A New Metric for Data Centers?

Results of a Field Test of the Rack Cooling Index (RCI)

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JOHNSON CONTROLS

Background

- As an owner of multiple data centers - and as a manager of our customers' data centers - Johnson Controls has experienced the challenges of cooling high density computing environments.
  - 10K/ft.^{2} Primary data center- Blades & Super Servers
  - 2 million ft.^{2} under contract - High Tech & Financial Services sites with loads exceeding 125w/ft.^{2}
  - Controls-based strategies are utilized to optimize cooling capacity

Purpose of This Presentation

- The Rack Cooling Index (RCI) is a proposed methodology for measuring the effectiveness of a Thermal Management strategy.
- In an earlier test, the RCI demonstrated the differences between top-down and bottom-up cooling strategies in site with large concentrations of high density computing.
- By testing it in our own primary site, we hope to establish its potential value to a controls-based approach in a site with lesser amounts of high density computing.

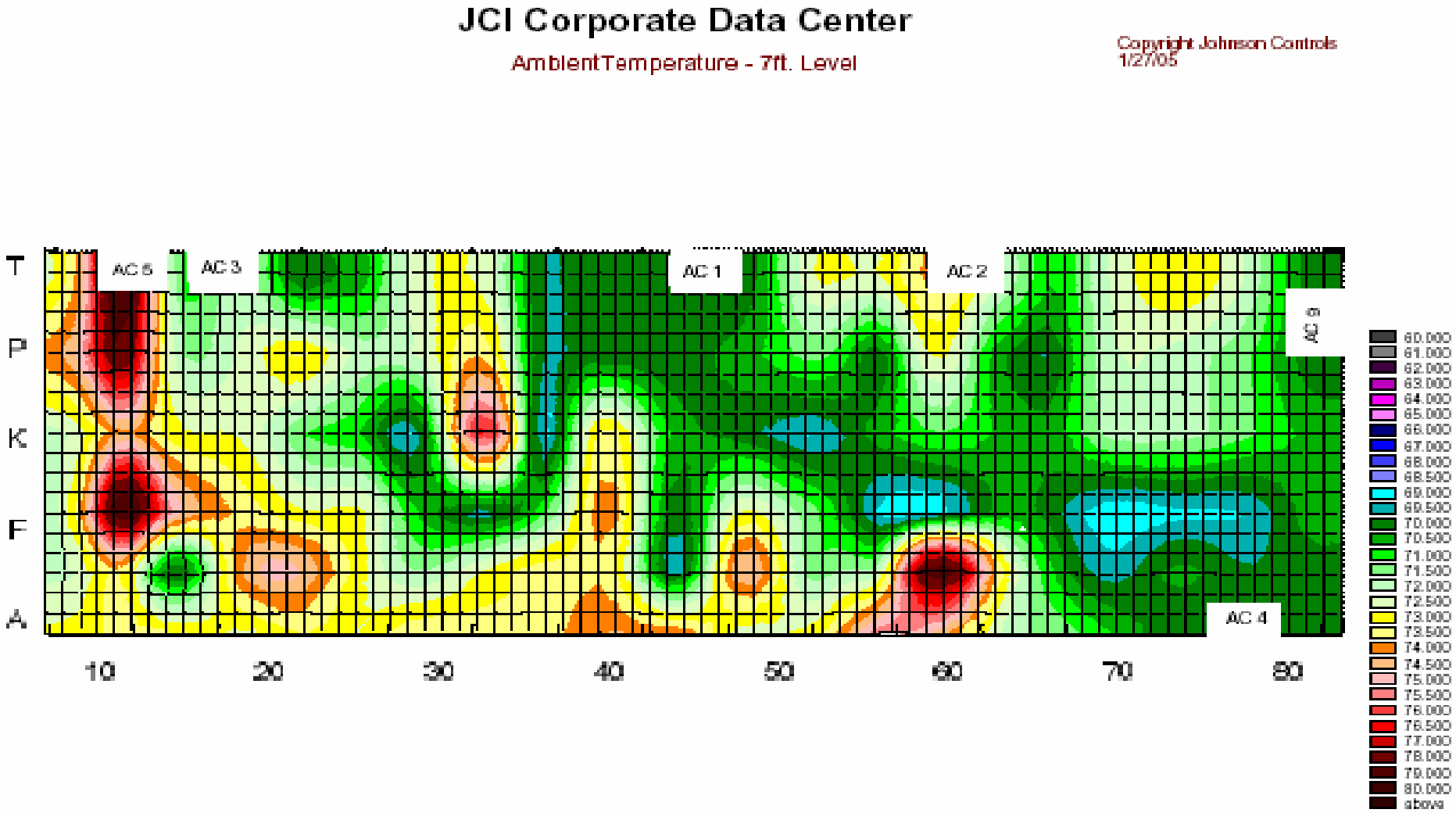
Agenda

- Definition of a controls-based strategy for Thermal Management
- Limitations of this approach in Legacy Sites
- The RCI
  - Background, Definition, and Calculation
  - Field Test Methodology and Results
- Conclusions
- Q & A

Elements of a Controls-based Strategy

- CRAC Supply and Return Temperature sensors tied to BAS
- Automated or manual measurement of Ambient Temperature, RH, and Airflow
- Application-driven identification of anomalies in performance signatures
- SME analysis of cause and effect
- Site implementation of recommendations
- Verification of results

Example - JCI Data Center



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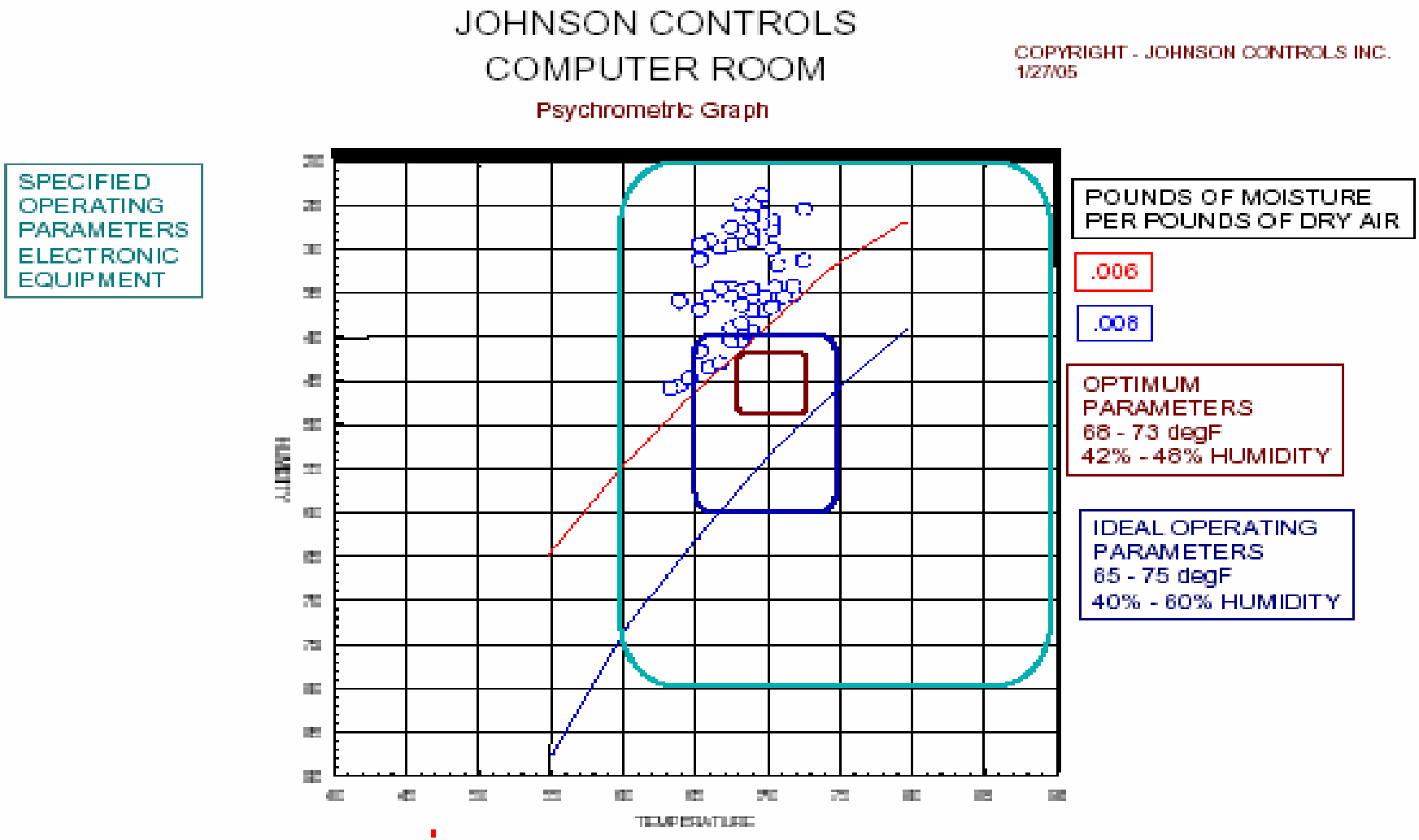

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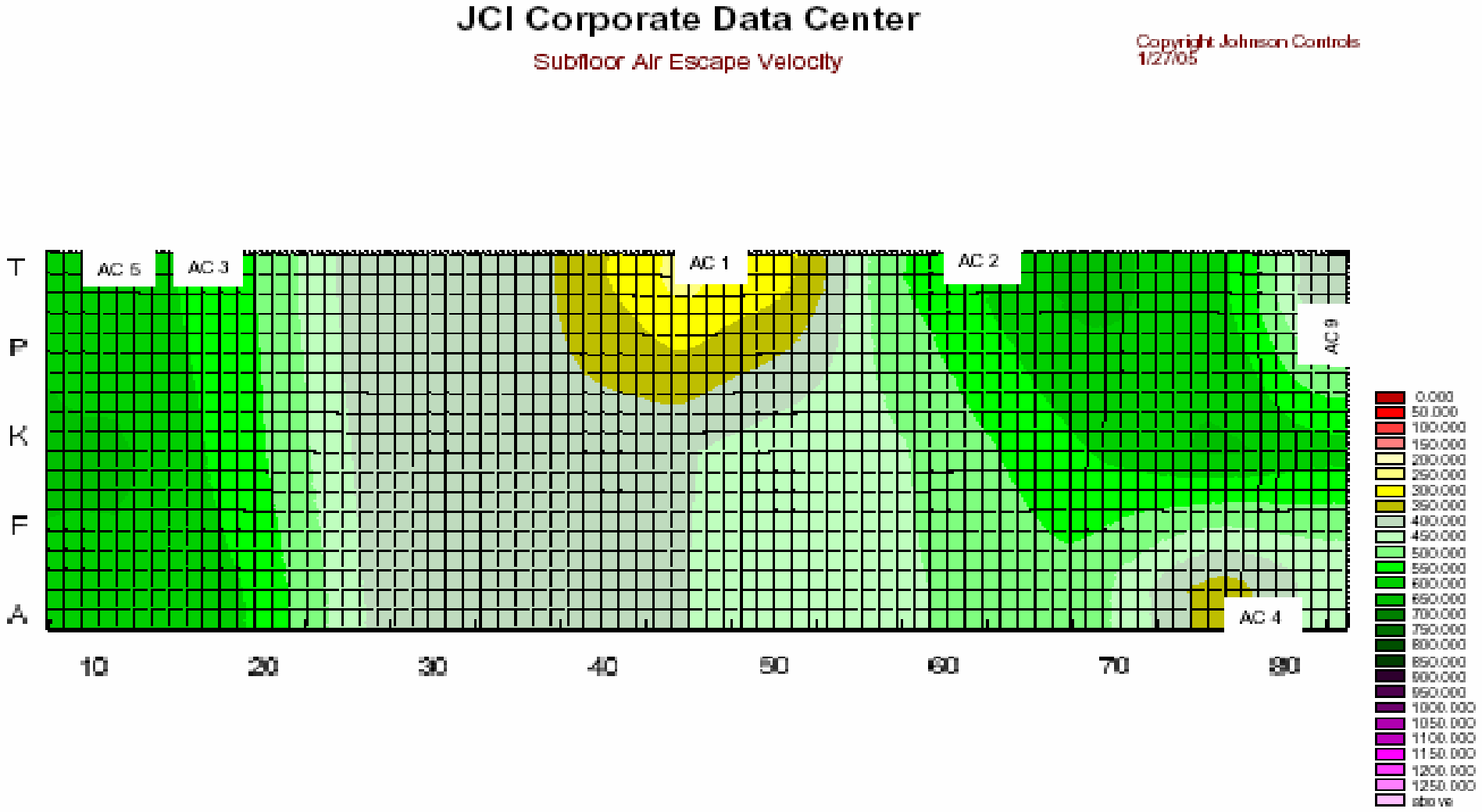


Example - JCI Data Center

OVERALL CONDITIONS -- PREVIOUS AUDIT (9/2/04)

Snapshot Data Summary

	Variable	Low	High	Average
JCI Data Center	Ambient Air Temperature 3 ft	61.2 degF	75.6 degF	69.8 degF
JCI Data Center	Ambient Air Temperature 7 ft	67.5 deg F	80.2 deg F	73.5 deg F
JCI Data Center	Ambient Air Relative Humidity	39.9%	59.2 %	46.5 %
JCI Data Center	Subfloor Escape Air Velocity	319 FPM	607 FPM	449 FPM
JCI Data Center	Subfloor Escape Air Temperature	60.1 degF	64.4 degF	62.0 degF

Value above specifications; Value within specifications; above ideal range; Value within ideal range; Value within specifications; below ideal range; Value below specifications; No specifications applicable

OVERALL CONDITIONS -- CURRENT AUDIT (1/27/05)

On January 27, 2005, the average 3 ft. level ambient temperature of the Johnson Controls Data Center was 68.6 deg F with a relative humidity of 33%. The moisture content of the room was very low, averaging .0049 lbs. of moisture per lb. of dry air. The ideal environment is considered 71 degrees at 45% relative humidity. The temperature variance throughout the room was 16 deg F at the 3 ft. level and 11.9 deg F at the 7 ft. level. The highest temperatures recorded were within the "hot" or discharge row at E10 to P10 and at the exhaust of the Blade Servers located at C59. The previous reduction in the number of perforated floor tiles continued to affect the room positively, keeping all subfloor escape velocities within the ideal range.

Mission Critical Facility Services OPTIMUM PARAMETERS 68 - 73 degF 42% - 48% HUMIDITY

Snapshot Data Summary

	Variable	Low	High	Average
JCI Data Center	Ambient Air Temperature 3ft	62.6 degF	78.6 degF	68.6 degF
JCI Data Center	Ambient Air Temperature 7ft	68.2 deg F	80.1 degF	71.7 deg F
JCI Data Center	Ambient Air Relative Humidity	19.4 %	46.2 %	33.0 %
JCI Data Center	Subfloor Escape Air Velocity	235 FPM	615 FPM	469 FPM
JCI Data Center	Subfloor Escape Air Temperature	58.8 degF	65.0 degF	61.8 degF

Value above specifications; Value within specifications; above ideal range; Value within ideal range; Value within specifications; below ideal range; Value below specifications; No specifications applicable

IDEAL OPERATING PARAMETERS
65 - 75 degF
40% - 60% HUMIDITY

SPECIFIED OPERATING PARAMETERS(IBM)
60 - 90 degF
20% - 80% HUMIDITY

Example - JCI Data Center

Key Findings

Finding #1: Cooling Capacity. The rated cooling capacity of the East Computer Room is 50 Tons. A sensible practice is to de-rate this capacity by 10%. During the repair of AC 5, actual tonnage used was at 45 Tons as represented by the sensible heat load discovered by field test during the repair of AC 5. The cooling requirements for this room consume all of the available capacity. This room is also designated for the expansion of additional servers and associated equipment. This will exceed the room's current cooling capacity. A serious overheating condition will occur should one of the AC's fail.

> **Recommendation:** Consider adding additional cooling resources to the East Computer Room. It is also recommended that there be a delay in deploying additional load to the East Computer Room until more cooling resources have been added.

Finding #2: Perforated Tile: The Dell servers generate significant heat when fully occupying server racks. Significant temperature rises occur because of stratification of air at these racks. This is caused by a lack of adequate air flow.

> **Recommendation:** Replace the current 25% open perforated tiles with 50% open tiles at the inlets to the Dell server racks. Some additional 25% open perforated tiles may also have to be replaced with solid tiles to prevent subfloor depressurization.

Finding #3: Subfloor Blockages. The subfloor in both the East and West Computer Rooms contains large quantities of unused and abandoned cable.

> **Recommendation:** Remove the unused cable from the subfloor. Develop a process that requires cable removal at the same time as the equipment decommissioning occurs.

Finding #4: Tile Cable Cutouts: Access holes have been cut in the solid tiles to allow cable access to equipment from the subfloor. This also impacts subfloor static pressure and further compromises the subfloor air distribution system.

> **Recommendation:** Use appropriate materials such as foam, pillows or nylon brush to close these cutouts and maintain subfloor pressurization.

Finding #5: Air Conditioner Performance: The performance profiles of the various air conditioners deployed in the three computer rooms indicate that they are providing sufficient chilled air to their spaces. They are, however, operating at or close to their maximum capacities. For redundancy purposes, consideration should be given to increasing cooling capacity in all three computer rooms. A review of sensor calibration, set points and sensitivity should be conducted periodically. Individual performance profile graphs and recommendations are included in the body of the report.

Limitations of a Controls-based Strategy

- Typical characteristics of Legacy Sites
  - Limited under-floor space - 10-24 inches
  - Poor cable management and other obstructions
  - Limited above-floor space - 8-10 foot clearance
- Acceptable for low density computing
  - Controls can adequately regulate temperature and humidity
- Heat stratification in high density environments cannot be managed solely by controls
  - Airflow management must be precise

The Rise of Airflow Management Tools

- Computational Fluid Dynamics provide modeling
  - TileFlow
  - Flovent
  - Fluent Airpak
- As a result, expected values can be established for points below and above the raised floor
  - Augments controls-based strategies
- But what remains missing is a measure of “Room Health”

Room Health

Recognizes the inter-dependencies of:

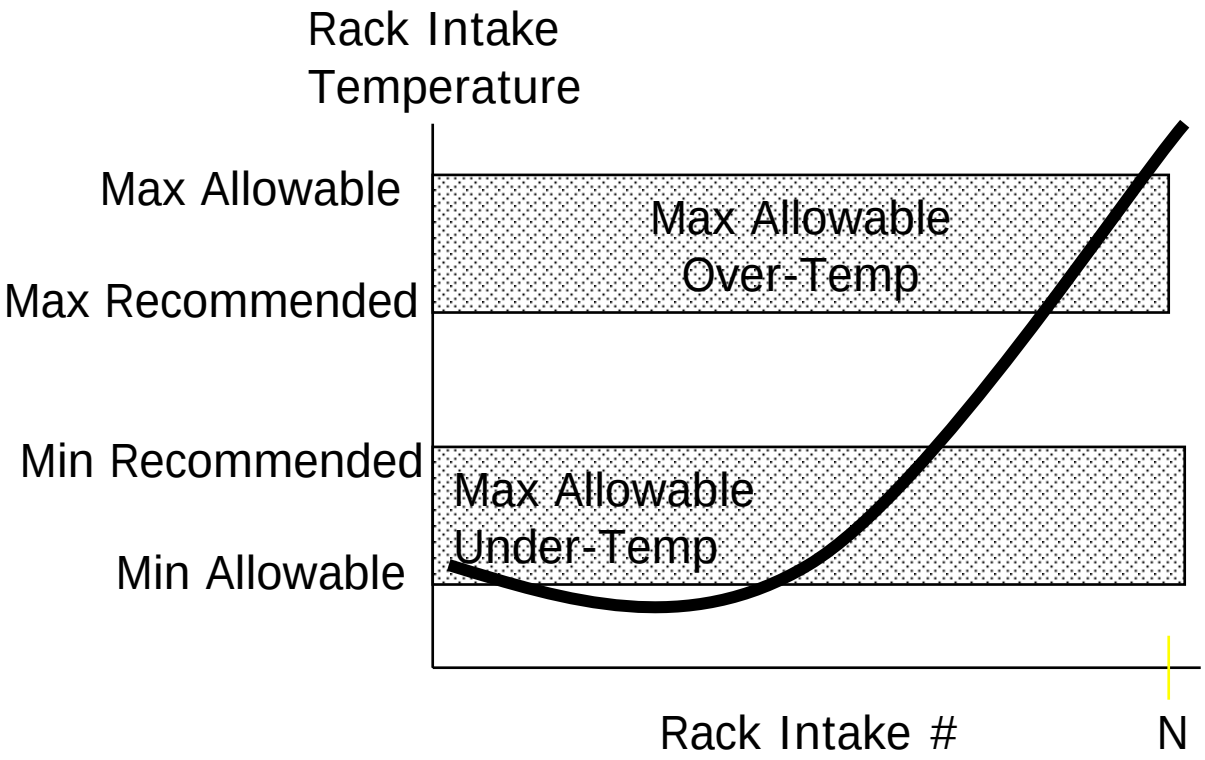
- The layout of computing equipment
- The equipment cooling class
- The space cooling system

The Rack Cooling Index (RCI)

- Developed by ANCIS
  - Magnus K. Herrlin, Ph.D.
    - Formerly, Principal Scientist for Telcordia Technologies
- The RCI: a dimensionless index that could become the basis for a common standard
  - measures how effectively equipment racks are cooled and maintained within industry thermal guidelines and standards
  - provides the basis for interpreting modeled or measured air intake temperatures

Definition of RCI_{HI} and RCI_{LO}

- Measures equipment room health at both the high and low ends of the temperature range



Calculation of RCI_{HI} and RCI_{LO}

- RCI_{HI} = (1-Total OverTemp/Max Allow. OverTemp)100 [%]

  Interpretation:

  RCI_{HI} = 100% All Intake Temps <max recommended

  RCI_{HI} < 100% At least one intake temp > max recommended

  RCI_{HI} = 0% At least one intake temp > max allowable

- RCI_{LO} = (1-Total UnderTemp/Max Allow. UnderTemp)100 [%]

  Interpretation:

  RCI_{LO} = 100% All Intake Temps >min recommended

  RCI_{LO} < 100% At least one intake temp < min recommended

  RCI_{LO} = 0% At least one intake temp < min allowable

Benefits of the RCI

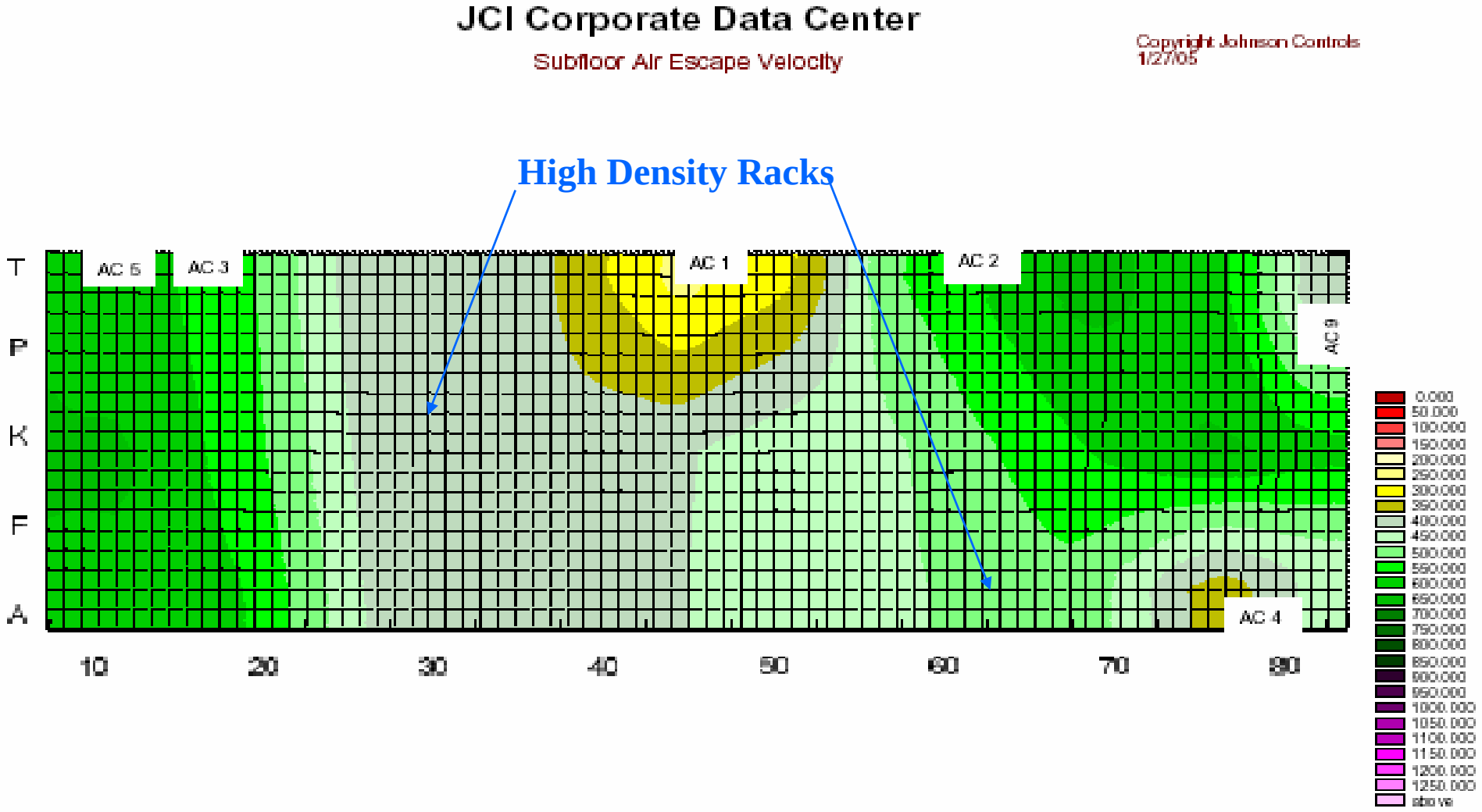
- Meaningful measure that can also be shown graphically
- Easily understood numerical scale - 100% means all racks are cooled to a standard or objective
- By using two indices, over-cooling of some racks does not compensate for under-cooling of others
- Provides the means to isolate potential heat-related failures
- Portable and non-dimensional - it work with any standard or guideline that specifies max/min temperature ranges.

Field Test Methodology

- Two racks of blade servers placed individually adjacent to low density equipment
- Portable temperature sensors placed within two inches of each server air intake
  - Continuous measurement for seven day periods
- Actual intake temperatures used to compute RCI, then compared to expected values
  - Ambient temperature readings from controls
  - Expected values derived from Environmental Audit.

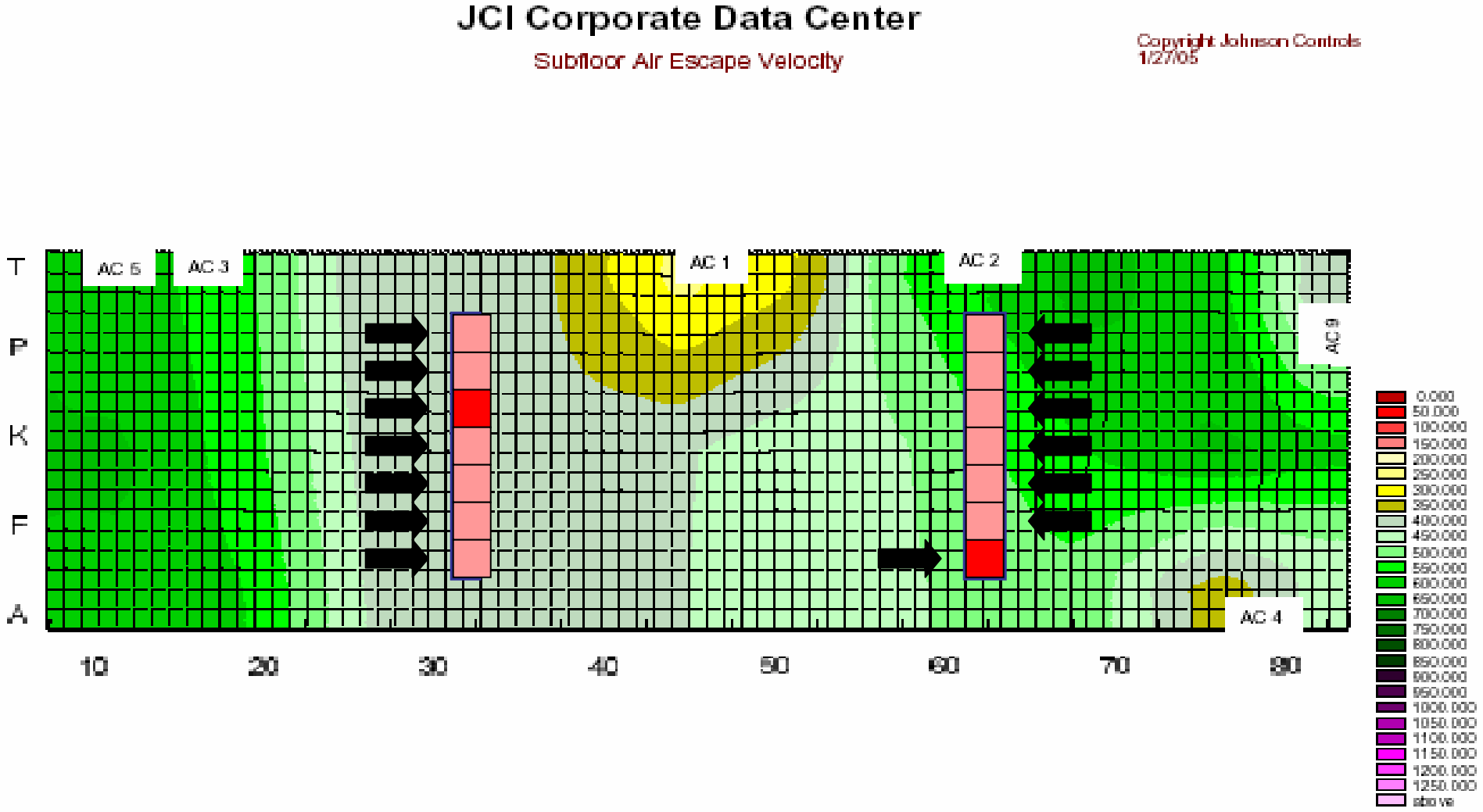
Field Test Methodology

Baseline Measurements



Field Test Methodology

Baseline Measurements



Field Test Methodology

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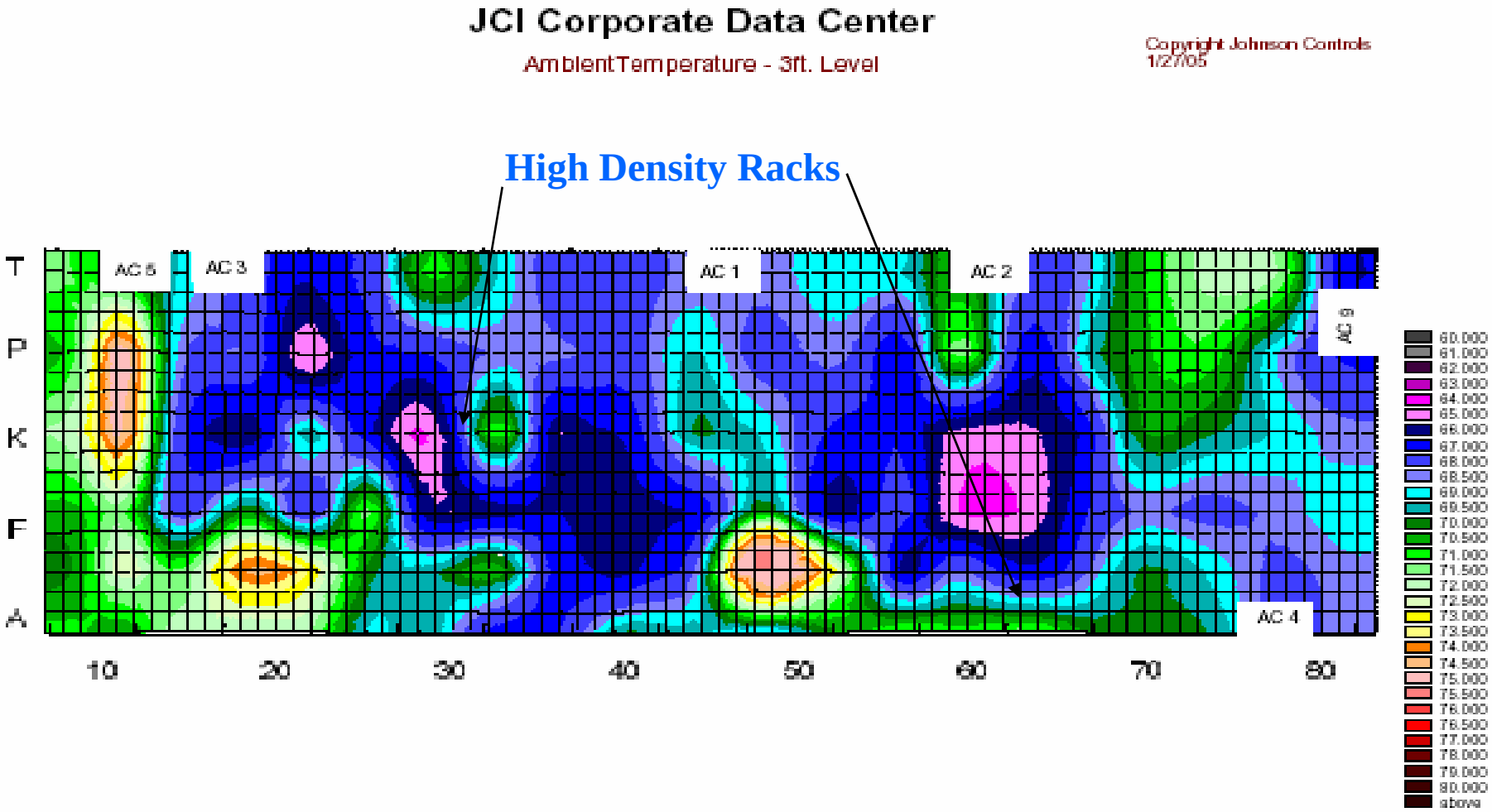

Field Test Methodology

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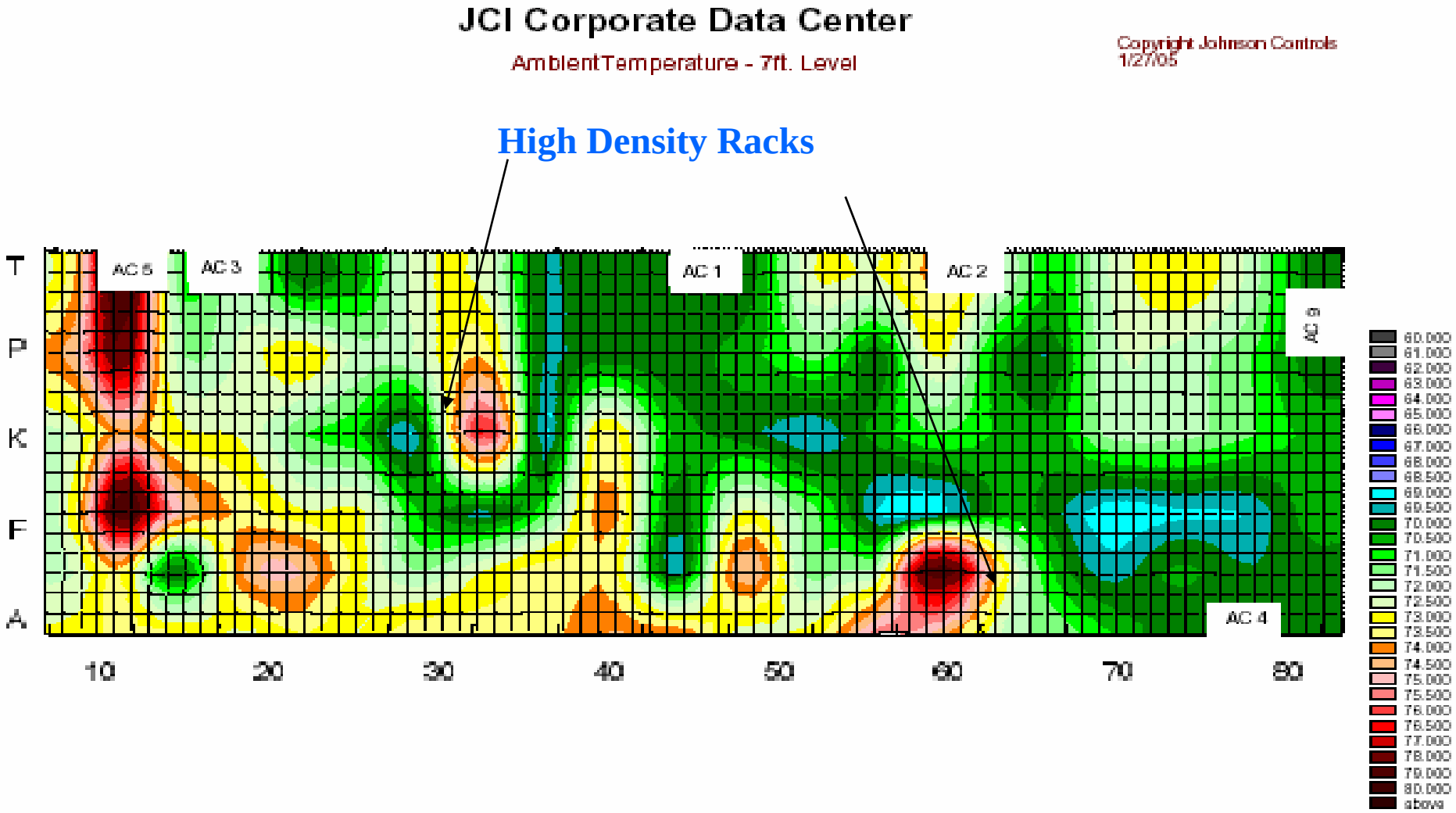


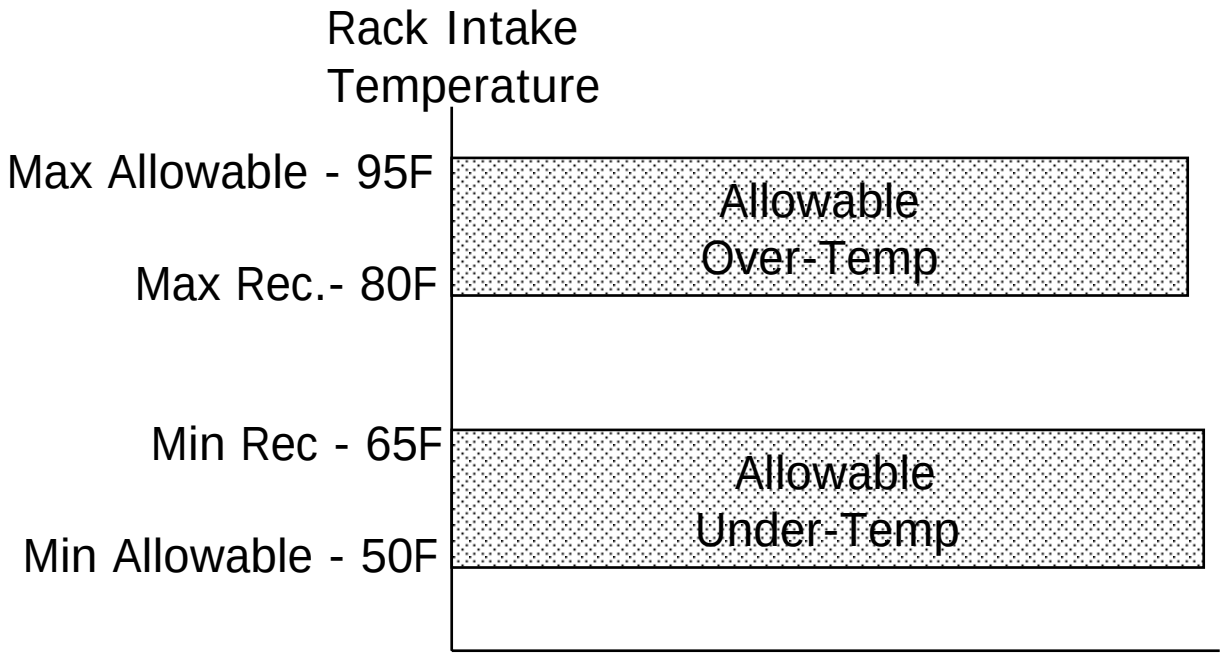
Field Test Methodology
Baseline Expectations

- Based on Ambient Temperatures, Escape Velocities, and CRAC Supply Temperatures ranging from 49^{o}F - 56^{o}F, we expected that Server Intake Temperatures would:
  - Experience an even rise in temperature from the lowest chassis (#3) to the highest (#7)
  - Remain within the manufacturer's acceptable High and Low ranges (50F^{o} - 95F^{o}), thus producing RCI's >0.

Field Test Methodology

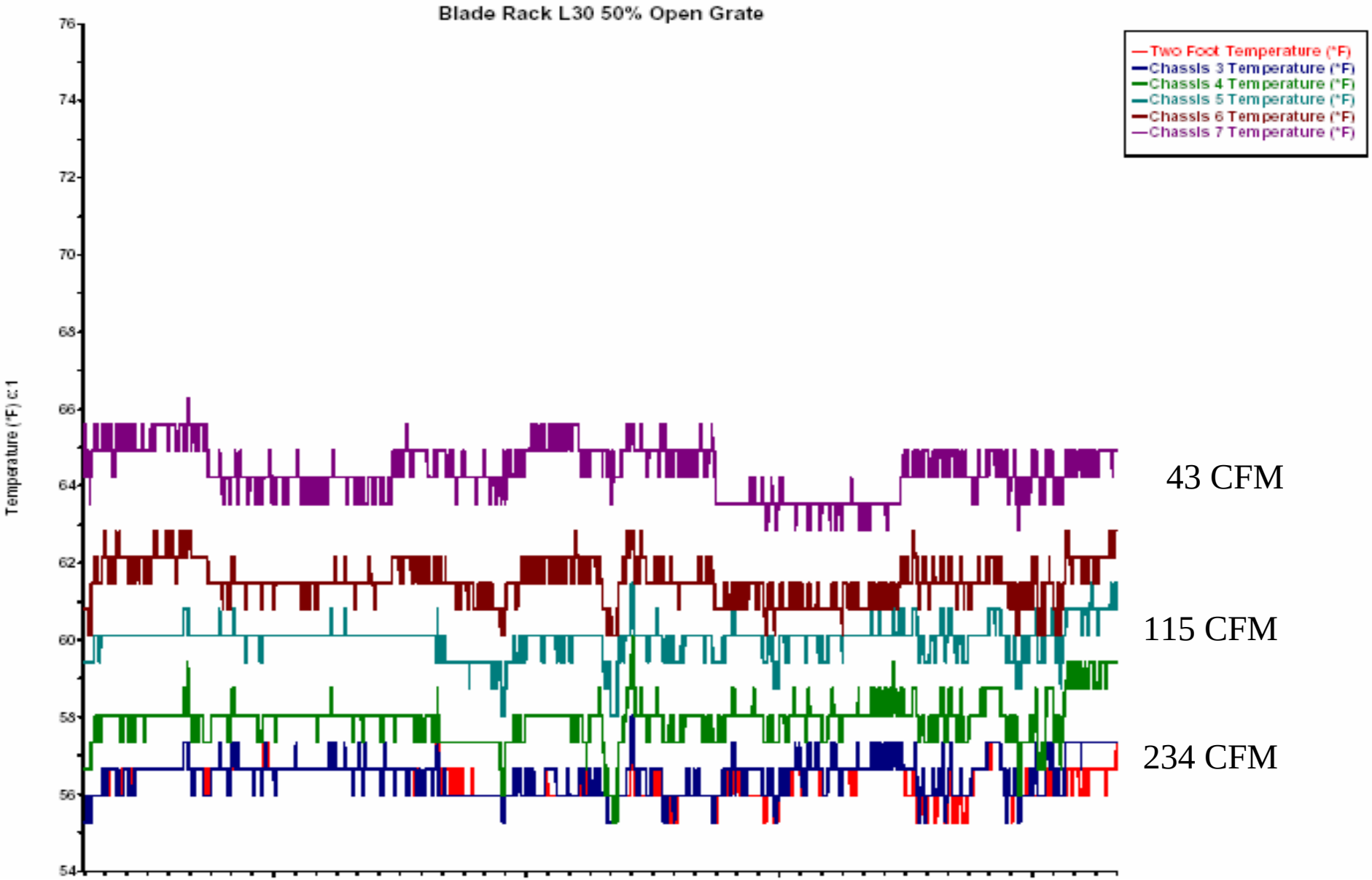
Allowable Temperatures

HP Bl20p G2



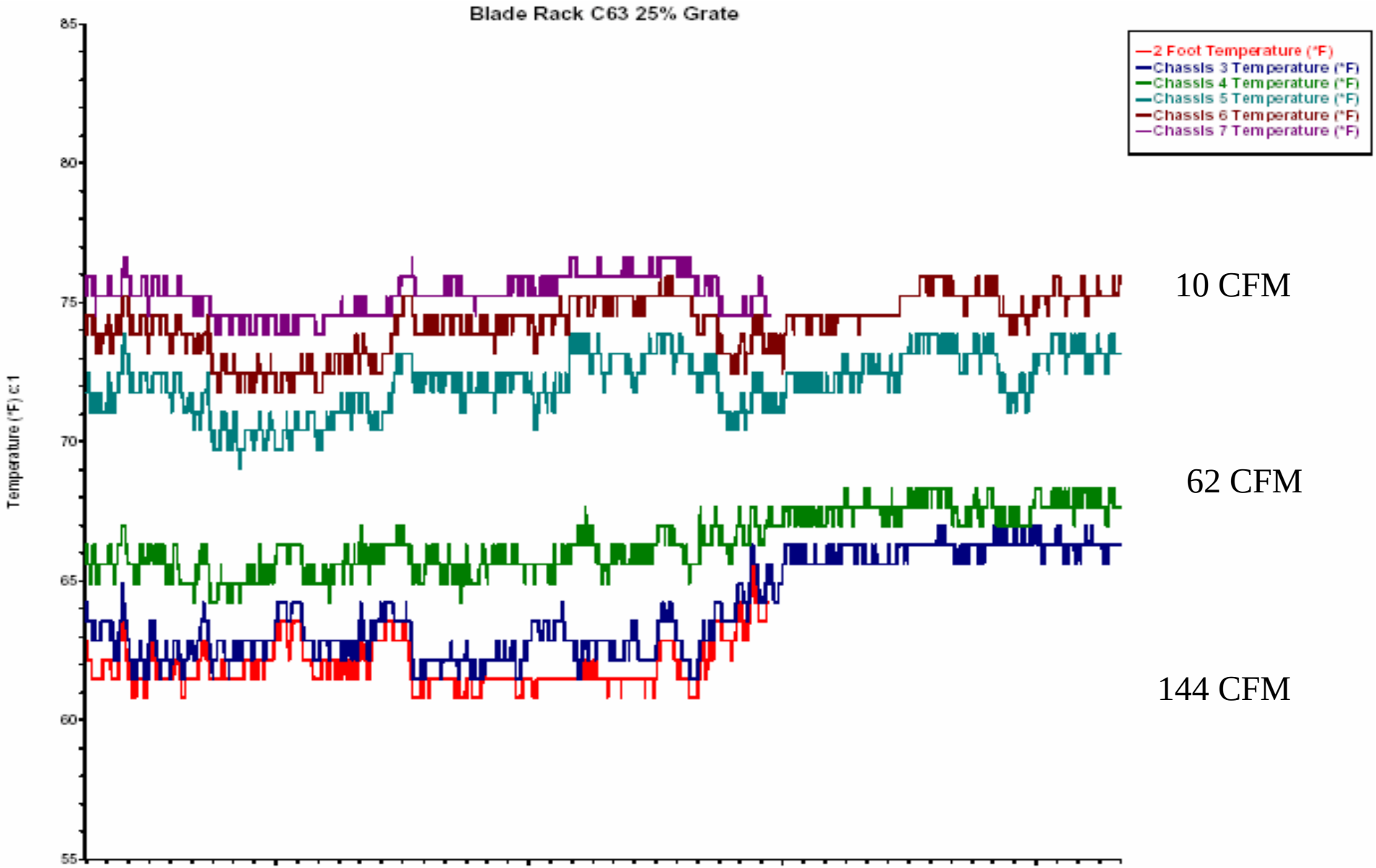
Field Test Methodology

Server Intake Temperatures



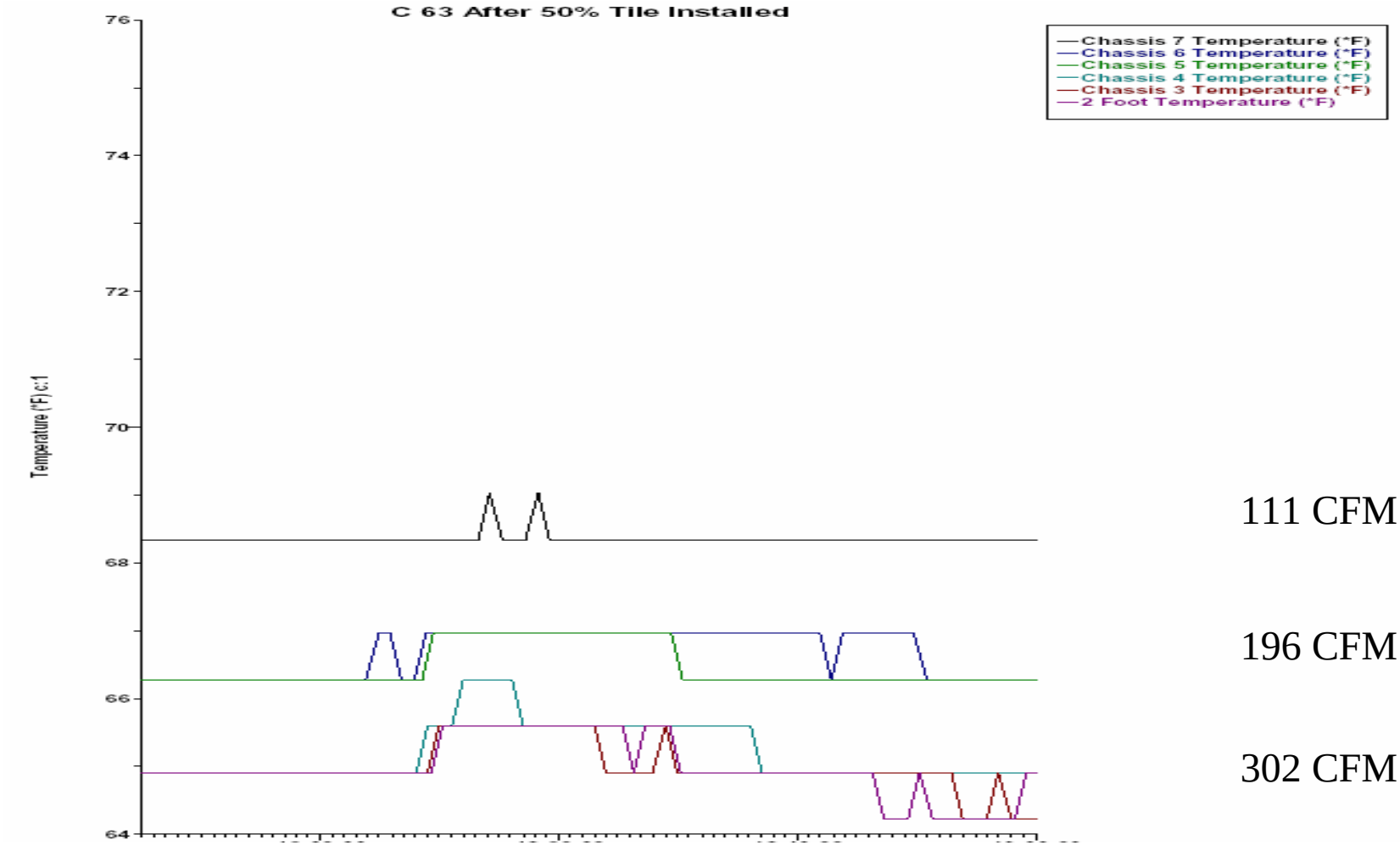
Field Test Methodology

Server Intake Temperatures



Field Test Methodology

Server Intake Temperatures



111 CFM

196 CFM

302 CFM

RCI Field Test
Conclusions

- Ambient Temperature readings are not a reliable indicators of Server Intake Temperatures. Even in data centers having low concentrations of high density computing, the RCI methodology - measuring temperature in close proximity to the load - identifies anomalies that are otherwise missed by Ambient Temperature.
- Concerns about the effects of high density computing may be causing facilities managers to over-compensate to the point where some servers border on their Minimum Allowable intake temperature, resulting in wasted energy if nothing else.
- Placement of high-density racks at the end of a row increases the probability of re-circulation.

Q & A

Thank You

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