VERTIV APPLICATION NOTE

Enhanced Efficiency in Data Center with Elevated Return Air Temperature

V-TM/124

Abstract

The strategy of data center temperature management has changed drastically with the introduction of new operating temperature guidelines by the American Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). A range of higher intake temperatures of the cooling devices has enabled substantial increase in computer room temperatures.

In comparison to ASHRAE 2008 edition, the revised 2015 edition recommends rack level intake temperature ranges and humidity level for most new devices have elevated from 64 °F to 80 °F (18 °C to 27 °C) to 41 °F to 89 °F (5 °C to 32 °C), and from 8% - 60% to 8% to 80% respectively. These increase in operating temperatures make higher load densities possible in server rooms without replacing air conditioning systems or making additional investments in the existing infrastructure. It also enables big cuts in energy usage assuming the same load capacity.

The increasing CRAC unit intake temperatures also enables the use of free cooling or free chilling (systems which use outdoor air to induce fresh air into the room or cool water instead of chilled water production units). Corrective action in designing the higher inlet to CRAC unit is one of prime factors among other parameters to make today's data center "Green".

Introduction

The purpose of this technical paper is to create an awareness about the elevated Return Air Temperature (RAT) design in critical applications that helps improve efficiency of cooling solution for data center, server rooms and similar eco-system. Additionally, this paper sheds light on the effect of rising Return Air Temperature; ASHRAE guidelines on data center room temperature; limitations on unlimited Higher Return Air Temperature; and optimum selection of thermal management design & solution. The cooling indices such as RTI, PUE etc. which are also crucial for data centers are also highlighted.

Thermal management is a major cost factor in data centers. In essence, the air conditioning system is a refrigeration system that ejects generated heat from data center into the outside environment. If cooling solution is implemented poorly, the power required to cool a data center can match or exceed the power used to operate the IT equipment itself.

Typically, data center HVAC units are controlled based on RAT. The lower is the supply Return Air Temperature in the data center, the greater is the cooling cost. The cooling power consumption of a data center depends on the amount of heat being removed (the number of IT equipment in the data center) and the temperature difference (ΔT) between the data center and the outside air.

Thus, this paper showcases the importance of higher return air temperature setpoints to cut down cooling cost, maximize the 'availability' of cooling capacity from same unit without compromising 'reliability'.

Index for Assessing Data Center Cooling Matrix*

Data center cooling matrix provides a systematic method to analyze - what amount of cold air should each server rack receive to successfully eliminate the heat generated in the data center or server rooms. Following are the indices which govern convention principles in Fluid Dynamic Analysis (FDA) to determine temperature performance of air circulating in the data center.

Return Temperature Index (RTI)

RTI indicates the output airflow rate from the cooling package to the equipment such as racks. It also shows the existence of re-circulation or by-passed air.

$$\text{RTI} = [1 - \frac{T_{\text{Return}} - T_{\text{Supply}}}{\Delta T_{\text{equipment}}}]$$

If the RTI is more than 100%, it indicates re-circulation and if the RTI is less than 100% the flow is by-passed. Therefore the ideal percentage for this index is 100%. Ideally, an optimized data center would have an RTI metric value of 100%. However, this is theoretical. In the actual practice, some amount of by-pass air and re-circulation air will always exist. The point is to minimize these conditions to increase the efficiency of the data center air handling system.

**Return Air Heat Index (RHI) & Supply Air Heat Index (SHI)*

Two dimensionless metrics called Supply Heat Index (SHI) and Return Heat Index (RHI) are used to measure the temperature performance of data center. These indices can be used to analyze convective airflow in equipment room with raised-floor. Energy efficiency of data center depends not only on the type of cooling system but also on the equipment room configuration which influences the mixing of cold and hot air.

These indices are formulated as follows:

$$\text{SHI} = (\frac{\delta Q}{Q+\delta Q})$$

$$\text{RHI} = (\frac{Q}{Q+\delta Q})$$

where Q is the total heat propagation of racks and indicates the amount of cold air enthalpy increase before it enters in the rack, i.e.

$$Q = \sum_j \sum_i m_{ij}^r C_p((T_{OUT}^r)_{ij} - (T_{in}^r)_{ij})$$

Ideally, SHI+RHI = 1; as RHI increases, SHI decreases, and the design reaches the ideal cooling system design for data center. This determines how less mixing of cold air with the output hot air from the rack (usually RHI > 0.8 (80%) is acceptable).

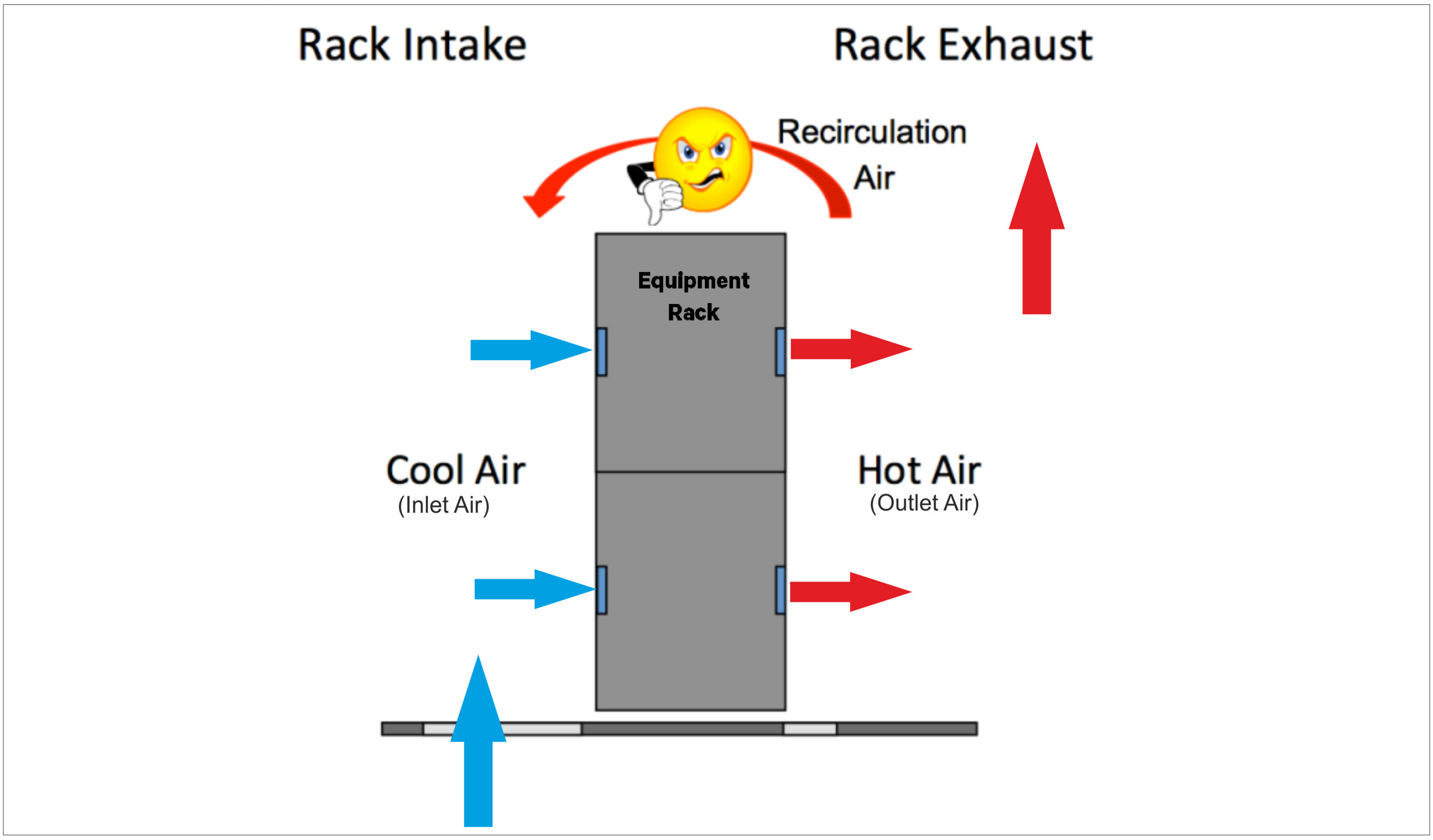

Fig 1: Wide Range of Evaporating Temperature

Eco-sensor software's comprehensive measurement function can accurately measure data center's PUE, RCI, and RTI values, identify existing cold spots, hot spots and racks with potential improvement.

Data Center Efficiency Metrics

Power Usage Effectiveness (PUE) is defined as the ratio between data center input power (Total facility power) and IT load power (IT equipment power). The benefits of determining data center infrastructure efficiency as part of an effective energy management plan is widely recognized.

$$\text{PUE} = \frac{\text{Total facility power}}{\text{IT equipment power}}$$

The main objective of an IT infrastructure manager is to minimize the gray space loads (passive infrastructures such as UPS, power distribution & cooling devices); simultaneously maximize the utilization of IT infra. load. Cooling or thermal management system consumes 35% to 40% of overall power consumption in data center. Hence, there is a need for subsequent action on cooling design i.e. raised temperature in the server rooms to be discussed in the next segment.

Data centers are estimated to save 4% to 5% in energy costs per degree (1 °C) rise in Return Air Temperature. Higher temperature setting implies more hours of "free-cooling" through economizers on the air or water side.

With a recommended temperature of 64 °F/18 °C to 77 °F/25 °C instead of 57 °F/14 °C to 59 °F /15 °C in the server room (means unit Return Air Temperature is more than 89 °F/32 °C to 95 °F/35 °C rather than 75 °F /24 °C), the periods of the year when free cooling can be used without turning the compressor on are considerably extended. This generates substantial energy savings and improves PUE. The same applies to free cooling, which can be used more often during the year to cool the cooling coil, with recommended temperatures now being set at 59 °F/15 °C to 64 °F/18 °C rather than 44 °F/7 °C for water.

ASHRAE Temperature Guidelines

Currently, ASHRAE TC 9.9 publication is used to select a higher operating temperature, and the IT experts validate the ability of legacy cooling equipment to operate in the newer temperature ranges.

In the earlier edition, the ASHRAE recommended air temperature envelope for data centers was 68 °F to 77 °F (20 °C to 25 °C) that was a pragmatic assertion, which focused on the consideration that eleven data centers could be efficiently operated together. The factors such as reliability and uptime were the primary concerns, whereas - energy cost was secondary. Since then, ASHRAE has issued a recommended temperture range of 64 °F to 81 °F (18 °C to 27 °C) and, in 2011, published classes[1] that allow a temperature range of 41 °F to 113 °F (5 °C to 45 °C). The A3 (40 °C/104 °F) and A4 (45 °C/113 °F) classes were created to support new energy saving technologies such as economization. A summary of the ASHRAE recommended range and classes are given in Tab 1.

Tab 1: ASHRAE Recommended Range and Classes of Air Cooling Equipment

Class	Equipment Environment Specification for Air Cooling						
	Product Operation					Product Power Off	
	Dry-Bulb Temperature °C	Humidity Range Non-condensing	Maximum Dew Point (DP) °C	Maximum Elevation m	Maximum Temperature Change[f] in an Hour (°C)	Dry-Bulb Temperature °C	Relative Humidity (RH) %
Recommended (Suitable for all 4 classes)							
A1 to A4	18 to 27	9 °C DP & 15% DP and 60% RH	....	....	....	....	....
Allowable							
A1	15 to 32	12 °C DP & 8% RH to 17 °C DP and 80% RH	17	3050	5/20	5 to 45	8 to 80
A2	10 to 35	12 °C DP & 8% RH to 21 °C DP and 80% RH	21	3050	5/20	5 to 45	8 to 80
A3	5 to 40	12 °C DP & 8% RH to 24 °C DP and 85% RH	24	3050	5/20	5 to 45	8 to 80
A4	5 to 45	12 °C DP & 8% RH to 24 °C DP and 90% RH	24	3050	5/20	5 to 45	8 to 80
B	5 to 35	8% RH to 28 °C DP and 80% RH	28	3050	NA	5 to 45	8 to 80
C	5 to 40	8% RH to 28 °C DP and 80% RH	28	3050	NA	5 to 45	8 to 80

Data Center Temperature Management

Today, data center power bills and carbon footprint reports hit the desks of CFOs and CIOs, who are continuously impelling to improve things. A number of prominent end-users operate their data centers at higher temperature to gain efficiencies and encourange their counterparts to follow suit. But the process isn't as simple as raising the thermostat in home. Let's ponder upon three widely discussed analogies on higher Return Air Temperature in server rooms.

1) Raising Return Air Temperature & maintaining cold aisle - hot aisle arrangement.

The cutting edge servers are relatively denser than their predecessor version. It means more temperature difference (ΔT) between inlet and outlet air across servers.

The configuration of IT equipment (such as Cold Aisle and Hot Aisle arrangement) is one of the best practices that any typical data center follows. This configuration places the intake of IT equipment on the Cold Aisle (supply) and the discharge of hot air towards the Hot Aisle (return). Current practices permit most server rooms to use 75 °F/24 °C supply air in the Cold Aisle, as the only temperature that counts in a server room is the air intake into the server hardware.

The benefits of higher Return Air Temperature are better heat exchange across the cooling coil, increased cooling capacity, and overall higher efficiency in the cooling unit. This effect is virtually applicable for all air conditioning equipment. Some equipment may have limitations on/in the maximum Return Air Temperature to handle, but in general, all cooling systems provide higher capacities with higher Return Air Temperature.

In this scenario, the CRAC unit experiences higher RAT which helps enhance the unit's capacity with the same compressor motor power consumption. This results in improved efficiency and adds values to the overall PUE improvement.

2) Raising unit inlet temperature complicates reliability, recovery, and equipment warranties.

Raising the data center temperature is part of the program to improve the efficiency of cooling solution. The temperature increase must follow the best practices in airflow management: using blanking panels, sealing cable cutouts, eliminating cable obstructions under the raised floor, and implementing some form of air containment. These measures can effectively reduce the mixing of hot and cold air, and allow for a safe and practical increase in temperature.

The 104 °F/40 °C server is an extreme case that encourages thoughtful discussion and critical inquiry among data center operators. After their study, a facility that was operating at 62 °F/17 °C is now operates at 70 °F/21 °C. Thus another users are also compelled to raise their temperature from 70 °F to 76 °F/21 °C to 24 °C. These changes can significantly improve energy efficiency, without compromising availability or equipment warranties.

3) Higher inlet temperatures of CRAC unit may result in uncomfortable working conditions for data center staff and visitors.

Not all data center environments have high user volume. Some high performance/supercomputing applications operate in a lights-out environment and include a homogeneous collection of hardware. These applications are well suited for higher temperature setpoints.

In addition to human comfort, the reliable operation of IT equipment is also important. The 2011 version of ASHRAE Standard TC 9.9 recommends server inlet temperatures in the range 64 °F to 80 °F / 18 °C to 27 °C. With Cold Aisle Containment (CACs), the temperature in the uncontained area can increase to 80 °F/27 °C, and in cases of high-density IT equipment, above 100 °F/38 °C. Therefore, entering in such a hot conditioned data center is unsustainable or impractical. With CACS, people's expectations need to be adjusted so they understand that the higher temperatures are "normal" and not a sign of impending system breakdown. This cultural change can be challenging for those workers who have not accustomed to enter a data center operating at higher temperatures.

Limitation with Legacy Cooling Technique

Precision Air Conditioning Technology is established over five decades of thermal management system in server room or critical IT infrastructure. There are two prime technologies listed-a) Direct Expansion (DX) & b) Chilled Water (CW).

In CW version, high Return Air Temperature has no limitation. In DX version indoor units generally equipped with scroll compressors in nearly all cases. And major challenge with scroll technology is that the compressor motor requires cooled suction gas, but it experienced higher temperature suction gas at high return air setpoint. If this return air setpoint exceeds 82 °F/ 28 °C then in such conditions compressor motor can be damaged, which was not possible previously. But in case of CW system, it not only helps the end unit, but also the whole system. Therefore, there are numerous cases where CW unit goes with the selection of RAT at air side 96 °F/ 98 °F (36 °C/37 °C) while water temperature is 68 °F/82 °F (20 °C/28 °C).

With the advent of new age technology such as “Inverter-driven compressor” (in DX Version), compressor's evaporating envelope expands.and hermetic scroll motor armature is strengthened. And inveter-driven compressor also induces high return air temperature, which considers as one of the most effective designing parameters in the data center industries.

Emerging Trends: Supply Air Control Logic with High Return Air Temperature

Return Air Temperature control aims to achieve a constant ambient temperature within the data center. This often results in a significant variation of the supply air temperature to IT equipment, which cannot be controlled by IT facility managers. Controlling the temperature at the supply side of the CRAC unit gives a better control to the facility manager as compared to the return side. This mechanism helps in prediction of the supply air temperatures to the server racks. Thus predictability of supply air temperature leads to the potential raise in both air side & water side temperatures. It also reduces the opearting cost as well as helps in savings the Capex and Opex costs of critical IT facilities.

In new age data center, higher density load and heterogenous load are common profiling factors. Due to these factors higher delta T also comes into picture. Nowadays supply air temperature logic is adopted in temperature control mechanism and thus, intelligent controller also plays a vital role in thermal management solution.

Cooling capacity is a product of airflow & temperature difference (ΔT). The higher ΔT variations cater variable loading conditions of IT equipment. In this condition, constant Return Air Temperature setting is not ideal. Intelligent controller assists dynamic changes in cooling capacity as well as maintaining constant pressure resulting in uniform cooling and power savings.

Wide range of evaporating temperature results better performance, but its operations are complex. Apart from perimeter cooling, row-based cooling is also favorable for high density (> 8 kw/racks). The close proximity to source AC system, CRAC unit always experience high inlet temperature.

Almost 4% to 5% capacity improves if facility manager decides to elevate per degree Return Air Temperature. Nowadays, 91 °F to 98 °F/33 °C to 37 °C Return Air Temperature setting is common and advisable with the appropriate technology based Precision AC solution.

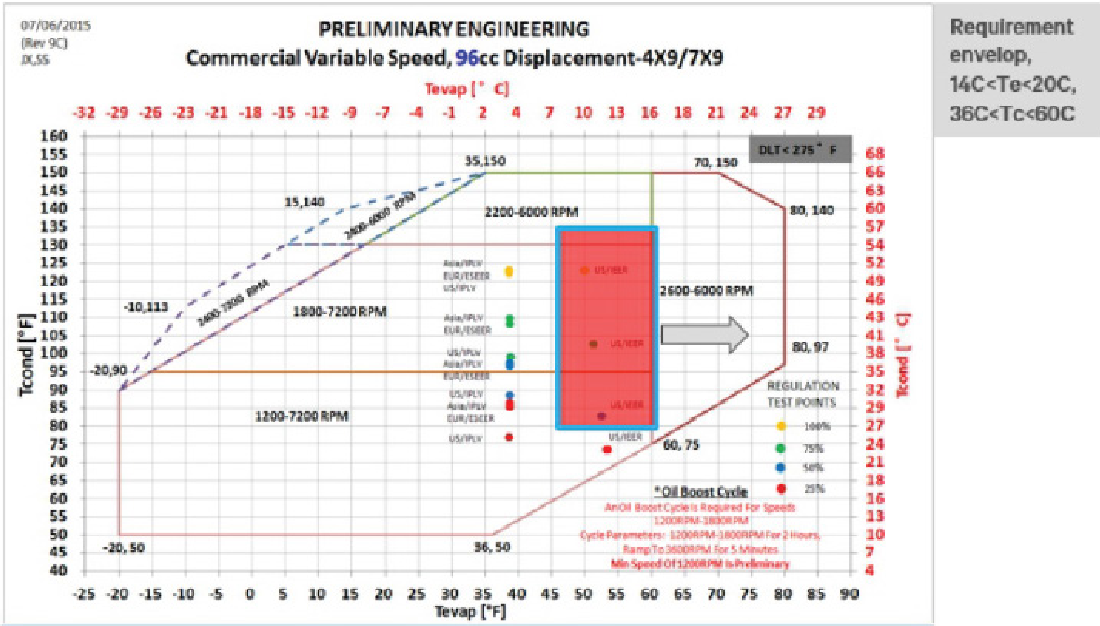

Fig 2: Wide Range of Evaporating Temperature Result in Better Performance

The two best emerging trends to adopt for next-gen data centers are higher return air temperature setpoint and supply air control logic. Based on site requirement designers are implementing any one of below mentioned architecture.

Tab 2: Architecture for Data Centers

Data Center Cooling Architecture	High Return Air Setpoint	Supply Air Logic	Under Floor Air Conditioning	Vertiv Solution
Hot Aisle – Cold Aisle arrangement	Generally possible	Emerging trend	Mostly Yes	• Vertiv has Liebert PEX3, Liebert PEX4, Liebert DM with all modern features. • Energy saving high Return Air Temperature setpoint enabled
Row Cooling arrangement	Higher Return Air Temperature is normally designed	Emerging trend	Mostly No	• Vertiv has Liebert CRV series with all modern features. • Easy to deploy
Self-Contained Cooling arrangement	Higher Return Air Temperature is normally designed	Emerging trend	Mostly No	• Vertiv has Smart solutions for small data center infrastructure. • Easy to deploy
Aisle Containment	Higher Return Air Temperature is an obvious choice to avail the best PUE	Best to deploy	Mostly No, but can be deployed	• Among few elite brands, Vertiv has Smart Aisle solution with all modern features. • The greatest choice for ultimate reliability, availability & top-notch efficiency for medium size data center

Conclusion

The raise in data center temperature is gaining its momentum in the market but needs to address its air circulation concerns properly. Often reliability and availability are the two essential factors for any IT professional to keep updated with the data center industry. The IT facility managers not only need to safeguard the data center costs but to make it more energy efficient. As temperature is closely attached with airflow management; IT facility managers must understand how the airflow gets around, into, and through the server racks.

Computational Fluid Dynamics (CFDs) can help by analyzing the profiles of air streams in the data center; however, the cooling equipment can't always rely on the specifications. The data entered in the cooling equipment could miss some crucial obstructions, onsite monitoring records, etc. In such scenarios indexing factors are critically applied to ensure the CFD data and calculations are accurately performed.

With airflow concerns addressed, professionals can focus to find the ideal temperature setting which aligns with business requirements that eventually improves energy efficiency of the data center. All the proactive measures and analysis will give better rewards in terms of reduced energy bills, improved carbon footprint, and enhanced capacity.

Reference

[1] *ASHRAE Technical Committee (TC) 9.9 Mission Critical Facilities, 'Data Center Power Equipment Thermal Guidelines and Best Practices', ASHRAE 2016.*

[2] *Kevin Heslin, 'Implementing Data Center Cooling Best Practices', UptimeInstitute Journal, June 2014.*

[3] *David King, 'The Benefits of Supply Air Temperature Controls in in Datacenter', Futute Facilities Ltd, August 2010.*

Vertiv.com | **Asia-Pacific**

V-TM/124