How Hot Can You Go? Raising Operating Temperatures in Data Centers

Wednesday, May 17
11:15 AM – 12:30 PM
Panelists

- Dave Breland, Intuit
- John Dumler, Digital Realty
- Dale Sartor, Lawrence Berkeley National Laboratory
- John Clinger, ICF, Moderator
Dave Breland

Intuit
HOW HOT CAN I GO?

Intuit’s Journey in Quincy Washington
FIRST- I NEEDED A GUIDE

ASHRAE Datacom Series formerly TC 9.9
2.2.1 Environmental Class Definitions for Air-Cooled Equipment

Compliance with a particular environmental class requires full operation of the equipment over the entire allowable environmental range, based on nonfailure conditions.

**Class A1:** Typically a data center with tightly controlled environmental parameters (dew point, temperature, and RH) and mission-critical operations; types of products typically designed for this environment are enterprise servers and storage products.
<table>
<thead>
<tr>
<th>Class</th>
<th>Dry-Bulb Temperature, °F</th>
<th>Humidity Range</th>
<th>Maximum Dew Point, °F</th>
<th>Maximum Elevation, ft</th>
<th>Maximum Rate of Change, °F/h</th>
<th>Dry-Bulb Temperature, °F</th>
<th>Relative Humidity, %</th>
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</thead>
<tbody>
<tr>
<td><strong>Recommended (Suitable for all four classes; explore data center metrics in this book for conditions outside this range.)</strong></td>
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<tr>
<td>A1 to A4</td>
<td>64.4 to 80.6</td>
<td>15.8°F DP to 59°F DP and 60% rh</td>
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<tr>
<td><strong>Allowable</strong></td>
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<tr>
<td>A1</td>
<td>59 to 89.6</td>
<td>10.4°F DP and 8% rh to 62.6°F DP and 80% rh</td>
<td>62.6</td>
<td>10,000</td>
<td>9/36</td>
<td>41 to 113</td>
<td>8 to 80</td>
</tr>
<tr>
<td>A2</td>
<td>50 to 95</td>
<td>10.4°F DP and 8% rh to 69.8°F DP and 80% rh</td>
<td>69.8</td>
<td>10,000</td>
<td>9/36</td>
<td>41 to 113</td>
<td>8 to 80</td>
</tr>
<tr>
<td>A3</td>
<td>41 to 104</td>
<td>10.4°F DP and 8% rh to 75.2°F DP and 85% rh</td>
<td>75.2</td>
<td>10,000</td>
<td>9/36</td>
<td>41 to 113</td>
<td>8 to 80</td>
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<tr>
<td>A4</td>
<td>41 to 113</td>
<td>10.4°F DP and 8% rh to 75.2°F DP and 90% rh</td>
<td>75.2</td>
<td>10,000</td>
<td>9/36</td>
<td>41 to 113</td>
<td>8 to 80</td>
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<tr>
<td>B</td>
<td>41 to 95</td>
<td>8% to 82.4°F DP and 80% rh</td>
<td>82.4</td>
<td>10,000</td>
<td>N/A</td>
<td>41 to 113</td>
<td>8 to 80</td>
</tr>
<tr>
<td>C</td>
<td>41 to 104</td>
<td>8% to 82.4°F DP and 80% rh</td>
<td>82.4</td>
<td>10,000</td>
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<td>41 to 113</td>
<td>8 to 80</td>
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</table>

* For potentially greater energy savings, refer to the section “Detailed Flowchart for the Use and Application of the ASHRAE Data Center Classes” in Appendix C for the process needed to account for multiple server metrics that impact overall TCO.
HOW DO I KNOW?

Is there some way for me to know for sure?
Dell states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within Dell Requirements.
Dell states 10°C - 35°C while the ASHRAE Guideline allows 15°C - 32°C. ASHRAE Guidelines are well within Dell Requirements.
HP states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within HP Requirements.
HP states 10°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within HP Requirements.

50° to 95°F (10° to 35°C) at sea level with an altitude derating of 1.8°F per every 1000 ft (1.0°C per every 305 m) above sea level to a maximum of 10,000 ft (3050 m), no direct sustained sunlight. Maximum rate of change is 18°F/hr (10°C/hr). The upper limit may be limited by the type and number of options installed. System performance may be reduced if operating with a fan fault or above 86°F (30°C).
Cisco states 0°C – 40°C while the ASHRAE Guideline allows 15°C – 32°C.
ASHRAE Guidelines are well within Cisco Requirements.
Cisco states 0°C – 40°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within Cisco Requirements.
NetApp states 0°C – 40°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within NetApp Requirements.
Apple states 0°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within Apple Requirements.

**Electrical and operating requirements**

- Line voltage: 100–240V AC
- Frequency: 50Hz to 60Hz, single phase
- Maximum continuous power: 450W
- Operating temperature: 50° to 95° F (10° to 35° C)
- Relative humidity: 5% to 95% noncondensing
- Maximum altitude: 16,400 feet (5000 meters)
- Typical acoustical performance, sound pressure level (operator position): 12 dBA at idle
Pure Storage states 5°C – 35°C while the ASHRAE Guideline allows 15°C – 32°C. ASHRAE Guidelines are well within Pure Storage Requirements.

<table>
<thead>
<tr>
<th>ENVIRONMENTAL</th>
<th>RANGE</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>//M10, //M20, //M50, //M70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>5°C to 35°C</td>
<td>Derate 1°C per 300 m above 950 m</td>
</tr>
<tr>
<td>Non-operating Temperature</td>
<td>0°C to 60°C</td>
<td>Non-condensing</td>
</tr>
<tr>
<td>Operating Humidity</td>
<td>10 – 80%</td>
<td>At a maximum temperature of 33°C.</td>
</tr>
<tr>
<td>Non-operating Humidity</td>
<td>5 – 95%</td>
<td>Non-condensing, web bulb 33°C.</td>
</tr>
</tbody>
</table>
Although OSHA does not have a particular regulation or standard that covers high-temperature environments, the General Duty Clause, Section 5(a)(1) of the Occupational Safety and Health Act of 1970 (OSHA 2012b), requires each employer to “furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm.” OSHA has interpreted this rule such that employers shall provide means and methods that will reduce the likelihood of worker heat stress. These means or methods may include issuing personal protective equipment (PPE), minimizing exposure through frequent breaks, frequent hydration, and developing a heat stress program. There are various manufacturers that produce PPE for hot working environments.

### Table E.1: Permissible Heat Exposure Threshold Limit Value (TLV) (ACGIH 1992)

<table>
<thead>
<tr>
<th>Work/Rest Regimen</th>
<th>Work Load¹</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous work</td>
<td></td>
<td>30.0°C (86°F)</td>
<td>26.7°C (80°F)</td>
<td>25.0°C (77°F)</td>
</tr>
<tr>
<td>75% work, 25% rest, each hour</td>
<td></td>
<td>30.6°C (87°F)</td>
<td>28.0°C (82°F)</td>
<td>25.9°C (78°F)</td>
</tr>
<tr>
<td>50% work, 50% rest, each hour</td>
<td></td>
<td>31.4°C (89°F)</td>
<td>29.4°C (85°F)</td>
<td>27.9°C (82°F)</td>
</tr>
<tr>
<td>25% work, 75% rest, each hour</td>
<td></td>
<td>32.2°C (90°F)</td>
<td>31.1°C (88°F)</td>
<td>30.0°C (86°F)</td>
</tr>
</tbody>
</table>

¹ Values are in °C and °F (wet-bulb globe temperature [WBGT]).
INTUIT’S JOURNEY IN QUINCY WASHINGTON

THEN
- Original Design 72°F top of Rack
- CWS Temp 47°F
- Economizer Start OAWBT 45°F with a CWST of <47.5°F.
- Economizer Stop 48.5°F CWST
- Averaged 48% of year on economizer at current load

NOW
- Current Control 78.5°F top of Rack
- Warn 80°F Alarm
- CWS Temp 61°F
- Economizer Start OAWBT 58°F with a CWST of <61.5°F.
- Economizer Stop 64°F CWST
- Now average 65% on water side economizer
One of Our Cooling Plants
Balance data halls using Purkay instruments and Tileflow Software, to ensure cold aisle temps ≤ 78.5°F at top of rack.

Raised CWST to get all of the CRAH control valves at their mid range.

Operators monitor weather patterns and redundant cooling tower storage to extend economizer hours when possible.

My biggest bang is staying on my economizer as long as possible.

With my water side economizer, it’s as far as I can go. Most later version data centers around me are using 100% outside air or probably half have gone to the Munters Evaporative Cooling units.

SO THIS IS HOW WE HAVE DETERMINED HOW HOT WE CAN GO
John Dumler

Digital Realty
How Hot Can You Go?
Raising ITE Operating Temperatures in Data Centers
05/16/17
1. Digital Realty Company Overview

2. Better Buildings Commitment

3. How Hot Can You Go?
   A. Simple Colo Case Study
Digital Realty at a Glance (NYSE: DLR)
Leading Global Data Center REIT

Investment Management Approach Focused on Return on Invested Capital

- **145** PROPERTIES \(^{(1)}\)
- **30+** METROPOLITAN AREAS
- **23 MILLION RENTABLE SQUARE FEET \(^{(2)}\)**

**Equity Market Capitalization** \(^{(3)}\):
- **$18 Bn**

**Enterprise Value** \(^{(3)}\):
- **$25 Bn**

**Largest Publicly Traded U.S. REIT** \(^{(4)}\):
- **12th**
- **2016 MAY**

High-Quality Customer Base, including Global Companies Across Various Industries

- **2,000+ CUSTOMERS**

Investment Grade Ratings \(^{(5)}\):
- FitchRatings: **BBB**
- Moody’s: **Baa2**
- S&P Global Ratings: **BBB**

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1) As of December 31, 2016. Includes investments in fourteen properties held in unconsolidated joint ventures.
2) As of December 31, 2016. Includes 2.0 million square feet of active development and 1.1 million square feet held for future development.
4) U.S. REITs within the RMZ. Source: companies’ financials based on latest public filings. Based on equity market capitalization as of February 23, 2017.
5) These credit ratings may not reflect the potential impact of risks relating to the structure or trading of the Company’s securities and are provided solely for informational purposes. Credit ratings are not recommendations to buy, sell or hold any security, and may be revised or withdrawn at any time by the issuing organization in its sole discretion. The Company does not undertake any obligation to maintain the ratings or to advise of any change in ratings. Each agency’s rating should be evaluated independently of any other agency’s rating. An explanation of the significance of the ratings may be obtained from each of the rating agencies.
## High-Quality, Diversified Customer Base

### TOP 20 CUSTOMERS

<table>
<thead>
<tr>
<th>Customer Rank</th>
<th>Locations</th>
<th>% of ABR (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IBM</td>
<td>23</td>
</tr>
<tr>
<td>2</td>
<td>CenturyLink</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>EQUINIX</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>ORACLE</td>
<td>10</td>
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<tr>
<td>5</td>
<td>at&amp;t</td>
<td>44</td>
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<tr>
<td>6</td>
<td>facebook</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>LinkedIn</td>
<td>4</td>
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<td>8</td>
<td>JPMORGAN CHASE &amp; CO.</td>
<td>16</td>
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<tr>
<td>9</td>
<td>Morgan Stanley</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>verizon</td>
<td>53</td>
</tr>
</tbody>
</table>

### Customer Rank Locations % of ABR (1)

<table>
<thead>
<tr>
<th>Customer Rank</th>
<th>Locations</th>
<th>% of ABR (1)</th>
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<tbody>
<tr>
<td>11</td>
<td>Fortune 50 Software Company</td>
<td>6</td>
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<tr>
<td>12</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>13</td>
<td>TATA COMMUNICATIONS</td>
<td>17</td>
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<tr>
<td>14</td>
<td>NTT Communications</td>
<td>14</td>
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<tr>
<td>15</td>
<td>rokspac0</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>Hewlett Packard Enterprise</td>
<td>5</td>
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<tr>
<td>17</td>
<td>amazon</td>
<td>14</td>
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<tr>
<td>18</td>
<td>UBER</td>
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<td>19</td>
<td>ebay</td>
<td>2</td>
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<tr>
<td>20</td>
<td>NaviSite</td>
<td>4</td>
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</table>

**Total Annualized Base Rent**: 43.4%

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**Note**: As of December 31, 2016. Represents consolidated portfolio plus our managed portfolio of unconsolidated joint ventures based on our ownership percentage. Our direct tenants may be the entities named in this table above or their subsidiaries or affiliates. 

1) Calculation based on annualized base rents (monthly contractual cash base rent before abatements under existing leases as of December 31, 2016 multiplied by 12).
Unmatched Global Scale
Providing Customer Solutions in 30+ Metro Areas
Industry Leading Sustainability
Track Record and Commitment to Energy Efficiency

Management and organizational commitment to sustainability

- Full time REIT-sustainability expertise in-house
- Senior executive with sustainability management responsibility
- Integrated cross-functional teams

Track record of sustainable project investment

- Successfully allocated $493 million of proceeds from data center industry’s first green bond
- Signed long term contract to purchase 100% renewable energy for US colocation business

Industry-leading clean energy solutions

- 600 gigawatt-hours of renewable power sourced globally
- #6 in EPA Green Power Partnership Tech and Telecom sector for renewable energy

Award-winning data center designs with third party certification

- 50+ green building certifications globally
- 5 new certifications in 2016 including Green Mark Platinum rating for 3 Loyang Way, Singapore

Thought leadership and innovation in energy efficiency

- US DoE Better Building’s Challenge for data centers participant; 20% energy savings by 2024
- The Green Grid board-level and technical committee membership

Better Buildings Summit | May 16, 2017
Better Buildings Challenge Update

• How is Digital involved?
  – Digital has publicly committed to reduce our non-IT energy intensity, within a 20MW sub-portfolio of properties, by 20% over 10 years.
  – ~25% Cumulative Progress (vs. 2013 baseline)
    • Air Management Improvements
    • Controls enhancements
    • CRAH/C EC fan upgrades
    • Operational efficiencies
  – EPA Energy Star Certifications
How Hot Can You Go?

**WHY RAISE TEMPERATURES?**

Raising Temps because....
- A vendor told me it was required by code
- I’ll save energy by just doing it
- I heard it was a good idea at a conference
- My competition is doing it
- I think I can get good PR miles out of it
- My boss told me to

Raising Temps because....
- **ENERGY SAVINGS**
  - Lower fan/pump energy
  - More Economizer Hours
  - Better efficiency performance on HVAC
- **Couple w/ Containment for improved reliability (X FACTOR)**
  - ASHRAE Thermal Guidelines
  - Reduce hardware failures

David Quirk P.E. – VP, DLB Associates
Why is air management important: Big Picture

### Air Flow Problems in Data Centers

**Recirculation air flow**
- Return air
- Recirculated air (if servers need more air than supplied)
- Supply air

**Bypass flow**
- Bypass air flow
- Bypass air flow
- Bypass air flow

**HVAC (Air conditioning) – CRAC unit**
- Too much airflow (over-cooling)
- Too little airflow (under-cooling)

**Current**

**Cold Spots**
- IT CFM demand = CRAH/C CFM
- Better Buildings Summit | May 16, 2017

**Hot Spots**

**Balance**
- Delivery
“Seeing” Air Management Issue

FLIR ONE ~ $250
Real-World Findings:
Existing Annual Energy Costs for fans on 9th Floor from CRAC’s
16 units x 4.1HP x 3 motors/unit
= 12.3HP/unit x 16 units
= 196HP

196HP x 0.746kW/HP
= 146kW

146kW x 8760hrs/year
= 1,278,969kWh/year

1,278,969kWh/year x $0.08/kwh
= $102,000/year in energy costs from fans only.

IT airflow demand ~600kW x 130CFM/kW = 78,000 CFM
Actual Airflow = 15,000 CFM x 16 units = 240,000 CFM
-> 3x airflow, @ 0.3” W.C.

How Do We Quickly Identify And Address Air Management Issues and make...
Audit Tool: Audit-Buddy

- Collects data on temperature and humidity on a rack level
  - Plots graphs and produces tables for quick visual analysis by operators
  - Spread out sensors help identify under and over-compensated spots on a rack level
  - Comes in both °F and °C for facilities using metric
- Investigate customer feedback/complaints conveniently
  - Provide accurate data to customers to prevent mistrust
  - Easily identify and rectify complaints
Audit-Buddy Scan Modes: QuickScan

- 20 secs active scan for each rack in an aisle (40 secs total per rack)
- Quick way to detect trouble spots on an aisle level before deep analysis
- Produces contour maps
  - Temperature
  - Humidity
  - Dew Point
  - Delta-T
• Deeper analysis on a rack level
• Last up to 1 hour to 7 days
• Samples every minute
• Generate time-trend vs temperature graph
• To track temperature trends on problematic racks with respect to time
## Scan Modes: Real-World Findings - Level 9 floor plan

<table>
<thead>
<tr>
<th></th>
<th>Nil</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tr>
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</table>

- **H**: Hot Aisle
- **C**: Cold Aisle

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Simple Colo Example - Findings & Actions

- Large span of cold isle temps, most at or below 68°F. Why? **WE MUST GO HOTTER**
- A few isolated hot spots. *(site controlling to worst case)*
- Step #1: Fixed Air Management issues:
  - Cold isle doors pre-existing
  - Added numerous blanking panels (many pre-existing)
  - Added dampers on perforated tiles to help balance airflow
    - Sanity check with balometer hood (CFM vs IT load – 800+CFM/tile)
- 0.3” W.C. - Modified CRAC fan controls to modulate fans to 70% minimum on low/no call for cooling.
- Identified CRAC in area of influence with sustained no-load and turned off.
  - Minimal temperature change (small drop – less warm air mixing with cool air under floor)
  - Saved $6,400/yr
- Level Set
- Start Increasing CRAC Return Air Set point – 1°F every full day.
Simple Colo Example - Findings & Actions

- Raised set points of remaining area of influence CRAC return temps between 6°F-8°F
  - (Baselines 70°F-72°F)
  - Increased capacity (1-3%)
  - Systematic process
- Rack inlets raised in somewhat linear fashion (surprising)
- Inlet temps remain within SLA’s, more efficient operation and reduced stranded capacity
- No operational issues to date.
- More Upgrades ongoing (targeting turning off another 3 CRAC units (of 16 total), additional containment, wireless monitoring.)

CONTINUE EVALUATING INCREASES
John R. Dumler, P.E., C.E.M.
Technical Operations Manager, Energy

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jdumler@digitalrealty.com

www.digitalrealty.com
Appendix
Data Hall: An Interactive Map – Aisle View

Aisle Display: Temp for Cabinets E21 to R21
Data Collected on: October 7-10, 2016
Current View: Cold Aisle - Inlet Temperatures

Max Temp: 73.2 °F  Min Temp: 67.9 °F  Avg Temp: 71.4 °F

Cabinet Order Shown: Same as Data Hall Plan View
Simple Colo Example - Identifying Issues & Baselining

“Seeing” Air Management Issue
A Temperature Contour Plot

Temperature Contour Plot
Generated 10-06-2016 12-04

QuickScan Temperature vs. Rack Number Plot (A)

[Series Name]

Rack Number

Location No.  1 Location No.  2 Location No.  3 Location No.  4 Location No.  5 Location No.  6

Temperature (˚F)

Bottom ASHRAE Limit

Return
Dale Sartor

Lawrence Berkeley National Laboratory
What does your Energy look like?

Compute Systems

Cooling Systems
The New Home for NERSC
UC’s Shyh Wang Hall

- Formerly, the Computation Research and Theory Facility (CRT)
- 142,000 square feet total
- IT load will dominate building
- 4 large AHUs for air-cooled loads
- 4 cooling towers with a heat exchanger for water-cooled loads
- Water-cooled supercomputers
- Air and water side economizers
- Air-side heat recovery for heating offices
- IT loads cooled without compressors
NERSC hosts Cori (#5 Top 500, Nov 2016)
File Systems and Air Cooled Computers
Air System Design Approach

- Annual PUE less than 1.1
- Air-Side Economizer
- Direct Evaporative Cooling for Humidification/Pre-cooling
- Low Pressure-Drop Design
Free Cooling – Outside Air Based Design

1. Blue = recommended supply
2. Green can become blue mixing return and outdoor air
3. Most of the conditions below and right of blue can be satisfied w/ evaporative cooling
4. Hot and humid hours will enter the “allowable” range or require cooling water from tower
Free Cooling – Water Based Design

- CRT Performance
- Annual PUE less than 1.1
- Closed-loop treated cooling water from cooling towers
- Headers, valves and caps for modularity and flexibility
1st Phase 20k Sq Ft Computer floor
Seismically isolated from building
12.5 MW power (40 MW max)
10 MW liquid cooling (20 MW max)
6 MW of liquid cooled systems installed
2 MW Air Cooling (17 MW max)
100 % Outside air capable
Real Life

• Performance
• Opportunities for improvement/optimization
• Lessons learned
Liquid Cooling Performance Baseline

![Graph showing Power (kW) vs. Outside Air Wetbulb Temperature (°F) for Baseline CWGP Pump kW, Baseline TWGP Pump kW, Baseline Total CT Fan Power kW, and Baseline Total System kW.](graph.png)
Liquid Cooling Performance Balanced

5 Degree Approach

Power (kW)

Outside Air Wetbulb Temperature (°F)

5 Deg Approach CWGP Pump kW
5 Deg Approach TWGP Pump kW
5 Deg Approach Total CT Fan Power kW
5 Deg Approach Total System kW
Baseline Conditions

65F < SAT < 75F
30% < RH < 70%

Heating (recirculation)
Humidifying (direct evaporation)

NO Dehumidifying
Allowing Lower Relative Humidity

Reduce Minimum Supply Air Temperature and Humidity

Min SAT = 55F
Min DP = 10F

Heating
Humidifying

NO Dehumidifying
# Electricity and Water Savings

<table>
<thead>
<tr>
<th>Measure Title</th>
<th>Energy Savings (kWh)</th>
<th>Water Savings</th>
<th>Cost Savings</th>
<th>PUE Reduction</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>1 Optimize Cooling Tower Fan and Pump Controls</td>
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<td>360,000</td>
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<td>$20,880</td>
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<tr>
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<tr>
<td>Physical Projects</td>
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<td></td>
</tr>
<tr>
<td>6 Cold Aisle Partial Containment</td>
<td>100,000</td>
<td>-</td>
<td>-</td>
<td>$5,800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,400,000</td>
<td>400,000</td>
<td>500,000</td>
<td>$100,000</td>
</tr>
</tbody>
</table>

IT kWh 48,200,000 Extrapolated based on typical operation
Total Non-IT kWh 3,200,000 Does not include CRAY fans
PUE 1.07
Estimated Post-Case PUE 1.04
Savings as a Fraction of Cooling System kWh 56%
### Rough Savings Estimates

<table>
<thead>
<tr>
<th>Measure Title</th>
<th>Energy Savings (kWh)</th>
<th>Water Savings</th>
<th>PUE Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Controls</strong></td>
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<td><strong>Total</strong></td>
<td>1,400,000</td>
<td>400,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>

**Cost of electricity**

- **Non IT load savings**: $1,190,000 kWh
- **Average mechanical kW savings**: 136 kW
- **Total cooling system energy**: 3,200,000 kWh
- **Total system power**: 365 kW
- **IT Load**: 5500 kW
- **IT kWh**: 48,200,000 kWh
- **Baseline PUE**: 1.07
- **PUE after implemented measures**: 1.04

**Note:** The table represents the estimated savings in energy and water, along with the PUE reduction for each measure. The total savings across all measures are calculated and noted in the **Total** row.
Measure Breakdown

- Cooling tower supply temperature reset based on wetbulb temperature
- Reduce minimum tower water pump speed based on minimum cooling tower flow
- Install booster pump to serve RTUs, lowering differential pressure in main cooling water loop
- Replace closed loop bypass valves with flow limiters
- Adjust closed loop differential pressure reset
- Reduce AHU supply air temperature as outside air temperature drops, and control fan speed based on max cold aisle temperature
- Turn off redundant cooling tower pump to improve pump efficiency
- Enable variable speed fan control on CRAY units and optimize cooling water temperature
- Expand cold aisle temperature/RH envelop based on ASHRAE 2015 guidelines
- Install firmware to enable ESS Mode (eco mode) for UPSs
Cooling System Optimization

Total Power Comparison

- Baseline Total System kW
- Reduced Min Speed Total System kW
- 4 Deg Approach Total System kW
- 5 Deg Approach Total System kW
Skip the Double Conversion Losses
Our Approach

1. Identify opportunities
2. Identify critical control boundaries
3. Try it out!
4. Verify using trend data
5. Repeat until optimized

All parties work closely throughout the project
Takeaways

- Involve full team from measure development through implementation
- Start with client priorities and question everything
- Incremental, iterative progress can be most affective
- Don’t underestimate interconnectivity of systems
- A sub 1.1 PUE data center can still be improved!
The source of cool air and cool views …
Questions?
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Berkeley, CA 94720

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(510) 486-5988

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