# *Airflow Impedance:*
## *The Silent Enemy of Data Center Cooling*

A White Paper on Data Center Airflow, Impedance and Cooling Management

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# ***Airflow Impedance:*** *The Silent Enemy of Data Center Cooling*

Today's data center cooling infrastructure has more demands placed on it than ever. Server virtualization makes the computing model more efficient, but the added load in blade servers combined with increased demands on storage and networking has created an environment where high heat densities are forcing facilities management to review their cooling topologies.

The challenges are very well defined: servers require inlet air temperatures between 66°F and 80° F. The volume of cooling air required is approximately 160 cubic feet per minute (CFM) per kilowatt (kW) for rack mount servers and 120 CFM per kW for blade servers. To accomplish this, the CRAC fan must move enough cool air to supply the server racks.

Simple as it is, in reality, it's very difficult to calculate whether there is sufficient underfloor pressure and airflow in a continuously evolving environment and/or, where heat densities vary from one rack to the next. In a heterogeneous computing environment, racks may house systems that range in heat density from 2 kW per rack to upwards of 35 kW per rack for high performance servers.

## Hot Spots and Meat Lockers

This variance can cause heat to build up as hot spots in one, two or several locations within the data center while the rest of the facility is over-cooled. By doing so, this "Meat Locker" effect increases the required cooling capacity upwards of two to three times the actual needed capacity – an inefficient, expensive cooling method.

## Airflow Impedance: The silent enemy to cooling efficiency

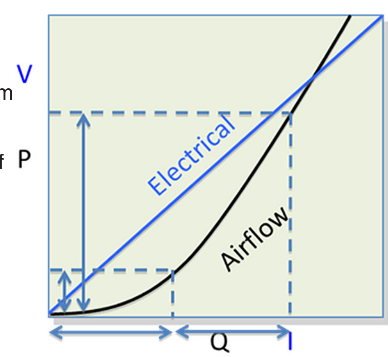
Many data centers are either at IT power or thermal capacity due to restrictions in cooling or space. However, these restrictions are typically caused by the lack of airflow management in the data center. Airflow distribution problems play a significant role in increasing power consumption costs. And airflow distribution in a data center is primarily determined by the underfloor airflow impedance, CRAC locations, and the distribution of perforated tiles.

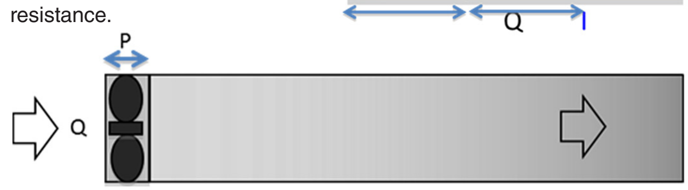
Airflow impedance can be caused by a number of things: excess cables, misplaced pipes, odd layouts, and other underfloor obstructions that limit cool air distribution. Impedance can also be a function of the underfloor distance that air has to travel: the greater the distance, the higher the potential that impedance will increase.

Airflow impedance through a confined space, such as a server enclosure or data center underfloor, can be thought of in the same context as electrical impedance. Per Ohm's Law: R = V/I, R is the resistance, V is the voltage, and I is the current forced through. Applied to airflow impedance: $Z = P / Q^2$, Z is airflow impedance, P is air pressure caused by your cooling fans, and Q is the airflow caused by the pressure generated (see Figure 1).

Figure 1

Airflow through a duct follows a simple pressure- airflow relationship. This is true for a server or the underfloor plenum in a data center. The pressure is proportional to the square of airflow. The ratio of pressure and airflow² is the airflow impedance. This is similar to Ohm's law of electrical resistance.




Or the pressure can be presented as:

$$P = Z * Q^2$$

The pumping power of fan is defined as:

$$W = P * Q = Z * Q^3$$

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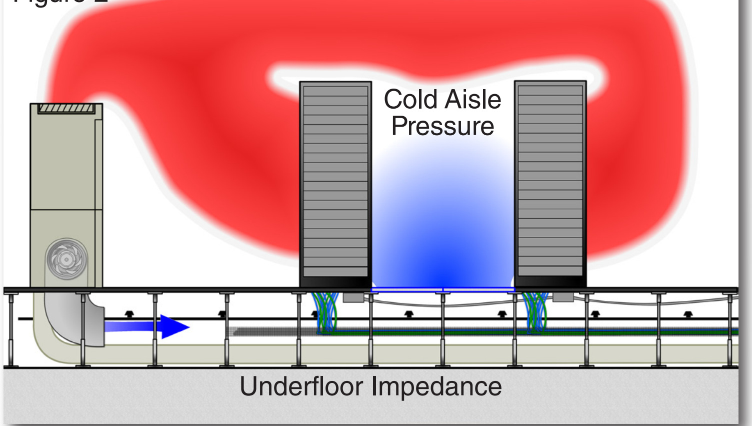
These equations show that in order to double airflow, there must be four times the fan pressure and eight times the pumping power consumed by the fans. But how? Fans reach a point of diminishing return when the cost of fan operation exceeds the savings.

Airflow takes the path of least resistance under the floor. The airflow reaching a server is decided by underfloor obstructions and CRAC performance. But servers pull airflow all of the time depending on their cooling demands. So enough cool air must be pushed through to the server or hot server exhaust will recirculate. These issues compound themselves when cooling an aisle of server racks (See Figure 2).

CRACs with variable-frequency drive (VFD) fans can help, however they alone cannot achieve full cooling efficiency since they cannot independently vary airflow at multiple locations simultaneously. The best way to manage this is to manage underfloor airflow impedance, through

Figure 2



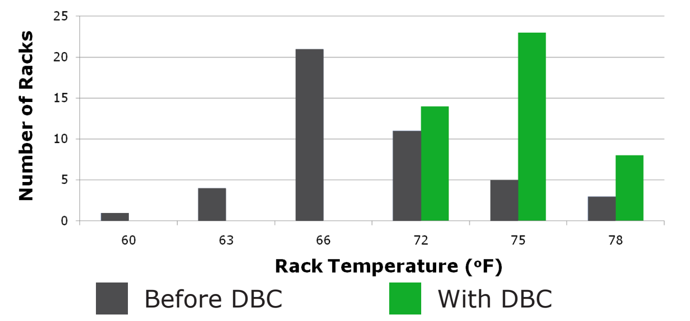

the strategic use of Demand Based Cooling (DBC). DBC dynamically provisions data center cooling when needed in numerous areas simultaneously. It also adds real-time management and delivery of cooling to a changing data center environment.

## Real World Examples

The following are examples of how controlling airflow distribution in two data centers helped improve data center cooling efficiencies.

One data center's server racks were at a wide temperature range of 60ºF - 78ºF. With all CRACs in operation, the hotter racks were kept at acceptable temperatures while several racks were overcooled. DBC narrowed the intake temperature spread to 72ºF - 78ºF with fewer CRACs through proper airflow management (See Figure 3). The narrow temperature band can now be moved by varying CRAC temperature setpoints.

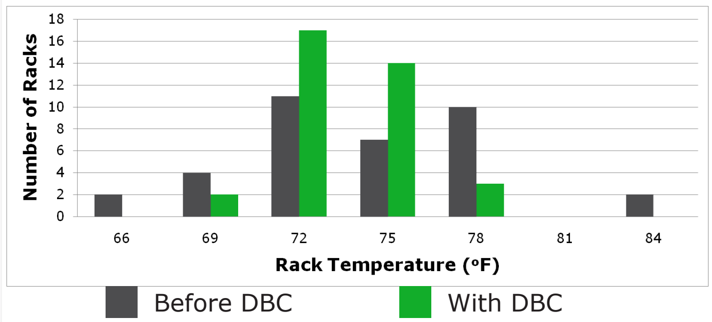
Figure 3




In a second example, one of North America's largest financial services companies needed to reduce large heat fluctuations during peak processing hours. DBC was chosen because it required no server downtime or rack movement, which was advantageous to the mission-critical operations performed at this site.

As a result of the DBC installation, which corrected air impedance, distribution and management, the data center achieved proper cooling efficiency. The graph below (See Figure 4) shows rack temperatures before and after installation.

Figure 4

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In addition, the local energy utility approved this DBC solution for rebates and the financial firm saw major savings. Before DBC, the company consumed $122,033 of energy per year in cooling alone. After DBC, the company cut that cost to $72,217, saving $49,816 or 40%.

## Summary

Airflow impedance is a factor that is overlooked when dealing with data center cooling issues. DBC is a holistic approach that can overcome the airflow impedance in a data center that, in turn, affects airflow distribution. Additionally, it can improve overall data center cooling efficiency. Many data centers are thought to be at IT or thermal capacity due to restrictions in cooling or space. However, the restriction is typically caused by the lack of airflow management within the data center.

Examining and resolving airflow issues can have a significant impact and make a data center's cooling system more efficient. By doing so, data center managers can lower energy usage, increase IT capacity and improve thermal reliability.

## About the Founder & Author

Rajesh Nair is Chief Technical Officer of the Milford, NH-based Degree Controls, the parent company of AdaptivCOOL (www.adaptivcool.com).