# Data Center Cooling Best Practices:

## Maximizing power efficiency through smart planning and design

Simple mainframe data centers have grown to full fledged Data Centers with a myriad of servers, storage, switching and routing options. As we continue to add equipment to these "rooms" we increase the heat generation while reaching peak capacity. In order to maximize cooling efficiency within Data Centers there are best practices provided by organizations such as ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers), which are followed or echoed in many of the industry standards. While some seem to be common sense, others are sometimes neglected.

## Addressing Cabling and Pathways

First, and most simply, in order to increase chiller efficiency, it is mandatory to get rid of the old abandoned cabling under raised floors. While cable abatement is a code requirement in some countries due to fuel loads, in all instances and all countries, it makes sense to remove blockages having an impact on air flow to equipment. While working on cable abatement strategies, it is a great time to look at upgrade projects to higher performing cabling which can be either wholly or partially funded through recycling of older copper cable.

While a properly designed under floor cable plant will not cause cooling inefficiencies, when the under floor void is full of cable, a reverse vortex can be created causing the under floor void to pull air from the room rather than push cool air up to the equipment. When pathways and spaces are properly designed, the cable trays can act as a baffle to help maintain the cold air in the cold aisles, or channel the air. Problems occur when there is little or no planning for pathways, They become over filled as many years of abandoned cable fills the pathways and air voids. Overfilling pathways can also cause performance issues. In designing an under floor system, it is critical to look at airflow, void space, cable capacity accommodating growth and other under floor systems such as power, chiller pipes, etc.

In both TIA-942A and the pending ISO 24764 data center standards, it is recommended that structured cabling systems are used and designed accommodating growth so that revisiting the cabling and pathways will not be necessary for the lifecycle of the cable plant. The reasoning behind this is to limit moves, adds and changes, which contribute to the spaghetti we see in many data centers today. In an ideal environment, the permanent link for the channels are run between all necessary cabinets and other central patching locations allowing moves adds and changes to be completed via patch cord changes instead of running new links. Using the highest performing copper cable plant available (currently 7A) assures a longer lifecycle and negates the need for a cable abatement project again in the foreseeable future.

The largest issue with cable abatement is determining which cables can safely be removed. This is compounded in older data centers that have more spaghetti than structure under the floor. One common practice is to upgrade existing copper and fiber cabling utilizing pre-terminated and tested trunking cables. Since cables are combined in a common sheath, once installed and all equipment is cut over to the new system, cables that are not in the common sheath/binder are easily identified for removal. In abatement projects, trunking cables provide the benefit of rapid deployment as the cables are factory terminated to custom lengths eliminating the need for time comsuming and labor intensive field terminations.

In some cases, companies move to opposite conveyance systems, i.e. under floor to overhead systems. If moving to an overhead system for abatement, the pathways should be run so that they do not block the natural rise of heat from the rear of cabinets. It is important to consult the proper structural and fire specialties to assure that the ceiling can handle the additional weight, holes for support rods and that the overhead system will not obstruct the reach of fire suppression systems. Just as it is important to plan to accommodate growth under the floor, it is equally important in an overhead system to assure that there is enough room for layers of tray that may be required for overhead pathways.

In order to determine whether an under floor system should be used, the largest factors to consider are the amount of floor void, cooling provided, and layout of the room. For overhead systems, the ceiling height, structural ability to hold mounting brackets, and placement of lighting and fire suppression are the key factors. In both cases, it is important to note that with today's higher density requirements, several layers of trays may be needed in either or both locations.

Running a combination of overhead and under floor systems may be necessary. The past practices of running day one cable tray and/or sizing cable tray based on previous diameters and density requirements can be detrimental to a data center's efficiency during periods of growth. Anticipated growth must be accommodated in day one designs to assure that they will handle future capacity.

Examination of the cabling pathways also includes addressing floor penetrations where the cabling enters cabinets, racks and wire managers. Thinking back to the old bus and tag days in data centers, the standard was to remove half a floor tile for airflow. In many data centers today, that half a tile is still missing and there is nothing blocking the openings to maintain the static pressure under the data center floor. Where the cable penetrations come through the raised floor tiles a product such as brush guards, air pillows or some other mechanism to stop the flow of air into undesirable spaces is paramount.

When you consider that most of the cable penetrations are in the hot aisle and not the cold aisle, the loss of air via these spaces can negatively affect the overall cooling of a data center. In an under floor system, cable tray can act as a baffle to help channel the cold air into the cold aisles if properly configured. While some would prefer to do away with under floor systems if these systems are well designed and not allowed to grow unmanaged, they can provide excellent pathways for cabling.

Cabling pathways inside cabinets are also critical to proper air flow. Older cabinets are notoriously poor at cable management, in large part because that they were not designed to hold the higher concentration of servers that are required today. Older cabinets were typically designed for 3 or 4 servers per cabinet when cabling and pathways were an afterthought. Newer cabinets such as the Siemon VersaPOD™ were designed specifically for data center cabling and equipment providing enhanced Zero-U patching and vertical and horizontal cable management assuring that the cabling has a dedicated without impacting equipment airflow. The same can be said for extended depth wire management for racks such as Siemon's VPC-12.

PODs are changing the face of data centers. According to Carl Claunch of Gartner as quoted in Network World…

"A new computing fabric to replace today's blade servers and a "pod" approach to building data centers are two of the most disruptive technologies that will affect the enterprise data center in the next few years, Gartner said at its annual data center conference Wednesday. Data centers increasingly will be built in separate zones or pods, rather than as one monolithic structure, Gartner analyst Carl Claunch said in a presentation about the Top 10 disruptive technologies affecting the data center. Those zones or pods will be built in a fashion similar to the modular data centers sold in large shipping containers equipped with their own cooling systems. But data center pods don't have to be built within actual containers. The distinguishing features are that zones are built with different densities, reducing initial costs, and each pod or zone is self-contained with its own power feeds and cooling, Claunch says. Cooling costs are minimized because chillers are closer to heat sources; and there is additional flexibility because a pod can be upgraded or repaired without necessitating downtime in other zones, Claunch said."

Lastly, a clean data center is a much better performer. Dust accumulation can hold heat in equipment, clog air filtration gear, and although not heat related, contribute to highly undesirable static. There are companies that specialize in data center cleaning. This simple step should be included yearly and immediately after any cable abatement project.

Inside the cabinets, one essential component that is often overlooked is blanking panels. Blanking panels should be installed in all cabinets where there is no equipment. Air flow is typically designed to move from front to back. If there are open spaces between equipment the air intakes on equipment can actually pull the heated air from the rear of the cabinet forward. The same can be said for spaces between cabinets in a row. Hot air can be pulled to the front either horizontally (around cabinets) or vertically (within a cabinet) supplying warmer than intended air to equipment which can result in failure. In a recent study of a data center with approximately 150 cabinets, an 11 degree temperature drop was realized in the cold aisles simply by installing blanking panels.

## Planning for Cooling

Hot aisle, cold aisle arrangements were made popular after the ASHRAE studied cooling issues within data centers. ASHRAE Technical Committee 9.9 characterized and standardized the recommendations.[1] This practice is recommended for either passive or active cooling or a combination of the two. The layout in Figure 1 shows four rows of cabinets with the center tiles between the outer rows representing a cold aisle (cold air depicted by the blue arrows). And the rear faces of the cabinets are directed towards the hot aisles (warmed air depicted by the red arrows). In the past, companies arranged all cabinets facing the same direction to allow an esthetically pleasing showcase of equipment. Looks, however, can be more than deceiving; they can be completely disruptive to airflow and equipment temperatures.

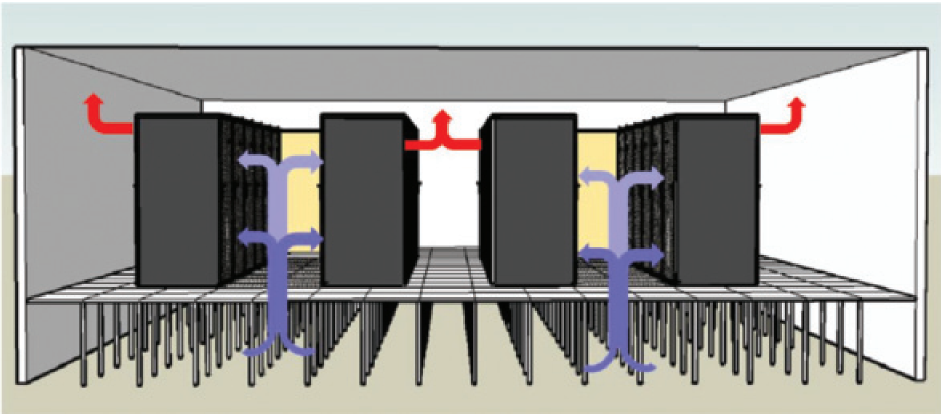

**Figure 1: Passive cooling, utilizing airflow in the room and door perforations.**

In a passive cooling system, the data center airflow utilizes either perforated doors or intakes in the bottom of cabinets for cold air supply to equipment and perforated rear doors to allow the natural rise of heated/discharged air from the rear of the cabinets into the CRAC (Computer Room Air Conditioner) intake for cooling and reintroduction into the raised floor.

Active cooling systems may be a combination of fans (to force cold air into the faces of cabinets or pull hot air out of the rear roof of cabinets), supplemental cooling systems such as in row cooling, etc. For the purposes of this paper, only passive cooling systems are addressed as the factors for active cooling are as varied as the number of solutions. In order to fully understand the capabilities of each, individual studies and modeling should be performed before any are implemented. ASHRAE recommends pre-implementation CFD (Computational Fluid Dynamics) modeling for the various solutions.

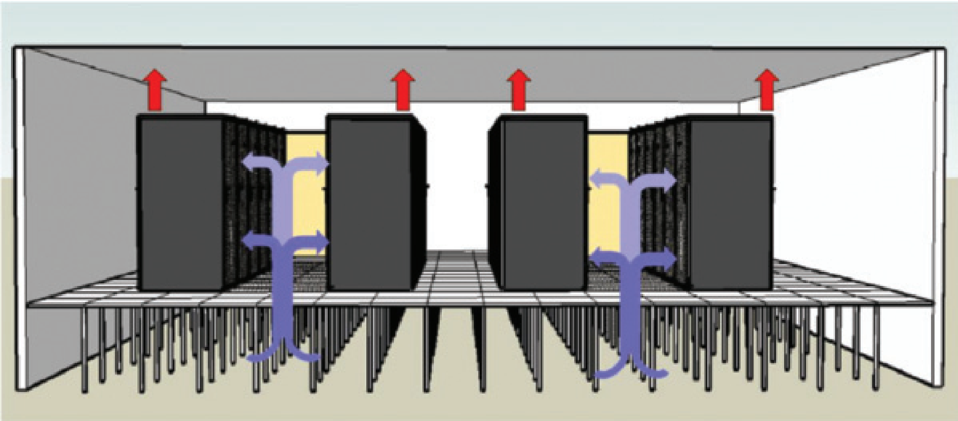

**Figure 2: One example of active cooling utilizing fans to pull hot air through the roof**

In order to determine the cooling needed, several factors must be known:

- Type of equipment
- Power draw of equipment
- Placement of equipment
- Power density (W/m$^2$ , W/ft$^2$)
- Required computer area (m$^2$, ft$^2$ )

"Computer room floor area totals in the data center would incorporate all of the computing equipment, required access for that equipment, egress paths, air-conditioning equipment, and power distribution units (PDU's). The actual power density is defined as the actual power used by the computing equipment divided by the floor area occupied by the equipment plus any supporting space." [2] This can be defined by the following formula:

*Actual power density (W/ft$^2$) = Computer Power Consumption (W) / required computer area (ft$^2$)*

White space should not be used in the calculations for actual power density. This figure is important when planning a data center. 1U servers have significantly different power density requirements than Blade chassis, storage towers and mainframes. Distribution of this equipment will change the requirements of the various areas of a data center. For instance if a single zone is selected for Blade servers with a greater power density, passive cooling may not provide adequate air temperatures.

In Table 1. IT Equipment Power consumption, it is obvious that one single solution may not address all power needs unless the varied densities are in the initial design. Data Centers using primarily legacy equipment operate at power densities as low as 30W/ft$^2$ (~320 W/m$^2$) as compared to more modern higher processing equipment which falls closer to the 60-1000W/ft$^2$ (~645 to 1,075 W/m$^2$).

| Equipment | W/ft$^2$ Power Range (~W/m$^2$) |
|---|---|
| 3U Legacy Rack Server | 525 – 735 (~5,645 – 7,900) |
| 4U Legacy Rack Server | 430 – 615 (~4,620 – 6,610) |
| 1U Present Rack Server | 805 – 2,695 (~8,655 – 28,980) |
| 2U Present Rack Server | 750 – 1,050 (8,065 – 11,290) |
| 4U Present Rack Server | 1,225 – 1,715 (13,170 – 18,440) |
| 3U Blade Chassis | 1,400 – 2,000 (15,050 – 21,500) |
| 7U Blade Chassis | 1,200 – 2,300 (12,900 – 24,730) |
| Mainframe (Large Partitioned Server) | 1,100 – 1,700 (11,830 –18,280) |

**Table 1. IT Equipment Power Consumption[2]**

Power consumption can be determined in several ways. Not all will provide an accurate depiction of power needs which in turn would not provide an adequate prediction of cooling demand. Past practices utilized the nameplate rating which as defined by IEC 60950[7] clause 1.7 states "Equipment shall be provided with a power rated marking, the purpose of which is to specify a supply of correct voltage and frequency, and of adequate current-carrying capacity." This rating is a maximum rating as listed by the manufacturer and very rarely will ever be realized. Utilizing this rating will cause oversizing of air conditioning systems and cause a waste in both cooling and money. Most equipment operates at 65-75% of this listing. The correct number to use is measured power consumption. If you will be incorporating new equipment into your data center, equipment manufacturers can provide you with this number.

Intelligent PDUs (iPDUs) can provide actual usage statistics for equipment power draw. By monitoring and trending power variances, data center managers can also determine actual power and cooling needs as opposed to using theoretical or modeled limits. This also allows better management of loads across the entire floor space.

In addition to the Watts required for equipment, you will also need to determine other sources of heat to be cooled in the data center. This includes lighting, humans, etc., APC has developed a simple spreadsheet to assist with these equations: [3]

| 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 x Power System Rating) + (0.05 x Total IT Load Power) | ________Watts |
| Power Distribution | Power System Rated Power in Watts | (0.01 x Power System Rating) + (0.02 x Total IT Load Power) | ________Watts |
| Lighting | Floor Area in Square Feet or 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 |
| Total | Subtotals from Above | Sum of Heat Output Subtotals | ________Watts |

**Table 2. Data Center Heat Source Calculation Worksheet (Courtesy of APC)**

According to APC, cooling capacity is generally about 1.3% of your power load for data centers under 4,000 square feet. For larger data centers, other factors may need to be taken into account such as walls and roof surfaces exposed to outside air, windows, etc. But in general this will give a good indication of overall cooling needs for an average space.

With that said, this is assuming an overall cooling to floor ratio with a similar load at each cabinet. The question gets asked "What cooling can your cabinet support" The variants are significant. Some variants to consider for cabinet cooling include equipment manufacturer recommendations. Many blade manufacturers for instance do not recommend filling cabinets with blades due to cooling and power constraints. According to the Uptime Institute, equipment failures in the top 1/3 of a cabinet is roughly 3x greater than at the lower portion of cabinets. This is due in part to the natural warming of air as heat rises. In order to increase equipment load in high density areas, some form of supplemental cooling may be required. That does not mean that you need to build in-row cooling into every single row, but rather evaluation for high density areas may makes sense. The same may be true for SAN areas and other hotter equipment.

Percentage of door perforation will also be a factor. According to the Industrial Perforators Association, measured air velocity through perforated doors varies with the percentage of perforation. The lower the perforation percentage, the more impact to airflow into the cabinet,as shown in Figure 3.[4] Siemon's VersaPOD™ doors have 71% O.A peforation allowing maximum air flow from cold aisle to hot aisle.

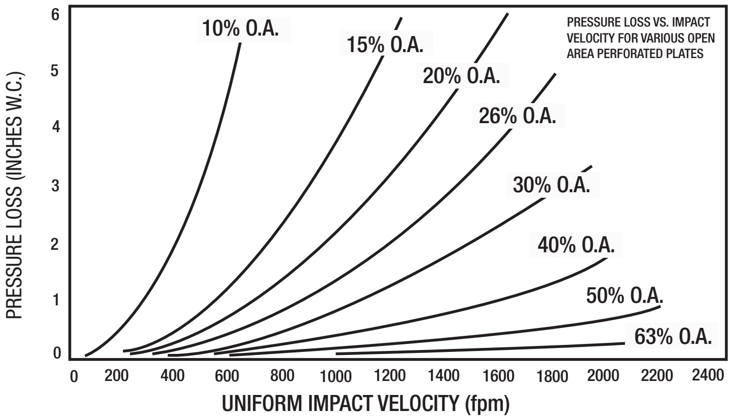


**Figure 3: Pressure Loss vs Impact Velocity for Perforated Plates**

There are supplemental (active) cooling methods that can be added to cabinets to enhance the airflow either forcing cool air into the cabinets or forcing hot air out. All of these cooling methodologies rely on blanking panels and other steps as outlined earlier in this. There are also workarounds for legacy equipment that utilize side discharge heated airflow, such as legacy Cisco® 6509 and 6513 switches. While some switch models now use front to rear airflow, other switches such as some of the Cisco Nexus 7000 based switches still use side airflow.

In side air discharge scenarios, equipment should be isolated cabinet to cabinet so that heated air does not flow into the adjacent cabinet. Some data centers chose to place this equipment in open racks. The Siemon VersaPOD has internal isolation baffles or side panels to assist with this isolation.

## Effectiveness of Cooling

Effectiveness of cooling is a necessary test to assure that assumptions made during design are providing the benefits expected. It can also be a good measurement to determine the efficiency of existing data centers and provide a roadmap for remediation on a worst case/first solved basis. The "Greeness" of a data center utilizes two metrics:

1. Data Center Infrastructure Efficiency (DCIE) (a reciprocal of PUE below) is a function of total data center power. This does not just mean servers, but rather includes storage, KVM switches, monitors, control PC's, monitoring stations, etc. Added to the electronics components are all supporting systems such as UPS, PDU's, switch gear, pumps, cooling systems, lighting and the like. The resulting total divided by Total Facility Power will result in DCIE. This is the preferred method used by IBM®. A DCIE of 44% means that for every 100 dollars spent, 44% is actually used by the data center. Improvements in efficiency can bring this number closer to the 100% ideal number.

2. Power Usage Effectiveness (PUE) is another calculation used by some manufacturers. Simply, DCIE = 1/PUE where PUE = Total Facility Power/IT equipment Power. In both cases, the higher the DCIE percentage, the better the data center is on a green scale.

These numbers will not, however, tell you individually how efficient a particular piece of equipment is on the same scale. To determine this, you will need to monitor power at the port for each piece of equipment. New power supplies exist that allow this type of monitoring. When planning for more energy efficient equipment, this can be an invaluable tool.

Another way to measure effectiveness of cooling is to measure cold aisle air temperature throughout the facility. Air is typically measured every other or every third cabinet along the cold aisle. It is normal to see fluctuations in temperature in the hot aisles due to various equipment heat discharge temperatures. But assuring that cool air supply is a consistent temperature will provide you with a clear indication of how well air circulation and conditioning is working. It will also allow you to plan where to put hotter equipment if supplemental cooling will not be introduced.

When active cooling is not an option, a data center will see the best consistency in air temperatures by spacing the hottest equipment around the data center rather than concentrating it all in a single "hot spot" area. Planning is a necessary roadmap for today's hotter equipment. While it may seem logical to have a blade server area, SAN area, etc. In practice, it may be more efficient to have this equipment distributed throughout the data center. It is important to consult your various equipment manufacturers for recommendations.

Regardless of the design methodologies one chooses to follow for their data center, Siemon has resources globally to help. For more information on data center best practices, copper and fiber cabling systems, or the VersaPOD, please visit www.siemon.com or contact your local Siemon representative.

## References


(1) Thermal Guidelines for Data Processing Environments. Atlanta: ASHRAE, Inc.

(2) Air-Conditioning Design for Data Centers-Accomodating Current Loads and Planning for the Future; Christopher Kurkjian, PE, Jack Glass, PE, ASHRAE, Inc.

(3) Calculating Total Cooling Requirements for Data Centers, APC, www.apc.com; http://www.apcmedia.com/salestools/NRAN-5TE6HE_R2_EN.pdf

(4) Industrial Perforators Association, http://www.iperf.org/IPRF_DES.pdf

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