	1	1	1	1	1									=13
79	1	1	1	1	1	1	1	1	1	1	1											=11
80.6	1	1	1	1	1	1	1	1														=8
	=13	=14	=15	=15	=16	=16	=16	=16	=15	=15	=15	=14	=14	=13	=12	=12	=11	=11	=10	=10	=9	=282

ITE Environment – ASHRAE Psychrometric Chart – 2004 / 2008 Recommended / Allowable

Criteria	2004	2008
Low End Temp.	68°F	64.4°F
High End Temp.	77°F	80.6°F
Low End Moisture	40% RH	41.9°F DP
High End Moisture	55% RH	60% RH & 59°F DP



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ITE Environment – 2011 Environment Specifications Table (Partial)

Class		Dry Bulb (°F)	Humidity Range	Max Dew Point (°F)	Max Elevation (ft)	Max Rate of Change (°F / hr)
Previous	Current					
Recommended						
1 & 2	**A1 to A4**	**64.4 to 80.6**	**41.9°F DP to 60% RH & 59°F DP**	N/A		
Allowable						
1	A1	59 to 89.6	20% to 80% RH	62.6	10,000	9* / 36
2	A2	50 to 95	20% to 80% RH	69.8	10,000	9* / 36
N/A	A3	41 to 104	10.4°F DP & 8% RH to 85% RH	75.2	10,000	9* / 36
N/A	A4	41 to 113	10.4°F DP & 8% RH to 90% RH	75.2	10,000	9* / 36

* More stringent rate of change for tape drives

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ITE Environment – New Data Center Classes

Previously there were four data center classes (Class 1 through 4). Two of the four classes applied to ITE used in data center applications (Class 1 & 2).

The new environmental guidelines have more data center classes to accommodate different applications and priorities of ITE operation.

This is critical because a single data center class forces a single optimization whereas each data center needs to be optimized based on the operator's own criteria (e.g. fulltime economizer use vs. maximum reliability).

The naming conventions have now been updated to better delineate the types of IT equipment. The old and new classes are now specified differently with the previous Classes 1, 2, 3 and 4 directly mapped to A1, A2, B and C.

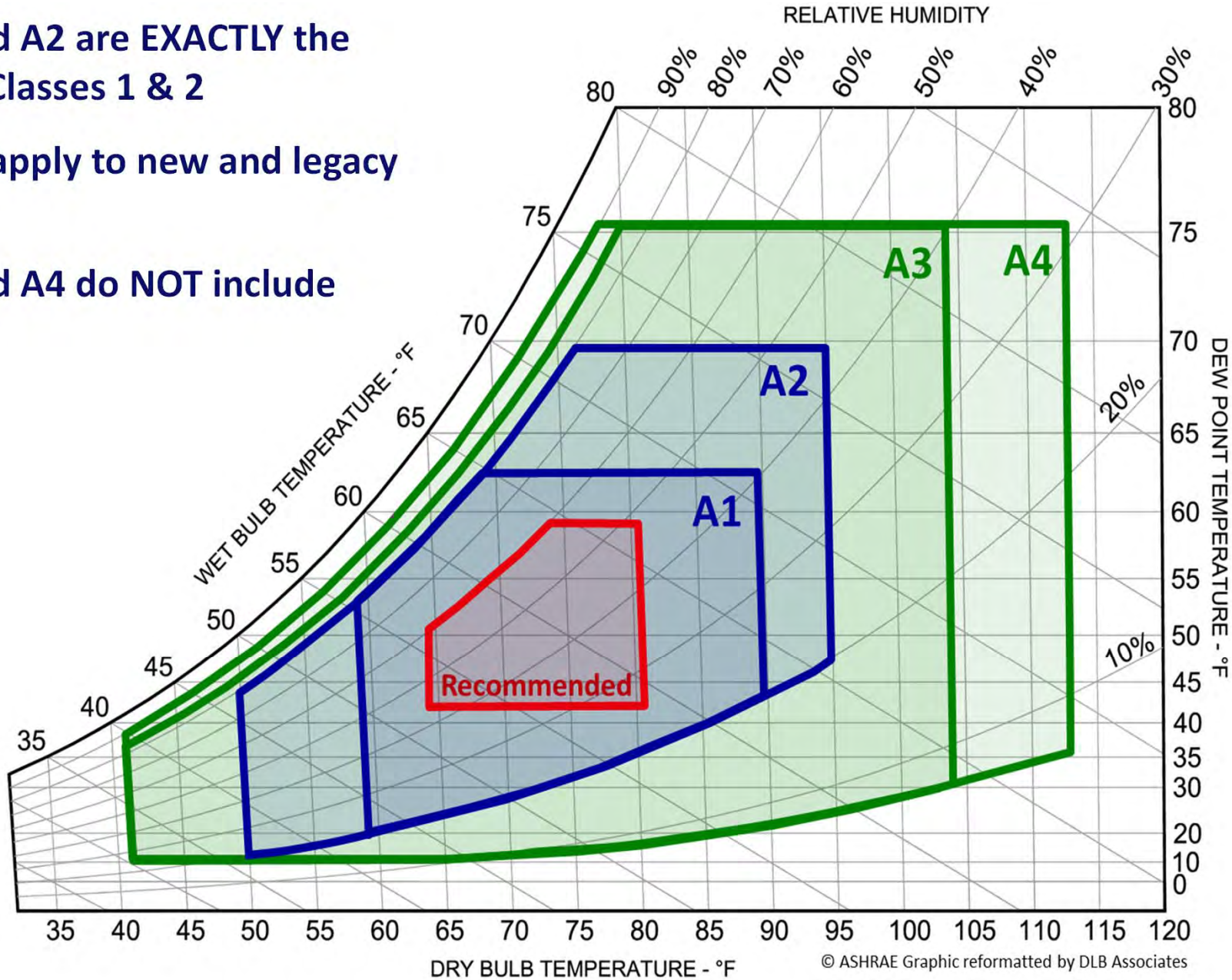
Two new data center classes have been introduced: A3 and A4.

ITE Environment – ASHRAE Psychrometric Chart – 2011

New Classes A1 and A2 are EXACTLY the SAME as previous Classes 1 & 2

Classes A1 and A2 apply to new and legacy equipment

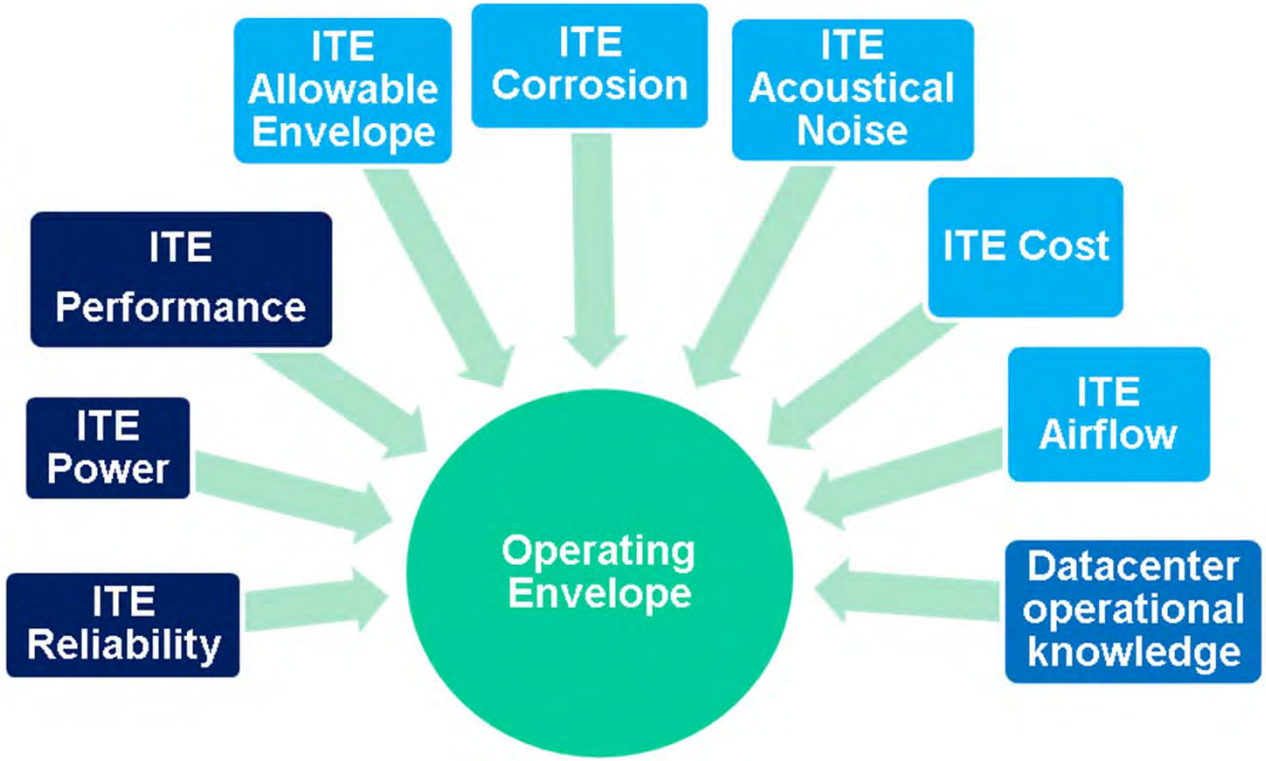
New Classes A3 and A4 do NOT include legacy equipment



2011 Thermal Guidelines – Operating Envelope

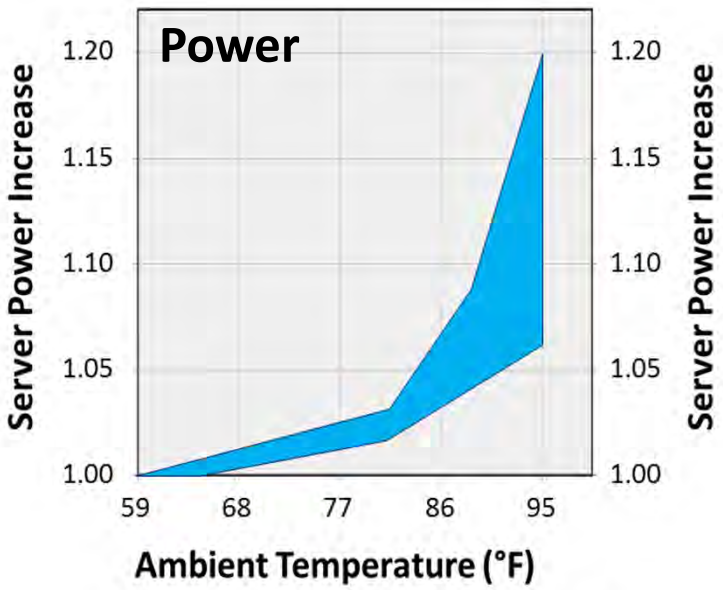
The data center optimization is a complex multi-variable problem and requires a detailed engineering evaluation to be successful.

Timeframe	Emphasis
Previously	Acoustic
Current	Energy



SHOW & TELL

Typical Power & Airflow vs. Ambient Temperature (multiple server manufacturers)



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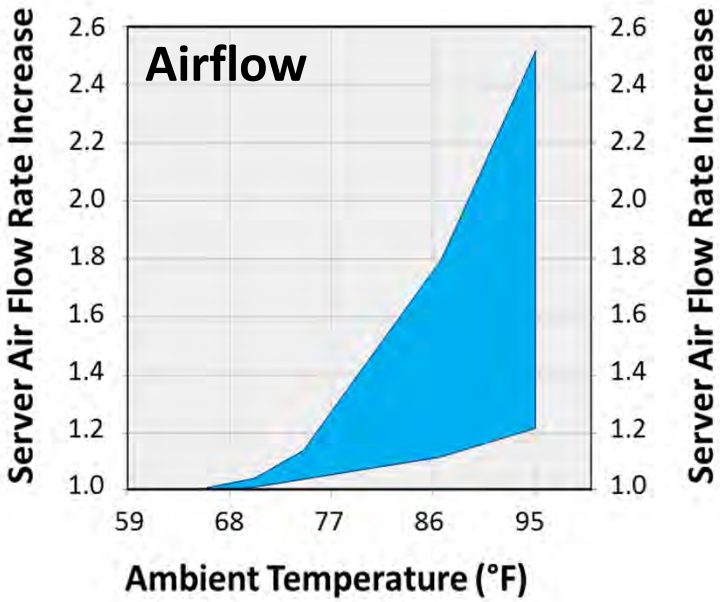

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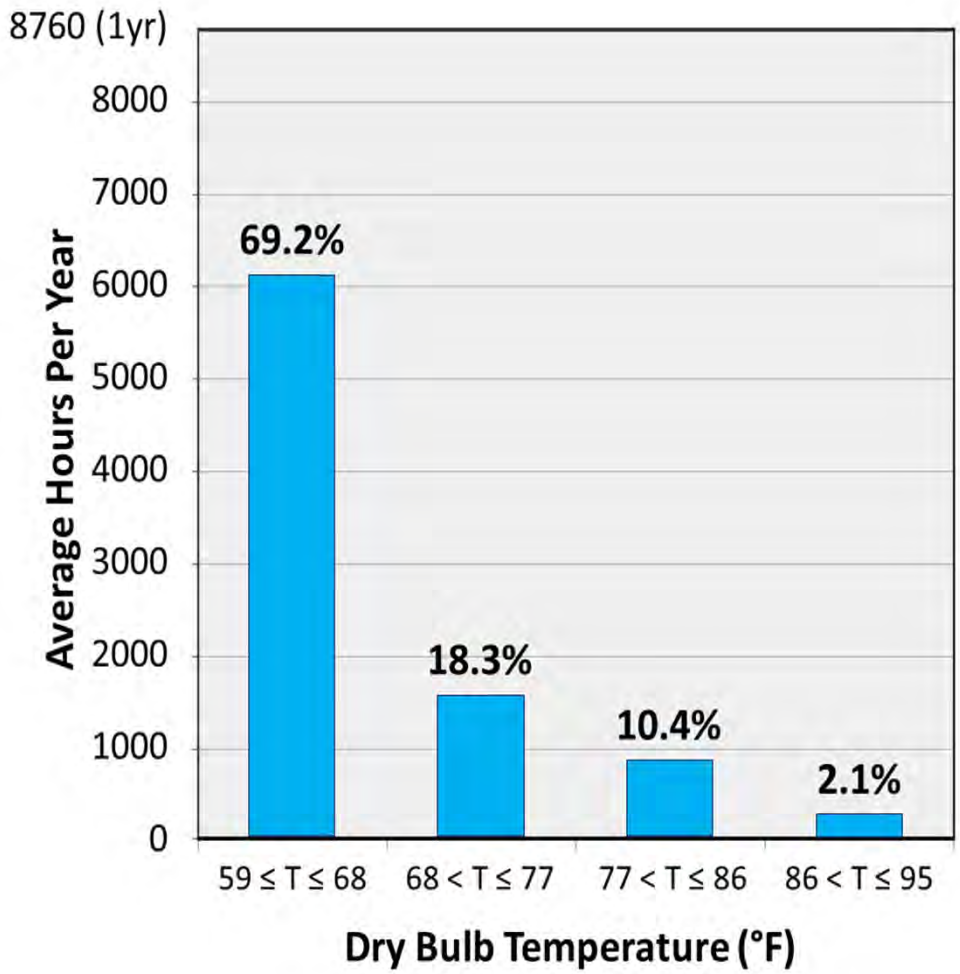
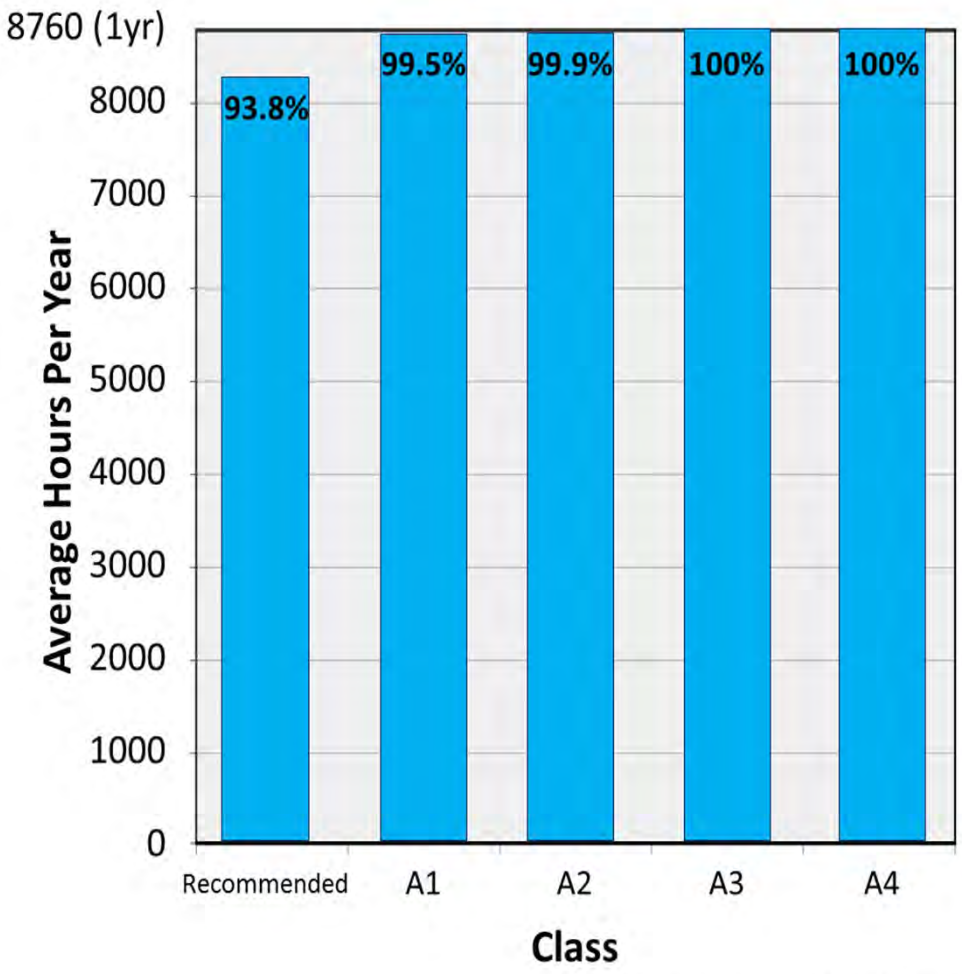
Power Increase Extrapolation From Graph					
Power	Power Increase Due to Temperature				
	68°F	77°F	80.6°F	89.6°F	95°F
Lowest	1.01	1.02	1.02	1.05	1.06
Highest	1.02	1.03	1.04	1.09	1.20

- Airflow and total power increase with temperature.
- Fan power required increases to the cube of fan speed (rpm)
- Total power increase includes both fan and component power

New York Time at Temperature Histogram

Avg. yearly dry bulb temp for New York with air mixing to maintain 59°F min.





Weather Data From ASHRAE Weather Data Viewer
(statistical average based on the most recent 25 years of data)

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Volume Server Failure Rate versus Ambient Temperature

Volume Server Failure Rate Versus Temperature				
Dry Bulb Temp (°F)	**Avg. Failure Rate**	**Annual Server Failure Rate**		**Comments**
		Typical	**Adjusted Due To Temp.**	
A	B	C	D = B x C	
59	0.72	4%	3%	Less Failures
68	1.00	4%	4%	Baseline
104	1.66	4%	7%	More Failures

NOTES

- Assumes continuous (7 x 24 x 365) operation with Dry Bulb Temp. at ITE inlet.
- Based on years of Server Manufacturers' actual failures, Component Manufacturer's failure data, and modeling (published by ASHRAE TC 9.9).

CONCLUSION:

Temperature has minimal impact on Server Failure

Volume Server Failure Rate versus Ambient Temperature

Server Reliability Trend vs. Ambient Temperature – Relative Failure Rates			
Dry Bulb Temp. (°F)	Hardware Failure Rate for Volume Servers (X-Factor)		
	Average	Lower Bound	Upper Bound
59	0.72	0.72	0.72
63.5	0.87	0.80	0.95
68	1.00 (Baseline)	0.88	1.14
72.5	1.13	0.96	1.31
77	1.24	1.04	1.43
81.5	1.34	1.12	1.54
86	1.42	1.19	1.63
95	1.55	1.35	1.74
104	1.66	1.51	1.81
113	1.76	1.67	1.84

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Lower bound, average, and upper bound are included since there is variation in server configuration and utilization

New York Net X-Factor Across The Whole Year

Time-at-Temperature Weighted Failure Rate Calculation for ITE in New York					
Location	**59 ≤ T ≤ 68°F**	**68 < T ≤ 77°F**	**77 < T ≤ 86°F**	**86 < T ≤ 95°F**	**Annual Failure Rate** (Net x-factor Total)
New York % Hours (R1)	69.2	18.3	10.4	2.1	-
X-factor (R2)	0.865	1.130	1.335	1.482	-
Failure Rate (R3 = R1 x R2)	0.599	0.206	0.139	0.031	**0.975**

Weather Data From ASHRAE Weather Data Viewer
(statistical average based on the most recent 25 years of data)

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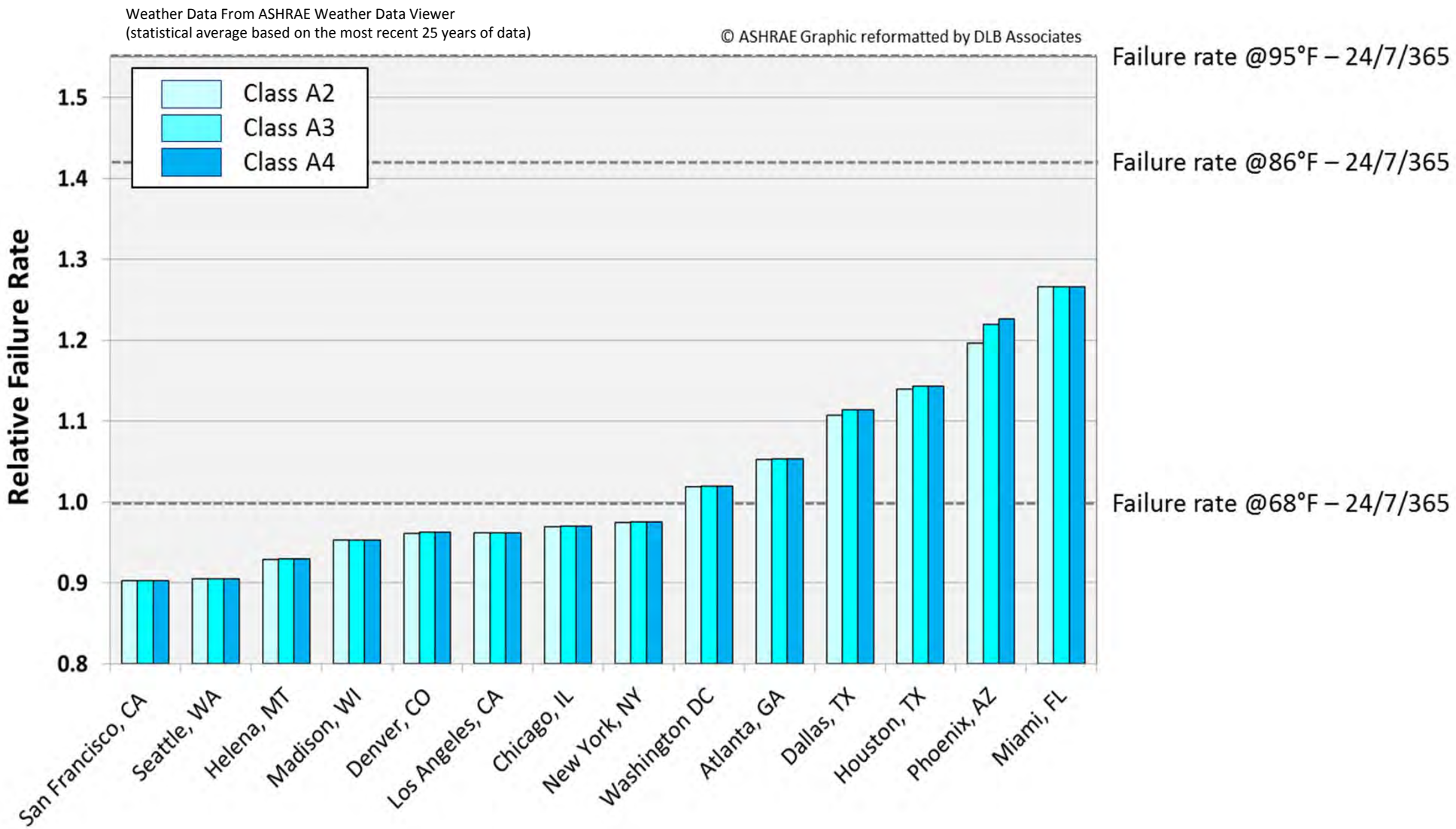
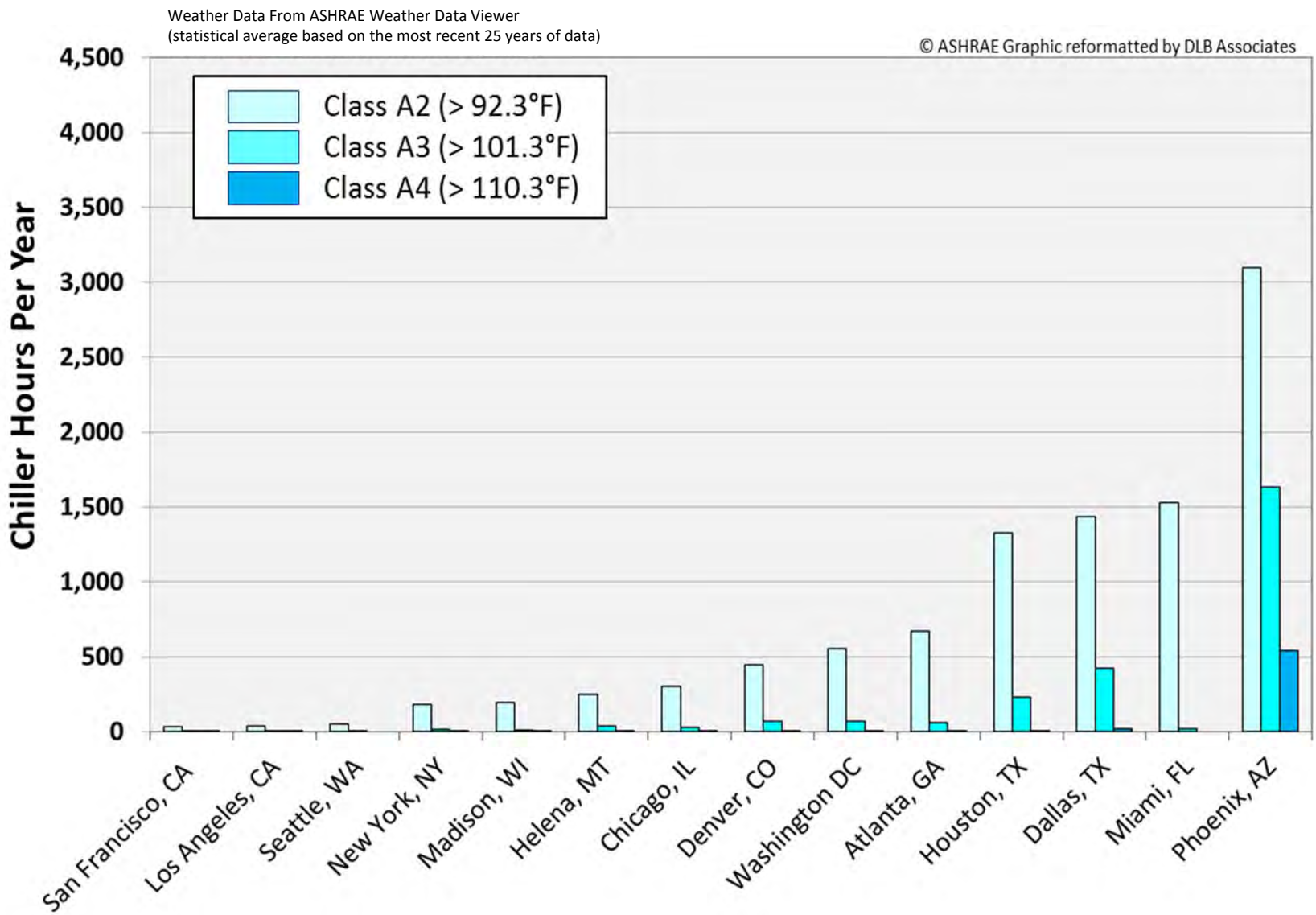
IT hardware failure in New York with a variable data center temperature is actually LOWER than if the data center was operating at a tightly controlled temperature of 68°F.

Whiteboard

Average Net Failure Rate Projections for Air-side Economization (US Cities)



Chiller Hours Per Year for Air-side Economization (US Cities)



* Assumes 2.7°F approach between outdoor air dry bulb and supply air due to fan friction

Use & Application Guidance for New ASHRAE Data Center Classes

Server Reliability vs. Contamination

Particulate and gaseous contamination becomes a more important consideration when there is an increased use of economizer systems.

The air quality and building materials should be checked carefully for sources of pollution & particulates and additional filtration should be added to remove gaseous pollution and particulates, if needed.

Products of Combustion

Pollen

Dirt

Smoke

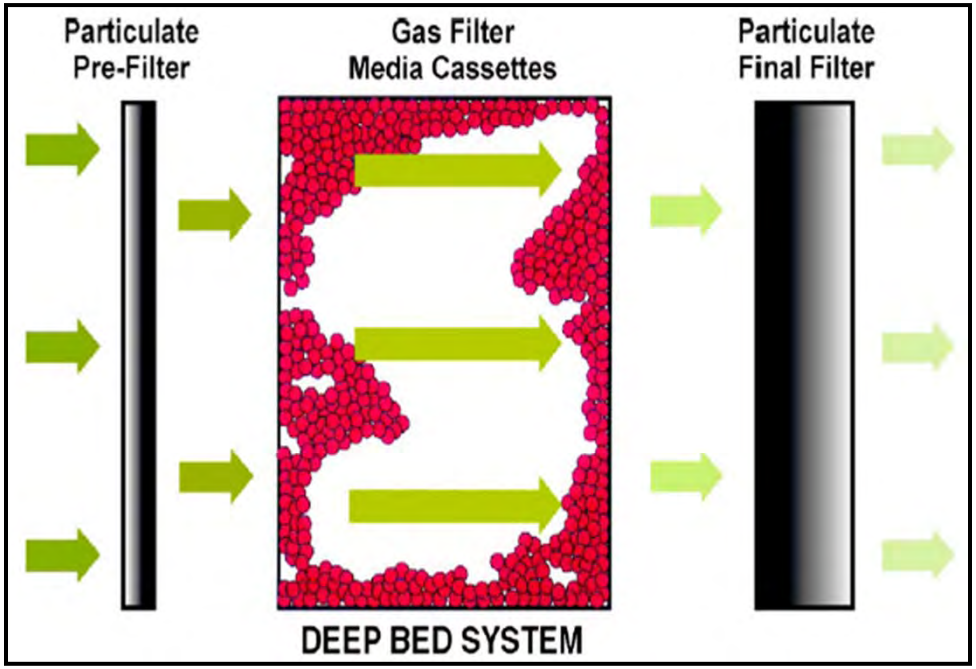
Server Failures due to Contamination

In 2006, European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) prohibited lead (element Pb) which is used in solder for electronics.

The lead solder was replaced with silver (element Ag) solder. Silver reacts with sulfides (e.g. smog) and chlorides (e.g. seawater).

Since the change to silver solder, server failures have increased.

Air Side Economizers can increase server failures but that can be mitigated through gas filtration.



Economizer Cycles – Particulates & Gaseous Contamination

Particulates should be filtered as outlined here:

1) **The room air may be continuously filtered with MERV 8 filters as recommended by ANSI / ASHRAE Standard 127-2007, "*Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners*"**
2) **Air entering a data center may be filtered with MERV 11 or MERV 13 filters as recommended by ASHRAE book titled, "*Particulate and Gaseous Contamination in Datacom Environments*"**

Gaseous contamination should be within the guidelines of the 2011 ASHRAE Whitepaper: "Gaseous and Particulate Guidelines for Data Centers" that meets:

1) **A copper reactivity rate of less than 300Å / month, and**
2) **A silver reactivity rate of less than 200Å / month**

For data centers with higher gaseous contamination levels, gas-phase filtration of the inlet air and the air in the data center is highly recommended.

SHOW & TELL

Liquid Cooling

With server heat loads steadily climbing, the ability for data centers to deliver either adequate airflow rates or sufficient chilled air is now being stretched to the limit.

Water and other liquids (dielectrics, glycols and refrigerants) may be used for Datacom Equipment heat removal instead of air.

1) **Heat rejection with liquids typically uses LESS transport energy**

2) **Liquid-to-liquid heat exchangers have closer approach temperatures than Liquid-to-air (coils), yielding increased economizer hours.**

In 2006, ASHRAE published *Liquid Cooling Guidelines for Datacom Equipment Centers* which established basic guidelines for implementing liquid cooling solutions.

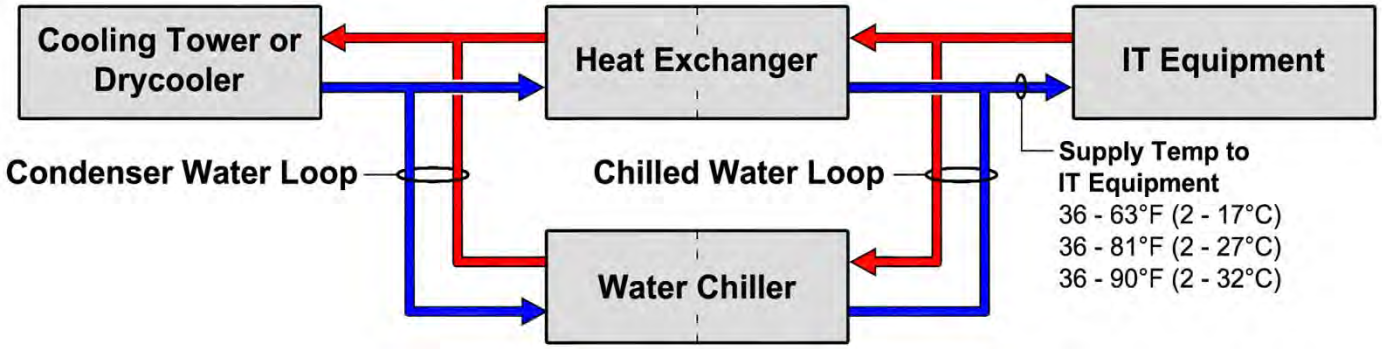
A 2011 whitepaper of the same name further defined classes and envelopes for implementing liquid cooling.

Liquid Cooling – ASHRAE 2011 Guidelines

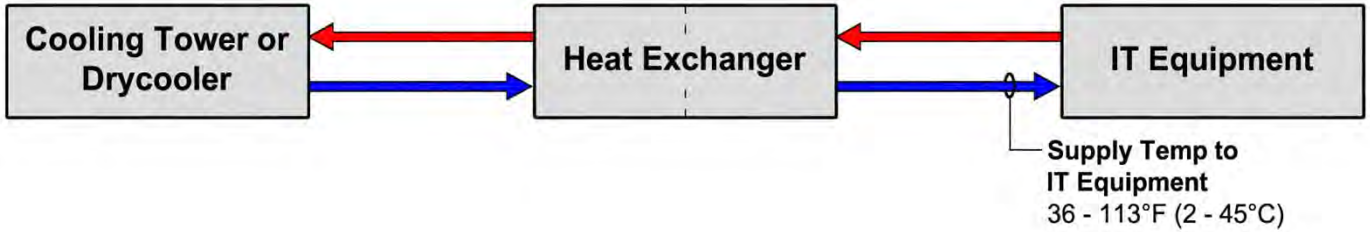
Liquid Cooling Classes	Typical Infrastructure Design		Facility Supply Water Temp.
	Main Cooling Equipment	Supplemental Cooling Equipment	
W1	Chiller / Cooling Tower	Water-side Economizer (cooling tower or drycooler)	36 – 63°F (2 – 17°C)
W2			36 – 81°F (2 – 27°C)
W3	Cooling Tower	Chiller	36 – 90°F (2 – 32°C)
W4	Water-side Economizer (cooling tower or drycooler)	N/A	36 – 113°F (2 – 45°C)
W5	Building Heating System	Cooling Tower	> 113°F (> 45°C)

Liquid Cooling – Typical Infrastructures for Data Centers

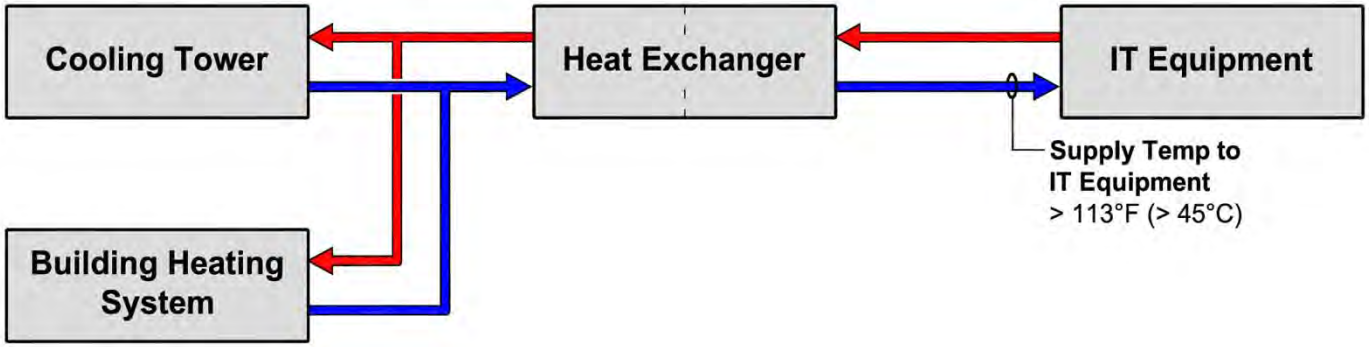
Class W1, W2, W3



Class W4



Class W5



Closing Comment

DO NOT CUT CORNERS; IT IS WAY TOO COSTLY

TC 9.9 Datacom Book Series

1. Thermal Guidelines for Data Processing Environments 3rd Edition (coming soon)
2. Datacom Equipment Power Trends & Cooling Applications 2nd Edition (coming soon)
3. Design Considerations for Datacom Equipment Centers (2006)
4. Liquid Cooling Guidelines for Datacom Equipment Centers (2006)
5. Structural & Vibration Guidelines for Datacom Equipment Centers (2008)
6. Best Practices for Datacom Facility Energy Efficiency (2008)
7. High Density Data Centers – Case Studies & Best Practices (2008)
8. Particulate & Gaseous Contamination in Datacom Environments (2009)
9. Real-Time Energy Consumption Measurements in Data Centers (2009)
10. Green Tips for Data Centers (2011)

TC9.9 Whitepapers – available for free download at www.tc99.ashraetcs.org

ASHRAE TC 9.9

2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance

Whitepaper prepared by ASHRAE Technical Committee (TC) 9.9
Mission Critical Facilities, Technology Spaces, and Electronic Equipment

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2011 Gaseous and Particulate Contamination Guidelines For Data Centers[1]

EXECUTIVE SUMMARY

Most data centers are well designed and are in areas with relatively clean environments, and most contamination is benign. Therefore, most data centers do not experience particulate or gaseous contamination-related information technology (IT) equipment failures. A small number of data centers, however, do. According to the major IT equipment manufacturers, the number of data centers with contamination-related failures is on the rise, though their numbers remain quite small.

In 2009, the IT manufacturer members of ASHRAE TC 9.9 authored a white paper (ASHRAE 2009a), titled "Particulate and Gaseous Contamination Guidelines for Data Centers," primarily targeted toward a minority of data centers that may have harmful environments resulting from the ingress of outdoor particulate and/or gaseous contamination. The document stated that for a small number of data centers, located mostly in the emerging markets, contamination can be a serious risk, and it provided insight into how to manage the contamination risk.

This white paper is an update to the original 2009 ASHRAE paper. The update is based on an ASHRAE survey of the air quality in data centers and on lessons learned in cleaning the air in contaminated data centers.

The reasons for the increasing number of data centers experiencing corrosion-related hardware failures are as follows:

- Change from lead-containing solder to lead-free solder, such as copper-tin-silver solder
- Changes in data center temperature and humidity operating conditions

1. This white paper on data center airborne contamination was prepared by ASHRAE TC 9.9, Mission Critical Facilities, Technology Spaces, and Electronic Equipment. The committee's members represent the following IT equipment manufacturers: AMD, Cisco, Cray, Dell, EMC, Hitachi, HP, IBM, Intel, Oracle, Seagate, and SGI. Helpful information for technical and nontechnical readers can be found in *Particulate and Gaseous Contaminants in Datacom Environments* (ASHRAE 2009b).

Contact Information

Don Beaty
DLB Associates
Tel: +1 (732) 910-1300
Email: dbeaty@dlbassociates.com

ASHRAE TC 9.9 Website

www.tc99.ashraetcs.org

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