WHITE PAPER

Effectiveness and Implementation of Modular Containment in Existing Data Centers

By
Lars Strong, P.E., Upsite Technologies, Inc.
Bruce Long, Upsite Technologies, Inc.

upsite technologies®
505.798.0200
upsite.com

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Executive Summary

Hot aisle containment and cold aisle containment have been used in computer rooms for years to improve efficiency, increase rack densities and improve overall utilization of the computer room. To date, the data center industry has mainly used hard wall containment and soft curtain containment to accomplish these goals. This paper will introduce and examine a simpler, more cost-effective and easier-to-implement solution called Modular Containment.

Many organizations are taking steps to improve airflow management (AFM) in their computer rooms. They may be motivated by a desire to improve IT equipment intake air temperatures, improve the reliability of equipment, increase cooling capacity, or reduce operating costs. The first step to improving computer room AFM is to implement the essential basic practices of sealing raised-floor openings with grommets and installing blanking panels. However even with these improvements in place, many companies still struggle to meet their goals.

Research has shown the average computer room has 3X to 4X more cooling capacity than required for the installed IT load. This excess of capacity is often installed to overcome hot spots that result from inefficient configuration and operations of the computer room. Overdriving the cooling system to eliminate hot spots and overcome poor airflow management implementation wastes energy and limits computer room cooling utilization.

Data centers can often realize a significant reduction in their cooling energy expense, a release of stranded capacity, and improvement in the computer room environment by investing in an aisle containment solution. Similar to the other types of containment, Modular Containment can eliminate hot spots, increase cooling capacity utilization, and provide energy savings over an uncontained computer room. The key benefit Modular Containment offers is rapid deployment with no disruption to existing operations, and the ability to reconfigure the installation as the needs of the computer room change. In many configurations, Modular Containment represents a simple alternative to traditional hot and cold aisle containment methods.

Introduction

Physical separation of hot and cold air is one of the most effective ways to increase efficiency and utilization in a data center. Managing airflow at the aisle level is essential to achieving these goals. Installation of AFM in the computer room will enable decreased energy usage (and associated energy costs), and increased utilization at the rack and row level, while maintaining or improving the computer room environment.

Traditionally the separation of hot and cold air required the implementation of fixed, highly customized hot aisle and cold aisle containment systems. This approach requires detailed engineering plans, costs additional funds to implement, disrupts the data center operations, and does not easily allow for future rack configuration changes. Unlike hard and soft containment designs, Modular Containment offers complete flexibility to adapt to the current aisle configuration without the need for engineered services or construction within the computer room. This means Modular Containment can be implemented with ease, and can grow and adapt with changes in the computer room.

Specifically, Modular Containment can enable:

- Reducing energy costs by allowing higher supply / return temperature set points on the cooling units. This increases the efficiency of cooling units by enabling a larger temperature differential across the heat extraction coils inside the units. In addition, this will effectively increase the utilization of the cooling units and the total capacity of the cooling system within the computer room as a whole.
- Eliminating hot spots. This can increase the reliability of the IT equipment by providing a lower IT inlet temperature and less thermal stress on the components. Eliminating hot spots also reduces energy consumption by allowing IT equipment fans to run at a slower speed.
- Increased economizer hours for those sites that are taking advantage of economizers.
- Reduced humidification/dehumidification costs. Increased cooling unit temperature set points reduces moisture condensation on the coils (latent cooling). This reduces, or eliminates, the cost of latent cooling and humidification.

- Increased rack densities. Improved AFM results in increased cooling capacity to the rack, and therefore higher potential rack densities. Modular Containment better manages the airflow to the racks, reduces hot and cold air mixing, and reduces bypass and recirculation air. This allows rack densities to increase without exceeding ASHRAE TC9.9 guidelines for rack inlet temperatures.

The remainder of this paper focuses on the components that make up modular containment, creating a modular containment solution from these components, models showing the expected benefits from the solution, and field data results from the implantation of a modular containment solution.

Modular Containment

Managing the airflow in the computer room is key to increased utilization, decreased energy usage and a more efficient computer room. The components in a modular containment system allow the data center operator to better manage airflow by addressing the five most significant hot and cold air-mixing areas in the data center:

- Containing cold air in cold aisles.
- Preventing airflow over the top of racks.
- Containing and directing hot air to the cooling units.
- Filling the gaps between racks in the equipment rows.
- Preventing conditioned or exhaust air from flowing around the ends of equipment rows.

The four major benefits of airflow management through modular containment are:

1. Enabling the reduction of supply airflow volume, which reduces operating costs and bypass airflow volume. For data centers with fixed drive cooling units it could mean reducing the number of cooling units operating at any one time. For data centers with variable frequency drive cooling units it would allow the blower speed to be reduced significantly, reducing energy usage and costs.
2. Prevention of hot air recirculation from back-to-front over the top of the racks. This would reduce the rack inlet temperatures at the top of the rack and may enable increasing the set points on the cooling units.
3. Prevention of hot air recirculation wrapping around the end of rows. This would reduce the rack inlet temperatures along the height of the rack and may also enable increasing the set points on the cooling units.
4. Prevention of bypass and recirculation air in gaps between the racks in a row. Bypass air simply goes back to the cooling unit without doing any work in cooling the IT equipment. This is inefficient and an energy waste. The recirculation air coming around the side of the racks mixes with the cold supply air and increases rack inlet temperatures. Reducing or eliminating the mixing will also aid in possibly increasing the set points of the cooling units.

Modular Containment has four airflow management components.

1. Angular Rack Top Baffles.
2. Vertical Rack Top Baffles.
3. Bi-Directional Doors.
4. Adjustable Rack Gap Panel.

Each is discussed in detail in the following sections.

Angular Rack Top Baffle

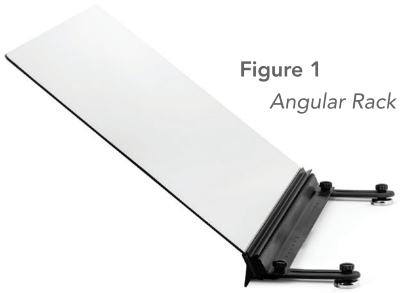


Figure 1
Angular Rack Top Baffle

Typically installed on the top front edge of an IT rack in a cold aisle. The Rack Top Baffles extend from the front edge of the rack into the aisle, reducing the open area of the aisle and slightly pressurizing the cold aisle relative to surrounding areas. In addition, the Rack Top Baffles significantly reduce the recirculation of hot exhaust air from the rack equipment across the top of the rack and back into the front intake of the rack.

Vertical Rack Top Baffle

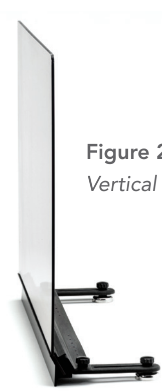


Figure 2
Vertical Rack Top Baffle

Typically installed on the top rear edge of the IT rack. These Rack Top Baffles further restrict hot/cold air mixing. They separate the hot exhaust air on the rear of the rack from the cold supply air on the front of the rack, and create a chimney effect that directs the hot air towards the ceiling plenum and returns of the cooling units. The recirculation of air over the tops of the rack is virtually eliminated. Vertical Rack Top Baffles can also be installed on the front of the racks in the cold aisle. In some computer room configurations, this may provide a better solution for air separation than the angular baffles.

Bi-Directional Doors

Figure 3
Bi-Directional Doors

Doors at the end of the aisles are the third component that further isolates the hot air and cold air mixing in the computer room. In most computer rooms, hot exhaust airflow wraps around the sides of the racks at the end of an aisle. This results in significant mixing of the hot and cold air, and elevated inlet temperatures for the IT equipment in these racks. The usual compensation for this is to add perforated tiles, increase the cooling unit's airflow volume, or decrease the temperature set points. Though these implementations often work, it is using a brute force approach. Increasing fan speeds or decreasing temperature set points has a significant impact on electrical usage and energy costs. To incur these inefficiencies for the sake of a few racks is a waste of resources and compromises utilization.

Adjustable Rack Gap Panel

Figure 4
Adjustable Rack Gap Panel

The final component to a Modular Containment System is the Adjustable Rack Gap Panel. The Adjustable Rack Gap Panel seals the space between the racks when they are not adjacent to one another. In many computer rooms, cabinets are not contiguous in the rows. The gaps are often due to obstructions, such as support columns, variable width cabinets, cabinets removed and not replaced, or many other reasons. The openings in the rows allow significant bypass and or recirculation of the exhaust air. Prevention of this improves overall computer room efficiency and reduces hot spots at the rack level.

Modular Containment System

Figure 5 shows the basic principles of a Modular Containment System. Containment in any computer room is best attained when there is a structured hot aisle / cold aisle layout. Specifically, when each equipment row has an equal length so the ends of the aisles can be effectively sealed with a pair of Bi-Directional Doors. While this is the ideal configuration, significant benefits can be realized from installation in other configurations such as a single row aisle, standalone equipment, legacy layout, rows of different lengths, etc.

Modular Containment is designed as a non-sealed architecture for hot and cold aisle containment. A non-sealed architecture is of benefit since there is considerable variation in the volume of air required by IT equipment. Even with highly refined airflow management, a slight excess volume of conditioned air is delivered to the cold aisle. This is primarily done to accommodate variations in IT equipment airflow volume demands. A slight excess airflow volume is also the result of having redundant cooling capacity running in the room so when a cooling unit fails there is still a sufficient volume of conditioned air available. If there is no opening for the excess volume to escape, excessive pressure can develop in the cold aisle. When this occurs, more air is forced through the IT equipment than required by the equipment. ASHRAE explicitly recommends against this condition of over-pressurized cold aisles. The open-sealing architecture of Modular Containment solves this problem by containing cold air to the level needed while allowing any excess volume to escape when required.

The Rack Top Baffles and Bi-Directional Doors install quickly and easily without the use of tools. Moving or reconfiguring these components is simple and does not require special skills. The rack top vertical panels work well in a traditional raised floor computer room, but can also provide similar benefits in a slab floor environment with dedicated cold aisle supply ducts. In a flooded supply / flooded return environment, caution should be used when installing Modular Containment, or for that matter, any type of barrier to airflow in the computer room. Disruption of airflows in this scenario could cause inadvertent rack inlet air temperature increases.

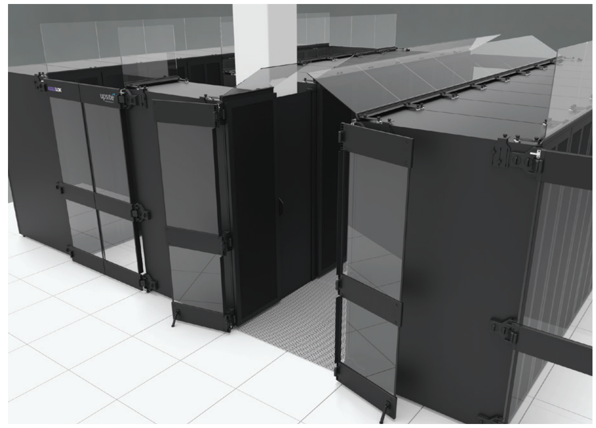


Figure 5
Modular Containment System

Implications on Fire Detection and Suppression Systems

Modular Containment utilizing the angular baffles will partially enclose the aisle from above. The Bi-Directional Doors will enclose the aisles from the end. The partial containment of the air in the aisles may affect the smoke patterns in the computer room, and therefore may impact the effectiveness of the fire detection systems. Furthermore the obstructions created by installing the Rack Top Baffles and Bi-Directional Doors may impede the fire suppression agent dispersion. As is the case with any containment solution, the local authority having jurisdiction (AHJ) will make the final determination as to whether the system meets fire and safety codes, and what, if any modification need to be made to bring the system into compliance.

Modular Containment CFD Analysis

Computational Fluid Dynamic (CFD) analysis conducted by Upsite and by 3rd parties has shown that Modular Containment can achieve many of the core benefits of traditional containment, such as reduced inlet temperatures, energy savings, and increased rack densities, but without the costs or inconveniences that accompany the current containment options. The major benefit of Modular Containment is its ability to attain a similar level of efficacy with a simple and cost-effective design.

No Aisle Containment (front view)

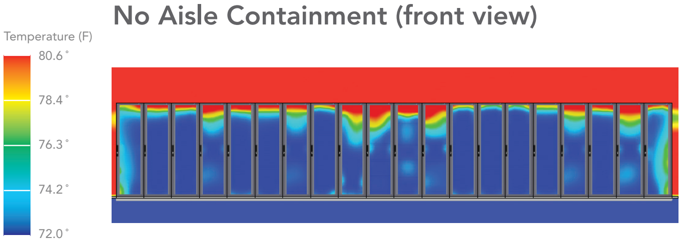


Figure 6
Front View of Racks

The CFD model shows significant recirculation of exhaust air over the tops of the racks. The color red indicates temperatures exceed ASHRAE TC9.9 recommended temperature of 80.6 Deg F.

With Modular Containment (front view)

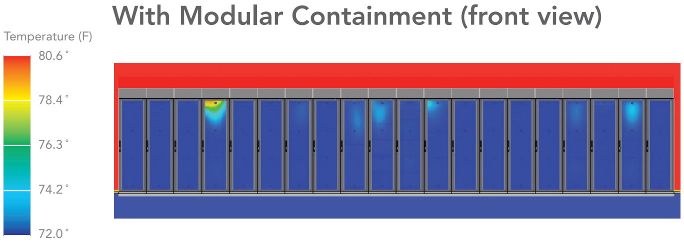


Figure 7
Front View of Racks

With Modular Containment the rack inlet temperatures become very consistent top to bottom, and are all below the ASHRAE TC9.9 recommended temperature of 80.6 Deg F. The maximum reduction in rack inlet temperatures was 10.3 Deg F and the average reduction in rack inlet temperatures was 3.7 Deg F. It is important to note the racks now have uniform inlet temperatures. This enables further optimization of cooling tile airflows and cooling unit operational set point temperatures.

No Aisle Containment (end view)

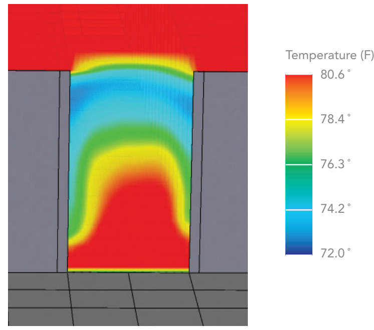


Figure 8
End View of Racks

The CFD model shows significant recirculation from back to front on the end aisle racks. Hot exhaust air from the rear of the racks is wrapping around and being pulled into the equipment inlet on the front of the rack. The color red indicates temperatures exceed ASHRAE TC9.9 recommended temperature of 80.6 Deg F.

With Modular Containment (end view)

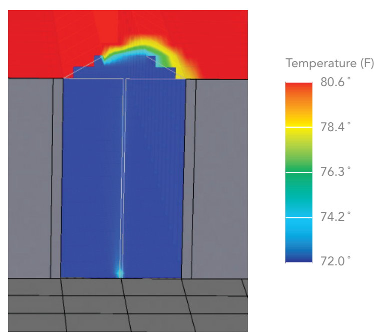


Figure 9
End View of Racks

With the installation of the Bi-Directional Doors the air recirculation around the ends of the aisles is stopped. All IT equipment inlet temperatures now meet the ASHRAE TC9.9 recommended temperature of 80.6 Deg F. For the aisle end cabinets the maximum reduction in rack inlet temperatures was 10.2 Deg F and the average reduction in rack inlet temperatures was 6.2 Deg F. As before, the uniformity of the rack inlet temperatures enables further optimization of cooling tile airflows and cooling unit operational set point temperatures.

Modular Containment Field Results

Basic Computer Room Architecture at a Global Financial Institution

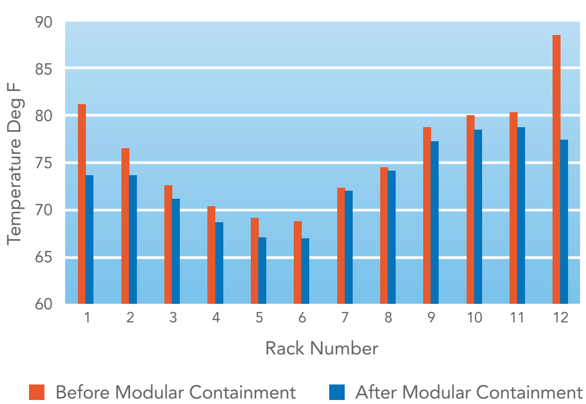
- Raised floor computer room.
- 25% open area perforated tiles in a four foot wide cold aisle.
- Down flow peripheral CRAH units.
- Angular Rack Top Baffles in cold aisle.
- Bi-Directional Doors on cold aisles.

Maximum Rack Inlet Temperature

Figure 10 shows across-the-board maximum rack inlet temperature reductions with the end aisle cabinets showing the most significant decrease from installation of the Bi-Directional Doors. The maximum inlet temperatures occurred at the top front of the rack. Recirculated exhaust air from back to front over the top of the rack and around the sides of the end racks was the major contributor to the increased inlet temperatures.

Figure 10

Maximum Rack Inlet Temperature

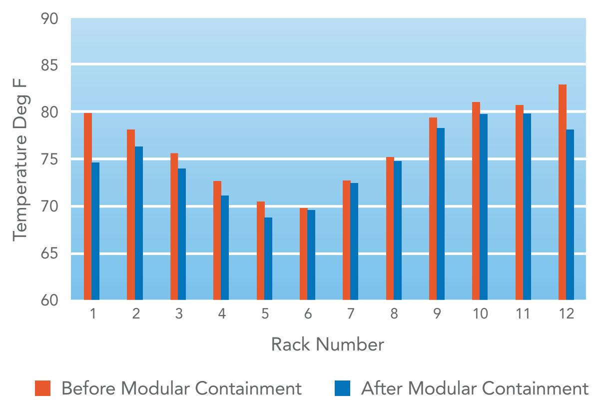


Average Rack Inlet Temperature

Temperatures were measured at four locations evenly spaced from top to bottom on the front of the rack. An average of these temperatures was used for each rack in Figure 11, which shows how the application of Modular Containment reduced average rack inlet temperatures across-the-board. For this site, the Rack Top Baffles and Bi-Directional Doors had less of an influence in the center of the row, while the most dramatic changes were at the end of the aisles.

Figure 11

Average Rack Inlet Temperature

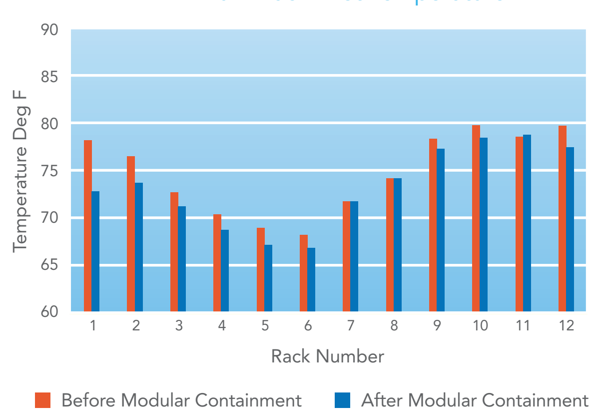


Minimum Rack Inlet Temperature

When examining the impact of Modular Containment to the minimum rack inlet temperatures, the results further reiterate that the most dramatic changes in temperature happen at the ends of the aisles.

Figure 12

Minimum Rack Inlet Temperature



Conclusion

Prevention of hot and cold air mixing is a key to all efficient computer room cooling strategies. Modular Containment effectively reduces the mixing of hot and cold air and creates an environment where substantial cost reductions can be achieved, while also allowing for increased rack, row and infrastructure utilization. Modular Containment also allows optimization to the configuration and operations of the computer room cooling infrastructure. This includes changes to the cooling systems such as raising chilled water set points, increasing both water and air side economizer hours, reducing fan speeds, cycling CRAC/CRAH units, etc.

The Modular Containment implementation also means significantly reduced installation complexity and costs, the ability to install in an existing computer room without interruption to operations, and the flexibility to change the Modular Containment configuration as the needs of the computer room infrastructure change. Other means of sealing both hot and cold aisles include hard wall containment, soft curtain containment and other products on the market. Though these products work well, they typically require a complex process of quoting, designing, customizing and professionally installing, and are often unnecessary for the densities present in the typical computer room.

Modular containment provides a means to achieve similar containment results without the cost and complexity of full containment systems.

About Upsite Technologies, Inc.

Upsite Technologies®, Inc., a pioneer and industry thought leader specializing in data center airflow management, provides a full suite of products and services designed to enable mission critical facilities to optimize cooling, increase reliability, and recover stranded capacity while reducing overall energy costs. Upsite Technologies was created by the late Ken Brill, founder of the Uptime Institute, and launched in 2001 with the original KoldLok® Integral grommet.

Upsite continues to successfully engineer, design and manufacture award-winning, patented solutions and believes that sharing our knowledge and science around airflow management supports the data center industry through open best practice discussions. Upsite's airflow management solutions are sold throughout the US, EMEA, Asia Pacific, and Latin America.

Additional information can be found at http://www.upsite.com.

About The Authors

Lars Strong, P.E.

Lars is a thought leader and recognized expert on data center optimization. He leads Upsite Technologies' EnergyLok Cooling Science Services, which originated in 2001, to optimize data center operations. He is a certified U.S. Department of Energy Data Center Energy Practitioner (DCEP) HVAC Specialist. Lars has delivered and continues to deliver value-added services to domestic and international Fortune 100 companies through the identification and remediation of dilemmas associated with the fluid mechanics and thermodynamics of their data center cooling infrastructure. Lars brings his knowledge and ability to teach the fundamentals of cooling science to numerous U.S. and international private and public speaking events annually.

Bruce Long

Bruce has over 15 years of experience in the design and development of new products, from concept to production, of uninterruptible power supply products for both the IT and commercial markets. He also spent seven years in the design, development and launch of data center assessment services and tools. These services were focused on improving data center efficiency, reducing energy consumption, optimizing cooling systems and improving operational excellence. He is a certified U.S. Department of Energy Data Center Energy Practitioner (DCEP). Bruce is also a past member of the Green Grid where he led the development of the EPA data center efficiency assessment service.