

# Cooling Audit for Identifying Potential Cooling Problems in Data Centers

## White Paper 40

Revision 3

by Kevin Dunlap

### > Executive summary

The compaction of information technology equipment and simultaneous increases in processor power consumption are creating challenges for data center managers in ensuring adequate distribution of cool air, removal of hot air and sufficient cooling capacity. This paper provides a checklist for assessing potential problems that can adversely affect the cooling environment within a data center.

## Introduction

There are significant benefits from the compaction of technical equipment and simultaneous advances in processor power. However, this has also created potential challenges for those responsible for delivering and maintaining proper mission-critical environments. While the overall total power and cooling capacity designed for a data center may be adequate, the distribution of cool air to the right areas may not. When more compact IT equipment is housed densely within a single cabinet, or when data center managers contemplate large-scale deployments with multiple racks filled with ultracompact blade servers, the increased power required and heat dissipated must be addressed. Blade servers, as seen in **Figure 1**, take up far less space than traditional rack-mounted servers and offer more processing ability while consuming less power per server. However, they dramatically increase heat density.



**Figure 1**

*Examples of compaction*

In designing the cooling system of a data center the objective is to create an unobstructed path from the source of the cooled air to the inlet positions of the servers. Likewise, a clear path needs to be created from the rear exhaust of the servers to the return air duct of the air-conditioning unit. A number of factors that can adversely impact this objective.

In order to ascertain that there is a problem or potential problem with the cooling infrastructure of a data center, certain checks and measurements must be carried out. This audit will determine the health of the data center in order to avoid temperature-related electronic equipment failure. They can also be used to evaluate the availability of adequate cooling capacity for the future. Measurements in the described tests should be recorded and analyzed using the template provided in the **Appendix**. The current status should be assessed and a baseline established to ensure that subsequent corrective actions result in improvements. This paper shows how to identify potential cooling problems in existing data centers that will affect the total cooling capacity, the cooling density capacity, and the operating efficiency of a data center. Solutions to these problems are described in White Paper 42, [Ten Cooling Solutions to Support High-Density Server Deployment](#).

## Check capacity

Remembering that each watt of IT power requires 1 watt of cooling, the first step toward providing adequate cooling is to verify that the capacity of the cooling system matches the current and planned power load.

The typical cooling system is comprised of a CRAC (Computer Room Air Conditioner) to deliver the cooled air to the room and a unit mounted externally to reject the heat to atmosphere. For more information on how air conditioners work and to learn about the different types, please refer to White Paper 57, [Fundamental Principles of Air Conditioners for](#)

[Information Technology](#) and White Paper 59, [The Different Types of Air Conditioning Equipment for IT Environments](#). Newer forms of CRAC units are appearing on the market that can be positioned closer (or even inside) data racks in very high-density situations.

In some cases, the cooling system may have been oversized to accommodate a projected future heat load. Over sizing the cooling system leads to undesirable energy consumption that can be avoided. For more on problems caused by sizing refer to White Paper 25, [Calculating Total Cooling Requirements for Data Centers](#).

Verify the capacity of the cooling system by finding the model nomenclature on or inside each CRAC unit. Refer to the manufacturer technical data for capacity values. CRAC unit manufacturers rate system capacity based on the EAT (entering air temperature) and humidity control level. The controller on each unit will display the EAT and relative humidity. Using the technical data, note the sensible cooling capacity for each CRAC.

Likewise, the capacity of the external heat rejection equipment should be of equal or greater capacity than all the CRACs in the room. In smaller packaged systems the internal and external components are often acquired together from the same manufacturer. In larger systems the heat rejection equipment may have been acquired separately from a different manufacturer. In either case they are most likely sized appropriately, however an outside contractor should be able to verify this. If the CRAC capacity and heat rejection equipment capacity are different, take the lower rated component for this exercise. (If in doubt when taking measurements, contact the manufacturer or supplier.)

This will give you the theoretical maximum cooling capacity of the data center. It will be seen later in this paper that there are a number of factors that can considerably reduce this maximum. The calculated maximum capacity must then be compared with the heat load requirement of the data center. A worksheet that allows the rapid calculation of the heat load is provided in **Table 1**. Using the worksheet, it is possible to determine the total heat output of a data center quickly and reliably. The use of the worksheet is described in the procedure below **Table 1**. Refer to White Paper 25, [Calculating Total Cooling Requirements for Data Centers](#) for more information.

The heat load requirements identified from the following calculation should always be below the theoretical maximum cooling capacity. White Paper 42, [Ten Cooling Solutions to Support High-Density Server Deployment](#) provides some solutions when this is not the case.

**Table 1**

*Data center or network room heat output calculation worksheet*

Item	Data required	Heat output calculation	Heat output subtotal
IT equipment	Total IT load power in watts	Same as total IT load power in watts	_____ watts
UPS with battery	Power system rated power in watts	$(0.04 \times \text{Power system rating}) + (0.06 \times \text{Total IT load power})$	_____ watts
Power distribution	Power system rated power in watts	$(0.02 \times \text{Power system rating}) + (0.02 \times \text{Total IT load power})$	_____ watts
Lighting	Floor area in square feet, or Floor area in square meters	2.0 x floor area (sq ft), or 21.53 x floor area (sq m)	_____ watts
People	Max # of personnel in data center	100 x Max # of personnel	_____ watts
<b>Total</b>	Subtotals from above	Sum of heat output subtotals	_____ watts

## Procedure

Obtain the information required in the “Data required” column. Consult the data definitions below in case of questions. Perform the heat output calculations and put the results in the subtotal column. Add the subtotals to obtain the total heat output.

## Data definitions

**Total IT load power in watts** - The sum of the power inputs of all the IT equipment.

**Power system rated power** - The power rating of the UPS system. If a redundant system is used, do not include the capacity of the redundant UPS.

## Check CRACs

If CRAC units in a data center do not work together in a coordinated fashion they are likely to fall short of their cooling capacity and incur a higher operating cost. CRAC units normally operate in four modes: cooling, heating, humidification and dehumidification. While two of these conditions may occur at the same time (i.e., cooling and dehumidification), all systems within a defined area (4-5 units adjacent to one another) should always be operating in the same mode. Uncoordinated CRAC units operating in opposing modes (i.e. dehumidifying and humidifying), called “demand fighting”, leads to wasted operating costs and a reduction in the cooling capacity. CRAC units should be tested to ensure that measured temperatures (supply & return) and humidity readings are consistent with design values.

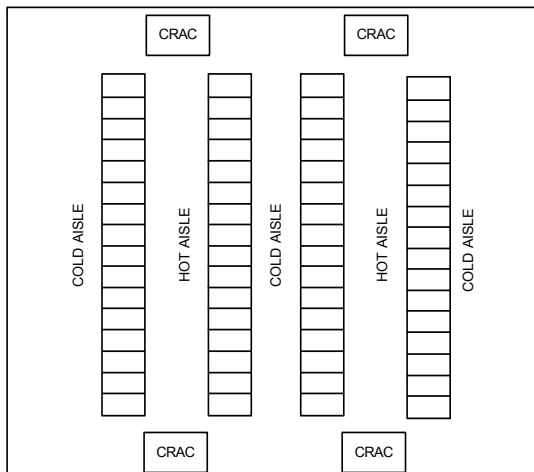
Demand fighting can have drastic effects on the efficiency of the CRAC system. If not addressed, this problem can result in a 20-30% reduction in efficiency which in the best case results in wasted operating costs and worst case results in downtime due to insufficient cooling capacity.

Operation of the system within lower limits of the relative humidity design parameters should be considered for efficiency and cost savings. A slight change in set point toward the lower end of the range can have a dramatic effect on the heat removal capacity and reduction in humidifier run time. As seen in **Table 2**, changing the relative humidity set point from 50% to 45% results in a significant operational cost savings.

The position of the CRAC units relative the aisle is important for air distribution. Depending on the air distribution architecture, CRAC units should be placed perpendicular to the aisle on either a cold or hot aisle as shown in **Figure 2**. When using a raised floor for distribution, the CRAC units should be placed at the end of the hot aisles. The hot air return path to the CRAC is directly down the aisle without pulling air over the tops of aisles where the opportunity for air to be re-circulated is increased. With less mixing of the hot air in the room, the capacity of the CRAC units will be increased by warmer return air temperatures. This could potentially lead to a requirement for fewer units in the room.

**Figure 2**

*Hot aisle positioning of CRAC units*



When a slab floor is used, the CRAC should be placed at the end of the cold aisle. This will distribute the supply air to the front of the cabinets. Some mixing will exist in this configuration and it should be implemented only when low power densities per rack exist.

**Table 2**

*Humidification cost savings example at lower set point*

Temperature 72°F (22.2°C)		
Relative humidity set point	50%	45%
Cooling capacities – kW (Btu / hr)		
Total cooling capacity	48.6 (166,000)	49.9 (170,000)
Temperature change (total sensible capacity)	45.3 (155,000)	49.9 (170,000)
Humidification requirement		
Moisture removed (total latent capacity) (Btu / hr)	3.3 (11,000)	0.0 (0,000)
Lbs / hr (kg / hr) humidification required – (Btu / 1074 or kW / 0.3148)	10.24 (4.6]	0
Humidifier runtime	100.0%	0.0%
kW required for humidification	3.2	0
Annual cost of humidification (cost per kW x 8760 x kW required)	\$2,242.56	\$0.00

Note: Assumptions and specifications for the example above can be found in the **Appendix**.

**Check set points**

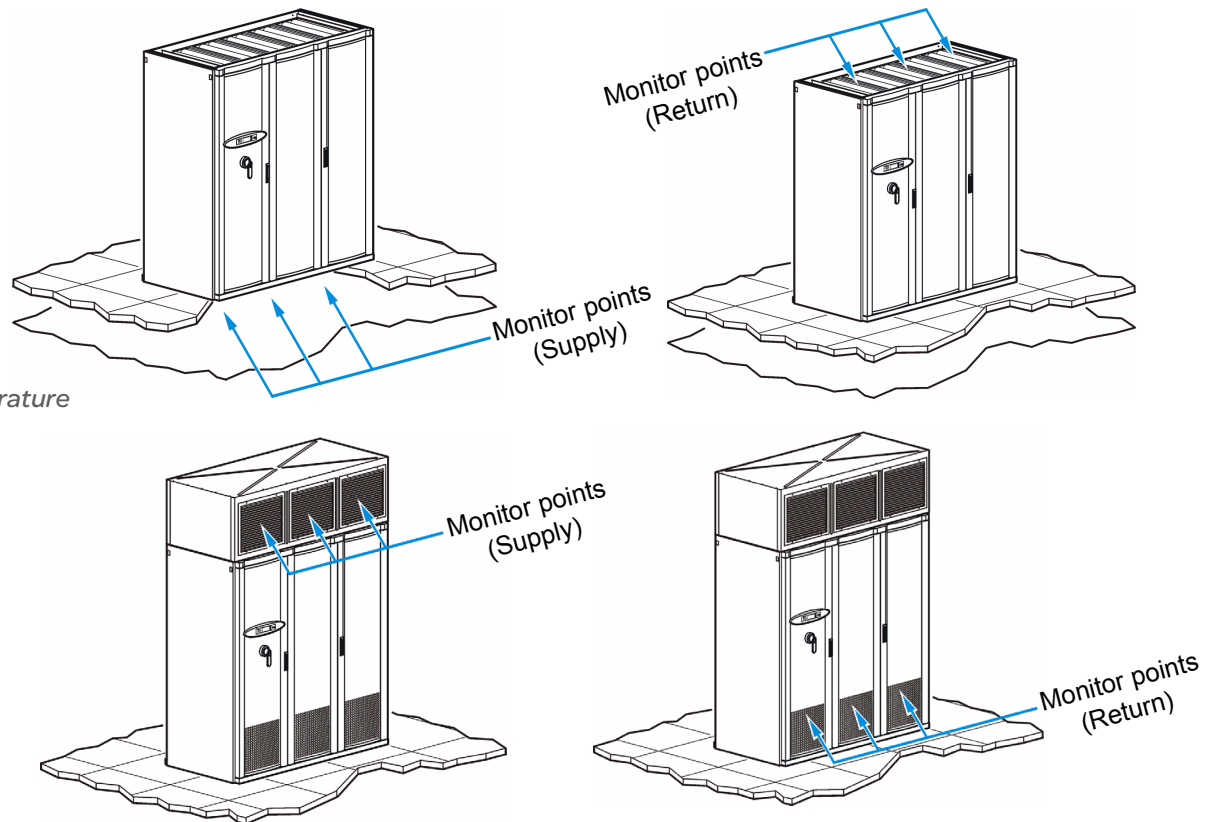
Set points for temperature and humidity should be consistent on all CRAC units in the data center. Unequal set points will lead to demand fighting and fluctuations in the room. Heat loads and moisture content are relatively constant in an area and CRAC unit operation should be set in groups by locking out competing modes through either a building management system (BMS) or a communications cable between the CRACs in the group. No two units should be operating in competing modes during a recorded interval, unless part of a separate

group. When grouped, all units in a specific group will be operating together for a distinct zone

Set point parameters should be within the following ranges:

- **Temperature – 68-77°F (20-25°C)**
- **Humidity – 40-55% Relative Humidity**

To test the performance of the system, both return and supply temperatures must be measured. Three monitoring points should be used on the supply and return at the geometric center as shown in **Figure 3**.



**Figure 3**

Supply and return temperature monitoring points

In ideal conditions the supply air temperature should be set to the inlet temperature required at the server inlet. This will be checked later by taking temperature readings at the server inlets. The return air temperature measured should be greater than or equal to the temperature readings from racks and aisles. A lower return air temperature than the temperature in racks and aisles indicates short cycling inefficiencies. Short cycling occurs when the cool supply air from the CRAC unit bypasses the IT equipment and flows directly into the CRAC unit air return duct. See White Paper 49, [Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms](#) for information on preventing short cycling. The bypass of cool air is the biggest cause of overheating and can be caused by a number of factors.

Also, verify that the filters are clean. Impeded airflow through the CRAC will cause the system to shutdown on loss of airflow alarm. Filters should be changed quarterly as a preventative maintenance procedure.

## Test main cooling circuit

This section requires an understanding of basic air condition equipment. For more information on this read White Paper 59, [The Different Types of Air Conditioning Equipment for IT Environments](#). Get your maintenance company or an independent HVAC consultant to check the condition of the chillers (where applicable), pumping systems and primary cooling loops. Ensure that all valves are operating correctly.

### Chilled water cooling circuit

The condition of the chilled water loop supply to the CRACs will directly affect the ability of the CRAC to supply proper conditioned air to the room or raised floor plenum. To check the supply temperature, contact your maintenance company or an independent HVAC consultant. As a quick check, the temperature of the piping supply to the CRAC can be used. Using a laser thermometer, measure the supply pipe surface temperature to the CRAC unit. In some cases, gauges may be installed inline with the piping, displaying temperature of the water supply.

Chilled water piping will be insulated from the air stream in order to prevent condensation on the pipe surface. For the most accurate measurement, peel back a section of the insulation and take the measurement directly on the surface of the pipe. If this is not possible, a small section of piping is likely exposed inside the CRAC unit at the inlet to the cooling coil on the left or right side of the coil.

### Condenser water circuit (water and glycol cooled)

Water and glycol cooled systems utilized a condenser in the CRAC for transferring heat from the CRAC to the water circuit. Condenser water piping will likely not be insulated due to the warmer temperatures of the supply water. Measure the supply pipe surface temperature at the entry point to the CRAC unit. Direct expansion (DX) systems should be checked to ensure that they are fully charged with the proper amount of refrigerant.

### Air cooled refrigerant piping

As with water and glycol cooled CRACs, refrigerant charge should be checked for the proper levels. Contact your maintenance company or an independent HVAC consultant to check the condition of refrigerant piping, outdoor heat exchangers and refrigerant charge.

Compare temperatures to those in **Table 3**. Temperatures that fall outside the guidelines may indicate a problem with the supply loop.

**Table 3**

Supply loop temperature tolerances

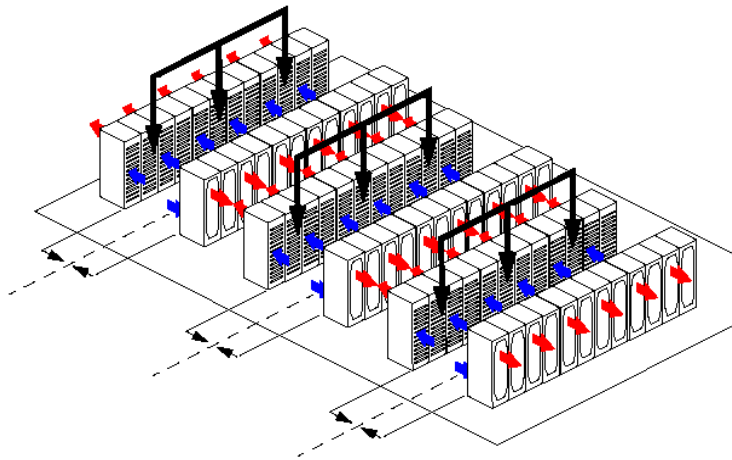
Chilled water	Condenser water (water cooled)	Condenser water (glycol cooled)
45°F (+/- 3°F)	Max 90°F	Max 110°F
7.2°C (+/- 1.7°C)	Max 32.2°C	Max 43.3°C

## Record rack and aisle temperatures

By recording the temperature at various locations between rows of racks, a temperature profile is created which helps diagnose potential cooling problems and ensures that cool air is supplied to critical areas. If the aisles of racks are not properly positioned hot spots can occur in various locations and may cause multiple equipment failures. The section on aisle and floor tile arrangement describes and illustrates a best practice for rack layouts. Take room temperatures at strategic positions within the aisles of the data center.<sup>1</sup> These measuring positions should generally be centered between equipment rows and spaced at approximately one point at every fourth rack position as shown in **Figure 4**.

**Figure 4**

ASHRAE TC9.9 hot aisle / cold aisle measurement points



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Aisle temperature measurement points should be 5 feet (1.5 meters) above the floor. When more sophisticated means of measuring the aisle temperatures are not available this should be considered a minimal measurement. These temperatures should be recorded and compared with the IT equipment manufacturers' recommended inlet temperatures. When the recommended inlet temperatures of IT equipment are not available, 68-75°F (20-25°C) should be used in accordance to the ASHRAE standard. Temperatures outside this tolerance can lead to a reduction in system performance, reduced equipment life and unexpected downtime. Note: All the above checks and tests should be carried out quarterly. Temperature checks should be carried out over a 48-hour period during each test to record maximum and minimum levels.

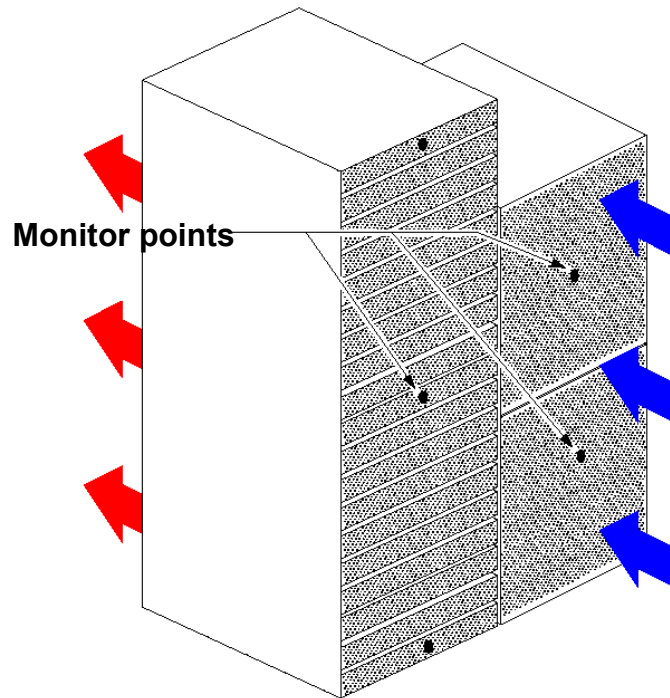
Poor air distribution to the front of a rack can cause the hot exhaust air from the equipment to recirculate back into the intakes. This causes some equipment, typically those mounted toward the top of the rack, to overheat and shutdown or fail. This step is to verify that the bulk inlet temperatures in the rack are adequate for the equipment installed. Take and record temperatures at the geometric center of the rack front at bottom, middle and top as illustrated in **Figure 5**. When the rack is not fully populated with equipment, measure inlet temperatures at the geometric center of each piece of equipment. Refer to the guidelines under "check CRACs" for acceptable inlet temperatures. Temperatures not within the guidelines represent a cooling problem for that monitoring point.

Monitoring points should be 2 inches (50 mm) off the face of the rack equipment. Monitoring can be accomplished with thermocouples connected to a data collection device. Monitoring

<sup>1</sup> ASHRAE Standard TC9.9 gives more details of positioning sensors for optimum testing and recommended inlet temperatures. ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers <http://www.ashrae.org>)



points may also be measured by using a laser thermometer for quick verification of temperatures as a minimal method.



**Figure 5**

ASHRAE monitoring points for equipment inlet temperatures

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## Check airflow from floor grilles

It is important to understand that the cooling capacity of the cabinet is directly related to the airflow volume delivery stated in CFM (cubic feet per minute). IT equipment is designed to raise the temperature of the supply air by 20-30°F (11-17°C). Using the equation for heat removal, the amount of airflow required at a given temperature rise can be quickly computed.

**CFM or m<sup>3</sup>/s** = the volume of airflow required to remove the heat generated by IT equipment

**Q** = the amount of heat to be removed expressed in kilowatts (kW)

**Δ°F or °C** = the exhaust air temperature of the equipment minus the intake temperature

$$CFM = \frac{3,412 \times Q}{1.085 \times \Delta^{\circ}F}$$

$$m^3 / s = \frac{Q}{1.21 \times \Delta^{\circ}C}$$

For example, to calculate the airflow required to cool a 1 kW server with a 20°F temperature rise:

$$CFM = \frac{3,412 \times 1kW}{1.085 \times 20^{\circ}F} = 157.23$$

$$m^3 / s = \frac{1kW}{1.21 \times 11^{\circ}C} = 0.0742$$

Therefore, for every 1 kW of heat removal required at a design DeltaT (temperature rise through IT equipment) of 20°F (11°C) you must supply approximately 160 cubic feet per minute (0.076 m<sup>3</sup>/s or 75.5 L/s) of conditioned air through the equipment. When calculating the necessary airflow requirement per rack, this can be used as an approximated design

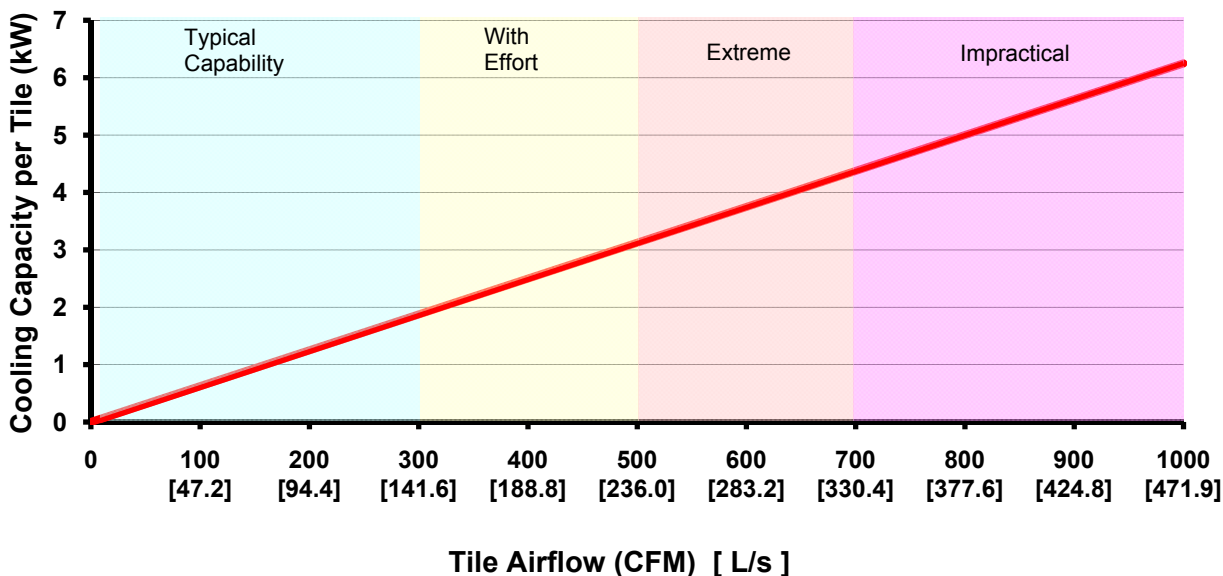
value. However, adherence to the manufacturer name plate requirements should be followed.

$$CFM / kW = 157.23 \quad (m^3 / s) / kW = 0.074 \quad (L / s) / kW = 74.2$$

Using the design value and the typical tile (~ 25% open) airflow capacity shown in **Figure 5** below, the max power density per cabinet should be 1.25 to 2.5 kW per cabinet. This is applicable to installations utilizing one tile per cabinet. In instances where cabinet to floor tile ratio is greater than one, the available cooling capacity should be divided among the cabinets in the row.

### Testing the airflow of a vented floor tile

Measuring the amount of available cooling capacity on a given floor tile can be accomplished simply laying a small piece of paper on it. If the paper gets sucked into the floor tile this means that air is being drawn back under the raised floor which indicates a problem with the rack and CRAC positioning. If the paper is unaffected it could be that there is not air getting to that tile. If the paper moves up off the floor tile this is an indication that air is being distributed from that tile. However, depending on the power density of the equipment being cooled, the amount of air from the tile may not be enough. In this case a grate or air distribution device may be required to allow more air to flow to the front of the racks.



**Figure 6**  
Available rack enclosure cooling capacity of a floor tile as a function of per-tile airflow

## Inspect enclosures

Unused vertical space within rack enclosures causes the hot air output from equipment to take a “short circuit” back to the inlet of the equipment. This unrestricted cycling of hot air causes the equipment to heat up unnecessarily which can lead to equipment damage or downtime. The use of blanking panels to combat this effect is described in more detail in White Paper 44, [Improving Rack Cooling Performance Using Blanking Panels](#). Visually examine each rack. Are there any gaps in the u positions? Are CRT monitors being used? Are blanking panels installed in these racks? Is an excess of cabling impeding the airflow?

If there are visible gaps in the U space positions, blanking panels are not installed or there is excessive cabling in the rear of the rack, then airflow within the rack will not be optimal as illustrated in **Figure 7**.

**Figure 7**

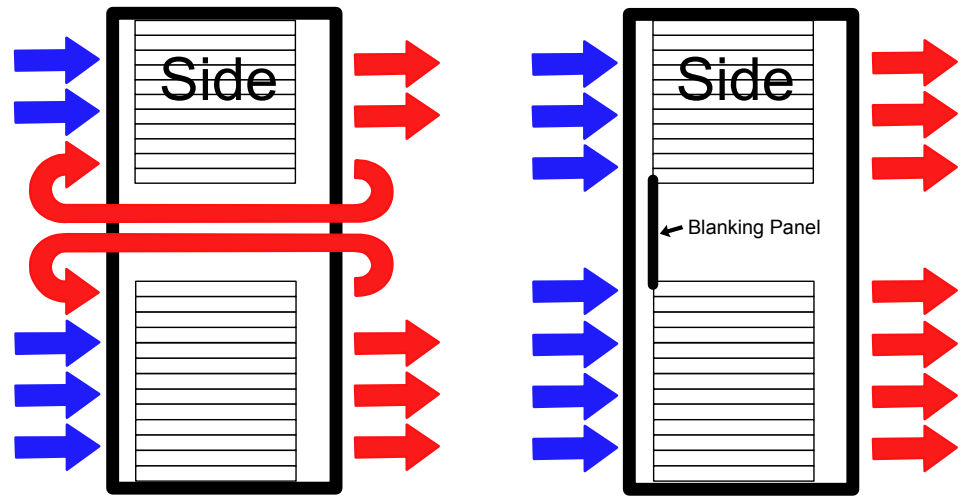
Diagrams of rack airflow showing effect of blanking panels

**7A (left)**

Without blanking panels

**7B (right)**

With blanking panels



## Check aisle, floor tiles, and air paths

Check sub-floors for cleanliness and / or obstructions. Any dirt and dust present below the raised floor will be blown up through floor grills and will be drawn into the IT equipment. Floor obstructions such as network and power cables will obstruct airflow and have a negative effect on the cooling supply to the racks.

Subsequent addition of racks and servers will result in the installation of more power and network cabling. Often, when servers and racks are moved or replaced, the redundant cabling is left beneath the floor.

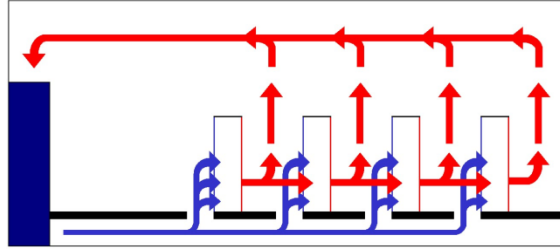
A visual inspection of the floor surface should be conducted when a raised floor is utilized for air distribution. Voids, gaps and missing floor tiles have a damaging effect on the static pressure of the floor plenum. The ability to maintain airflow rates from perforated floor tiles will be diminished with the presence of unsealed areas on the raised flooring.

Missing floor tiles should be replaced. The floor should consist of solid or perforated floor tiles in every section of the grid. Holes in the raised flooring tiles used for cabling access should be sealed using brush strips or other cable access products. Measurements conducted show that 50-80% of available cold air escapes prematurely through unsealed cable openings.

With few exceptions, most rack-mounted servers are designed to draw air in at the front and exhaust at the back. With all the racks facing the same way in a row, the hot air from row one is exhausted into the aisle where it will mix with supply or room air and then enter into the front of the racks in row two. This arrangement is shown in **Figure 8**. As air passes through each consecutive row the IT equipment is subjected to hotter intake air. If all the rows have the cabinets arranged so that the inlets of the servers face the same direction equipment malfunction is imminent.

**Figure 8**

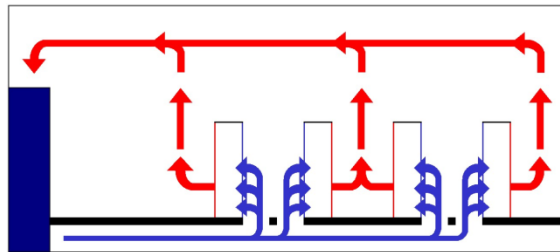
Rack arrangement with no separation of hot or cold aisles



Configuring the rack in a hot aisle / cold aisle configuration will separate the exhaust air from the server inlets. This will allow the cold supply air from the floor tiles to enter into the cabinets with less mixing as illustrated in **Figure 9** below. For more on air distribution architectures in the data center refer to White Paper 55, [Air Distribution Architecture for Mission Critical Facilities](#).

**Figure 9**

Hot aisle / cold aisle rack arrangement



Improper location of these vents can cause CRAC air to mix with hot exhaust air before reaching the load equipment, giving rise to the cascade of performance problems and costs described previously. Poorly located delivery or return vents are very common and can erase almost all of the benefit of a hot aisle / cold aisle design.

## Conclusion

Routine checks of a data center's cooling system can identify potential cooling problems early on to help prevent downtime. Changes in power consumption, IT refreshes and growth can change the amount of heat produced in the data center. Regular health checks will most likely identify the impact of these changes before they become a major issue. Achieving the proper environment for a given power density can be accomplished by addressing the problems identified through the health checks provided in this white paper. For more information on cooling solutions for higher power densities refer to White Paper 42, [Ten Cooling Solutions to Support High-Density Server Deployment](#).



### About the author

**Kevin Dunlap** is the Product Line Manager for modular / high density cooling solutions at Schneider Electric. Schneider Electric is a global leader in the development of precision power system technologies and one of the world's largest providers of equipment that serves the network-critical physical infrastructure. Involved with the power management industry since 1994, Kevin previously worked for Systems Enhancement Corp., a provider of power management hardware and software, which APC acquired in 1997. Following the acquisition, Kevin joined APC as a Product Manager for management cards and then precision cooling solutions following the acquisition of Airflow Company in 2000.

Kevin has participated on numerous power management and cooling panels, as well as on industry consortiums and ASHRAE committees for thermal management and energy efficient economizers.



## Resources



### [Ten Cooling Solutions to Support High-Density Server Deployment](#)

White Paper 42



### [Fundamental Principles of Air Conditioners for Information Technology](#)

White Paper 57



### [The Different Types of Air Conditioning Equipment for IT Environments](#)

White Paper 59



### [Calculating Total Cooling Requirements for Data Centers](#)

White Paper 25



### [Avoidable Mistakes that Compromise Cooling Performance in Data Centers and Network Rooms](#)

White Paper 49



### [Air Distribution Architecture for Mission Critical Facilities](#)

White Paper 55



### [Comparing UPS System Design Configurations](#)

White Paper 44



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## Appendix

### Assumptions and specifications for Table 2

Both scenarios in the humidification cost savings example in **Table 2** are based on the following assumptions:

- 50 kW of electrical IT loads which results in approximately 50 kW of heat dissipation
- Air temperature returning to CRAC inlet is 72°F (22.2°C)
- Based on 1 year operation (7x24) which equates to 8,760 hours
- CRAC unit volumetric flow of 9,000 CFM (4.245 m<sup>3</sup>/s)
- Ventilation is required but for simplification it was assumed that the data center is completely sealed - no infiltration / ventilation
- Cost per kW / hr was assumed to be \$0.08 (U.S.)
- CRAC unit specifications based on an APC FM50:
  - Standard downflow
  - Glycol cooled unit (no multi-cool or economizer)
  - Electrode steam generating humidifier (Plastic canister type with automatic water level adjustment based on water conductivity)
  - Humidifier capacity is 10 lbs/hr (4.5 kg / hr)
  - Humidifier electrical consumption is 3.2 kW
  - Voltage is 208 VAC

Figure A1

Audit checklist

### Cooling Audit Checklist

Capacity Check				
CRAC	Model	Total Capacity	Sensible Capacity	Quantity
Unit 1				
Unit 2				
Unit 3				
Unit 4				
Unit 5				
Unit 6				
Unit 7				
Unit 8				
Unit 9				
Unit 10				
<b>Total Usable Capacity = SUM (Sensible Capacity x Quantity)</b>				

Heat Load Requirement			
IT Equipment	Total IT load power in watts	Same as total IT load power in watts	
UPS with Battery	Power system rated power in watts	$(0.04 \times \text{Power system rating}) + (0.06 \times \text{Total IT load power})$	
Power Distribution	Power system rated power in watts	$(0.02 \times \text{Power system rating}) + (0.02 \times \text{Total IT load power})$	
Lighting	Floor area in square feet, or floor area in square meters	2.0 x floor area (sq ft), or 21.53 x floor area (sq m)	
People	Max # of personnel in data center	100 x Max # of personnel	
Total	Subtotals from above	Sum of heat output subtotals	
Capacity is equal to or greater than heat output? <input type="checkbox"/> Yes <input type="checkbox"/> No			

CRAC Monitoring Points			
Supply (average of three monitoring points for each)			
CRAC 1 _____	CRAC 6 _____	Acceptable Averages: Temp. 68-75F (20-25C), Humidity 40-55% R.H.	Meets Tolerance (check one)
CRAC 2 _____	CRAC 7 _____		All within range <input type="checkbox"/>
CRAC 3 _____	CRAC 8 _____		1-2 out of range <input type="checkbox"/>
CRAC 4 _____	CRAC 9 _____		>2 out of range <input type="checkbox"/>
CRAC 5 _____	CRAC 10 _____		
Return (average of three monitoring points for each)			
CRAC 1 _____	CRAC 6 _____	Acceptable Averages: Temp. 58-65F (14-18C)	Meets Tolerance (check one)
CRAC 2 _____	CRAC 7 _____		All within range <input type="checkbox"/>
CRAC 3 _____	CRAC 8 _____		1-2 out of range <input type="checkbox"/>
CRAC 4 _____	CRAC 9 _____		>2 out of range <input type="checkbox"/>
CRAC 5 _____	CRAC 10 _____		

Cooling Circuits			
Chilled Water	45F (+/- 3F), 7.2C (+/- 1.7C)		Meets Tolerance <input type="checkbox"/> Yes <input type="checkbox"/> No
Condenser Water - Water Cooled	Max 90F (32.2C)		(check one) <input type="checkbox"/> Yes <input type="checkbox"/> No
Condenser Water - Glycol Cooled	Max 110F (43.3C)		<input type="checkbox"/> Yes <input type="checkbox"/> No
Air Cooled	<i>Should be checked by qualified HVAC contractor</i>		

Aisle Temperatures			
Measurement points at 5 feet (1.5 meters) above the floor at every 4th rack (averaged for aisle)			
Aisle 1 _____	Aisle 6 _____	Acceptable Averages: Temp. 68-75°F (20-25°C)	Meets Tolerance (check one)
Aisle 2 _____	Aisle 7 _____		All within range <input type="checkbox"/>
Aisle 3 _____	Aisle 8 _____		1-2 out of range <input type="checkbox"/>
Aisle 4 _____	Aisle 9 _____		>2 out of range <input type="checkbox"/>
Aisle 5 _____	Aisle 10 _____		



**Figure A2**

Audit checklist (cont.)

<b>Rack Temperatures</b>				
<b>Measurement points at 5 feet (1.5 meters) above the floor at every 4th rack (averaged for aisle)</b>				
R1 ___ R2 ___ R3 ___	R46 ___ R47 ___ R48 ___	Acceptable Averages: Temp. 68-75°F (20-25°C), Top to bottom temperatures in each rack should not differ more than 5F (2.8C)	<b>Meets Tolerance (check one)</b>	
R4 ___ R5 ___ R6 ___	R49 ___ R50 ___ R51 ___		All within range	<input type="checkbox"/>
R7 ___ R8 ___ R9 ___	R52 ___ R53 ___ R54 ___		1-2 out of range	<input type="checkbox"/>
R10 ___ R11 ___ R12 ___	R55 ___ R56 ___ R57 ___		>2 out of range	<input type="checkbox"/>
R13 ___ R14 ___ R15 ___	R58 ___ R59 ___ R60 ___			
R16 ___ R17 ___ R18 ___	R61 ___ R62 ___ R63 ___			
R19 ___ R20 ___ R21 ___	R64 ___ R65 ___ R66 ___			
R22 ___ R23 ___ R24 ___	R67 ___ R68 ___ R69 ___			
R25 ___ R26 ___ R27 ___	R70 ___ R71 ___ R72 ___			
R28 ___ R29 ___ R30 ___	R73 ___ R74 ___ R75 ___			
R31 ___ R32 ___ R33 ___	R76 ___ R77 ___ R78 ___			
R34 ___ R35 ___ R36 ___	R79 ___ R80 ___ R81 ___			
R37 ___ R38 ___ R39 ___	R82 ___ R83 ___ R84 ___			
R40 ___ R41 ___ R42 ___	R85 ___ R86 ___ R87 ___			
R43 ___ R44 ___ R45 ___	R88 ___ R89 ___ R90 ___			

<b>Airflow</b>				
<b>Check all perforated tiles (where applicable), compare to tolerances</b>				
Perforated floor tiles	Airflow measurement (positive airflow check), volume tests should be carried out by a qualified HVAC contractor	Acceptable Averages: => 160 cfm/kW (75.5 L/s) / kW	<b>Meets Tolerance (check one)</b>	
			All within range	<input type="checkbox"/>
			1-2 out of range	<input type="checkbox"/>
			>2 out of range	<input type="checkbox"/>

<b>Inspecting the Rack</b>			
Blanking Panels	Are blanking panels installed in all rack spaces where IT equipment is not installed?	<b>Meets Tolerance (check one)</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No

<b>Air Path Below the Floor (where applicable)</b>			
Visible obstructions	Are blanking panels installed in all rack spaces where IT equipment is not installed?	<b>Meets Tolerance (check one)</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No
Missing tiles, gaps and voids	Are all floor tiles in place? Are cable access openings adequately sealed?		<input type="checkbox"/> Yes <input type="checkbox"/> No

<b>Aisle and floor tile arrangement</b>			
Perforated floor tile positions	Are blanking panels installed in all rack spaces where IT equipment is not installed?	<b>Meets Tolerance (check one)</b>	<input type="checkbox"/> Yes <input type="checkbox"/> No
CRAC positioning	Do the CRACs line up with the hot aisles?		<input type="checkbox"/> Yes <input type="checkbox"/> No
Hot aisle, cold aisle layout	Is there separation between hot and cold aisles (racks not facing the same direction)?		<input type="checkbox"/> Yes <input type="checkbox"/> No