DATA CENTER KNOWLEDGE

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Data Center Knowledge Guide to

Data Center Containment

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October 2012

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Executive Summary

Economics and growing demand for compute cycles, web-based applications and content are driving data centers to find new ways to keep power consumption in check. While doing so, enterprise data centers continue to struggle to add highly dense computing capacity in the same space. Data center airflow management cuts energy costs while enabling affordable, scalable, modular growth of compute pods in the facility. Rack or row-based containment is the best long-term approach to address a majority of these concerns.

A data center that examines the available containment approaches and aligns these with its infrastructure needs will secure the greatest efficiencies and the most benefit for IT and the business.

With most large data centers effectively employing some form of containment to address growing costs for electricity and a static amount of power supply, containment has taken strong root in the data center floor plan.

Contents

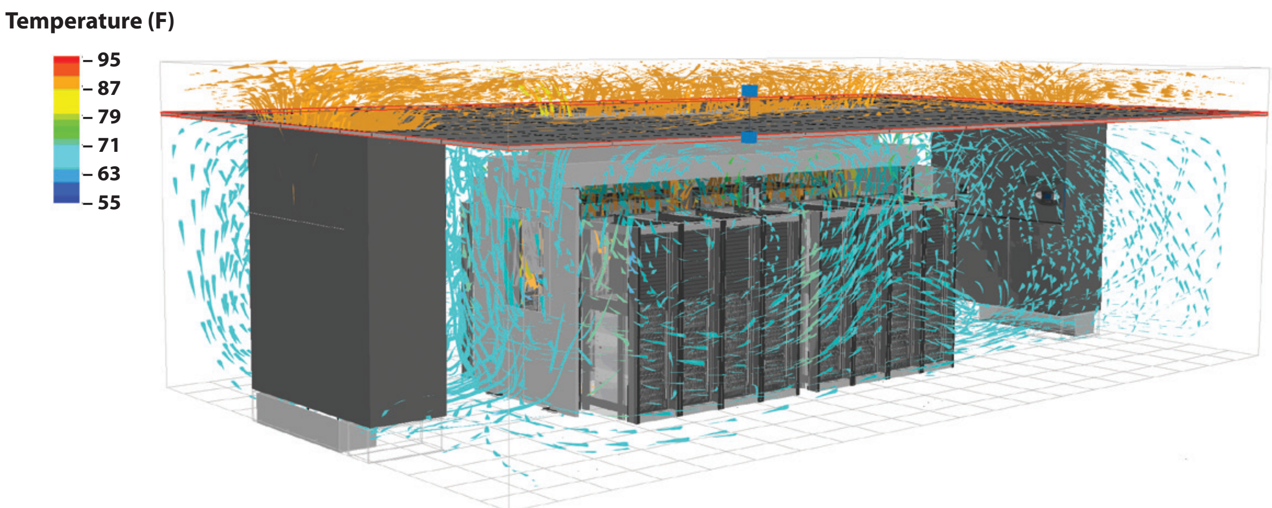
What is Data Center Containment?

Though the two are related, data center containment has a different focus than data center cooling. While cooling uses resources such as CRAC/CRAH units to cool equipment in data center racks and rows, containment increases the efficiency of cooling approaches.

Data center containment applies barriers, components and methods to contain and direct air flow to keep hot and cold air from mixing in the environment. Air mixing dilutes the cooling process by warming cool air intended to cool the equipment and cooling hot air before it hits cooling equipment coils, reducing energy efficiency of the CRAC/CRAH units.

Containment directs hot air to air conditioning return ducts and cold air to equipment rack fronts (see Figure One). Separating hot and cold air enables cooling equipment to efficiently bring the hottest air down to a predetermined, appropriate temperature, lowering energy bills and eliminating the need for additional cooling equipment. The industry refers to this substantial difference between the supply and return air temperatures as the Delta T (ΔT).

Airflow Resulting from Containment
(Figure One)



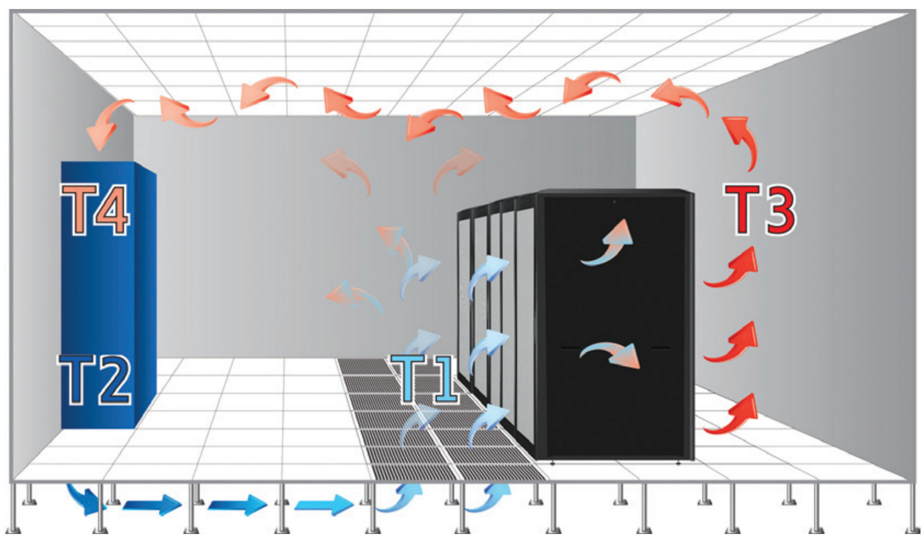
Understanding the Delta T

What is the Delta T? Delta T = Final Temperature minus Initial Temperature. The data center can measure Delta T for individual rackmounted IT devices, which vendors design to operate within defined inlet temperature ranges. The manufacturer typically pre-determines the temperature rise or Delta T, which can range from 20-40F. Although most server manufacturers specify their operating temperature range at 50-95F, ASHRAE TC9.9 recommends maintaining device inlet temperatures between 64.40-80.60F. Significant gradient of air temperatures beyond ASHRAE TC9.9 places devices at risk of thermal shutdown.

The data center can also measure Delta T for an individual IT rack or row of IT racks from the cold aisle front side of the rack(s) to the hot aisle rear side of the rack(s). However, measuring Delta T at the room level in a typical data center provides the most critical information for data center managers to provide a reliable environment for their IT devices while maximizing energy efficiencies.

To understand the thermal environment in a typical data center with open-air distribution (no containment), measure "the four temperatures" (see Figure Two). On the supply side, T2 is the average temperature of the cold air measured immediately as it exits the CRAH/CRAC units and T1 is the average temperature of the air measured at the front door (bottom/middle/top) of IT racks. Subtracting T2 from T1 will usually result in a Delta T of 10-20F, which identifies the supply path losses. Reduction of this supply path Delta T will increase cooling performance in the data center allowing higher rack densities.

Four Temperatures of Data Center Airflow Measurement
(Figure Two)



On the return side, T3 is the average temperature of the hot air measured at the rear door (bottom/middle/top) of IT racks and T4 is the average temperature of the air measured just before it enters the CRAH/CRAC units. Subtracting T4 from T3 on the return side will usually result in a Delta T of 10-20F, which identifies the return path losses. Reduction of this return path Delta T will increase cooling energy efficiency and could save data center managers up to 30% on their annual utility bill.

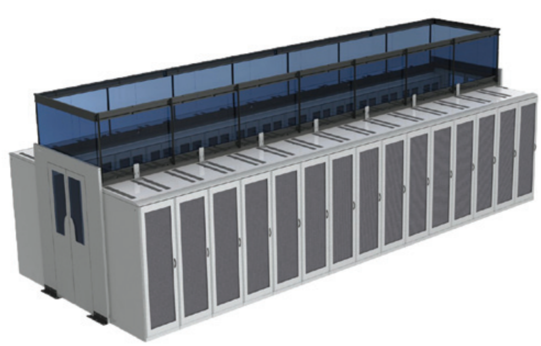
Containment Approaches

Legacy data centers employ a hot aisle/cold aisle arrangement of the IT racks. The fronts of the racks face each other and draw cold air into the rack to cool rack mounted IT devices (i.e. servers, switches, etc.). Conversely, the rear sides of the rows of racks face one another, expelling the hot air into the hot aisle. The issue with hot aisle/cold aisle designs is that the air is free to move wherever it will.

In a cold aisle containment approach, the data center installs end of row doors, aisle ceilings or overhead vertical wall systems to contain the conditioned air that cooling systems send into the cold aisles and ensure that only that air flows into the air intakes of the rack-mounted IT devices. The data center contains the cold aisle to keep the cold air in and the hot air out.

In hot aisle containment, the hot aisle is contained so that the precision air conditioning units only receive hot air from the aisles. Again, the data center contains the hot aisle to keep the hot air in that aisle and the cold air out (see Figure Three).

Data Center with Hot Aisle Containment
(Figure Three)



The History of Data Center Containment

During the mid- to late- 1980s, David Martinez of the Sandia National Laboratory attached fire code compliant welding curtains between the top of the CRAC units and the ceiling to form an airflow plenum to protect the first TeraFlop high-performance computing machine. "The goal was to utilize the interstitial space between the CRAC unit top and the ceiling to draw the return air back to the top of the CRAC units," says Martinez.

This helped to ensure sufficient airflow and to correct a short cycling issue. "It enabled us to make better use of our CRAC units' ΔT, which in turn resulted in our chiller plants running more efficiently," says Martinez. Martinez eventually found cold aisle containment to be effective as well. In the early 1990s, vendors began developing and marketing various containment systems.

What are ASHRAE and the IEEE?

ASHRAE (the American Society of Heating, Refrigerating and Air Conditioning Engineers) is the century old member organization focused on building HVAC systems, energy efficiency, and indoor air.

The IEEE (the Institute of Electrical and Electronics Engineers) is the global, professional member organization committed to advancing technology in service of humanity.

The data center community has opted for guidelines rather than standards to address both cooling and containment best practices because data center cooling components vary so much. The ASHRAE "Thermal Guidelines for Data Processing Environments" and several papers on data center containment systems from the IEEE are among those guidelines.

Today, containment solutions must meet fire codes and general human life safety requirements as well as provide access, from the top of the racks to the bottom, for maintenance activities.

Why Containment?

The data center is fraught with power and cooling challenges. For every 50 kW of power the data center feeds to an aisle, the same facilities typically apply 100-150 kW of cooling to maintain desirable equipment inlet temperatures. Most legacy data centers waste more than 60% of that cooling energy in the form of bypass air.

Data centers need more effective airflow management solutions as equipment power densities increase in the racks. Five years ago the average rack power density was one to two kW per rack. Today, the average power density is four to eight kW per rack and some data centers that run high density applications are averaging 10 to 20 kW per rack.

The cost of electricity is rising in line with increasing densities. "The cost of electricity is about US$0.12/kWh for large users. The forecast is for a greater than 15-percent rise in cost per year over the next five years," says Ian Bitterlin, Chief Technology Officer, ARK Continuity.

Containment makes existing cooling and power infrastructure more effective. Using containment, the data center makes increasingly efficient use of the same or less cooling, reducing the cooling portion of the total energy bill. Data centers can even power down some CRAC units, saving utility and maintenance costs. Containment allows for lower cooling unit fan speeds, higher chilled water temperatures, decommissioning of redundant cooling units and increased use of free cooling. A robust containment solution can reduce fan energy consumption by up to 25-percent and deliver 20-percent energy savings at the cold water chiller, according to the U.S. EPA.

Containment makes running racks at high densities more affordable so that data centers can add new IT equipment such as blade servers. Data center containment brings the power consumption to cooling ratio down to a nearly 1 to 1 match in kW consumed. It can save a data center approximately 30-percent of its annual utility bill (lower OpEx) without additional CapEx.

Containment Benefits

Vendors design containment solutions for fast, easy deployment and scalability for data center growth. Data center containment enables the creation of a high-capacity data center in a very short period of time (hours).

Containment enables IT professionals to build out infrastructure, data processing, and cooling loads in small, controlled building blocks as demand grows. This is more affordable than building the data center infrastructure to handle the maximum cooling and data processing load from day one, which is the traditional method. Containment increases its cost effectiveness as rack densities increase.

What is PUE?

PUE (Power Usage Effectiveness) is a formula for determining data center energy efficiency such that Total Power to Data Center divided by Power to Run Computer Infrastructure = PUE.

Data centers typically have more cooling capacity than the load requires. Still, this capacity does not cool equipment adequately. By raising the Delta T, containment avoids the capital expense of adding more mechanical cooling. As you operate cooling under higher return temperatures, cooling becomes more efficient.

The smaller the percentage of total energy the data center uses to feed cooling, the greater the percentage of total energy it uses to feed IT equipment. This results in a lower PUE, which should be closer to a 1:1 ratio.

Standardization is an operational benefit of containment. Vendors engineer containment into building blocks so that as the data center grows, the enterprise simply adds more uniform pods. Containment reliability and integrity derive from design redundancy that mitigates the downside risk of cooling system failures.

Containment aligns with the enterprise by offering a low TCO including low and progressive acquisition costs, quick time to deploy, and lower operational and maintenance costs. Maintenance costs grow only as the data center adds containment pods.

Why Now?

Airflow management using rack and row-based containment is growing in popularity. "According to our most recent survey, 78-percent of large data center operators have deployed airflow containment," says Matt Stansberry, Director of Content, Uptime Institute.

According to the U.S. EPA, improving the energy efficiency of America's data centers by only 10-percent would save more than 6 billion kWh per year, enough to power more than 350,000 homes and save more than $450,000,000 annually.

In a number of locales around the U.S., utility companies are offering data centers rebates to use for capital investment in containment solutions to drive higher efficiencies, save energy, and lower utility bills. Some rebates are sufficient to fund much of the expense of new containment solutions.

Containment Components

Containment components include rack containment using rack-based chimneys, and aisle containment using end of row doors, aisle ceilings and overhead vertical wall systems. Chimneys affix to the hot air side of the rack, ducting hot air into a drop ceiling or return plenum that leads to the air conditioning system. Passive chimneys use the plenum's negative pressure to pull the hot air out. Active chimneys with fans move hot air based on rack temperature or the difference in pressure inside and outside the rack.

End of row doors seal off the end of the aisle. Vendors offer end of row doors in a variety of practical configurations. The vendor should be able to tailor door selections to suit each data center's specific spatial requirements.

Door configurations include swinging or sliding doors that are available as single or double doors. The data center may require an emergency break out feature for sliding doors to meet emergency evacuation safety standards. When a smoke or fire alarm sounds, staff members can break through the door via a break out bar that opens a separate door on a hinge. This will ensure that staff are not trapped in an emergency.

Vendors offer additional door options including auto-close, soft close and auto lockout capabilities. Auto-close enables the door to quickly reestablish an airtight seal. Soft closing doors use snubbers to slow auto-closing. This ensures that the doors won't close on the staff or customers who are entering or leaving the aisle. Auto lockout stabilizes doors in the open position allowing hands to be free to move data center equipment in and out of the aisle.

Glass doors or small windows are available for data centers seeking visibility into the aisle. Glass doors and windows maintain aisle visibility without forcing staff to enter the aisle.

Data centers can top off their aisles with precise ceiling types and options as the vendor brings them closer to total containment. The vendor can deliver a horizontal structure, which is a flat-aisle covering or roof. The overhead vertical wall approach constructs one wall along the top of a row of racks, a second vertical wall on the top of the opposing row of racks and one at each end of the aisle, creating a rectangular box that contains the air.

Containment Considerations

There are a number of factors that data centers should consider when selecting containment solutions. The application specific environmental requirements of the data center including the cooling supply source and type, fire suppression design, the human factor and rack hygiene form one set of factors.

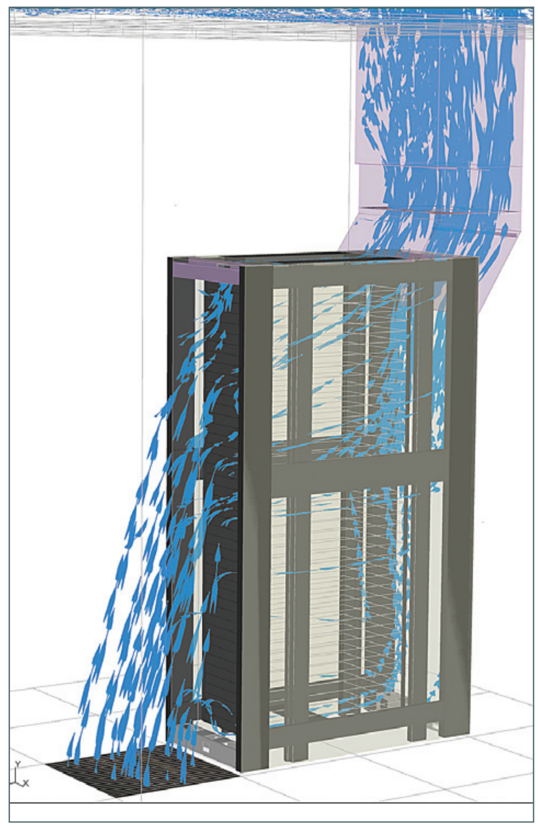
The data center should marry cooling that emanates from CRAC units, raised floors, perimeter cooling, and overhead cooling systems to the most compatible containment option. For example, while the hot aisle approach is usually best for CRAC/CRAH units, the cold aisle approach is usually best for perimeter cooling on raised floor or ducted cold air delivery from roof top chillers.

Data center fire suppression techniques including sprinklers, gas systems and VESDA systems can affect containment selection. Vertical walls (see Figure Four) and horizontal structures with intelligent panels are best suited for overhead fire suppression.

Vertical Wall
(Figure Four)

Data center employees and customers may not want to work in a data center environment that is 100-degrees. If the data center contains the cold aisle, the rest of the data center is the hot aisle, which can be 95- to 110- degrees. If the data center contains the hot aisle, the rest of the data center will be cold. When staff or customers enter the hot aisle, it will be 95- to 110-degrees. The data center may want to factor in the effect of requiring its personnel to acclimate to an environment that is either too hot or too cold while also considering the effect of moving between the two when working inside and outside the aisle.

Air Leakage Through the Rack
(Figure Five)



Once containment is in place, the rack becomes an airflow plenum. The data center that invests in containment should not waste the effort by permitting poor rack hygiene and air leakage through the rack (see Figure Five). In an aisle with 10 racks on each side or 20 in the pod, the racks make up approximately 60-percent of the total surface area. Leaking racks could lead hot and cold air to mix, defeating the data center's containment efforts.

The data center should plug leaks both around the 19-inch rails in front of the racks and in any empty U spaces among the rack mounted equipment by using blanking panels. Plug holes in raised floors around cabling with floor grommets.

Containment Providers and Due Diligence

Containment providers include Eaton, APC, Emerson, Chatsworth, Electrorack, AFCO Systems, Subzero Engineering, and Polargy.

When considering containment providers and their solutions, make sure to do your due diligence. Consider the following points during that process.

- **Know your heat containment needs** and how much heat you need to manage.
- **Know the thermal profile** of all equipment coming into the data center.
- **Know the fire protection codes** and how containment will affect these.
- **Know what else the containment strategy** will affect.
- **Know how much cooling** you need up front and how much to plan for the future.
- **Know what you are supporting** today for IT and the business and how business decisions will affect future planning.
- **Link facilities planning** to business planning.
- **Know room geometry** and the constraints of cold air delivery and hot air removal when planning for containment.
- **Know your space** and how well a vendor solution will integrate with the existing racks, whether uniform or non-uniform.
- **Know whether you will have an outage window** for installing containment and the risks around production equipment during containment assembly.

Matching Containment to Considerations

Each containment method has its own benefits and concerns. Hot aisle containment contains only the heat, channeling it away and leaving the rest of the data center as the cold aisle. Depending on how cold the cold aisle is, this may leave the data center with an expensive, frigid data center that is as costly as it is uncomfortable. With current ASHRAE standards recommending that data center equipment run at higher temperatures, the cold aisle may not necessarily have to be so cold that it incur costs or cause comfort concerns.

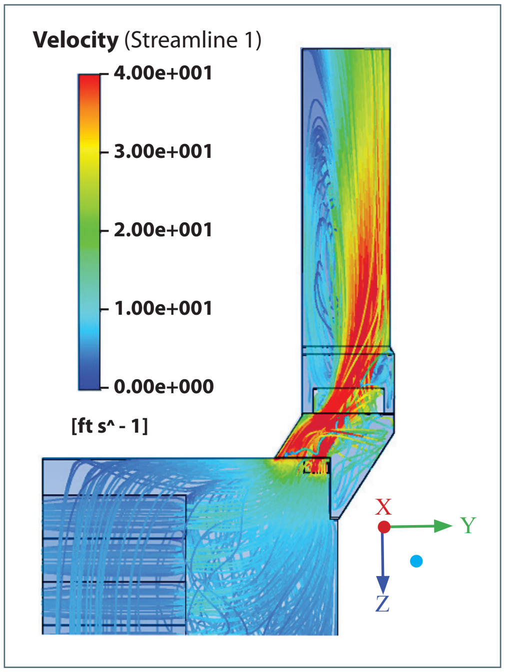
Hot aisle containment works well with CRAC/CRAH units because the data center manager can easily set these to cool the rest of the data center, regardless of the cooling units' relative location. However, hot aisle containment only works when the data center uses containment on all hot air exhaust paths.

Cold aisle containment is good for perimeter cooling because CRAC/CRAH units at the perimeter can supply the cold air through a raised floor. Cold aisle containment does not require the data center to use containment everywhere, but the data center must channel hot air back to CRAC units to maximize the efficiency of this method.

End of row doors are friendly to hot and cold aisle containment, raised floors and drop ceilings.

The data center should match ceiling approaches to important considerations such as overhead fire suppression, cable ladders, cable trays and piping. Methods for maintaining compliance with fire suppression systems in a horizontal structure ceiling include cutting holes in the horizontal structure and pulling fire suppression down into the aisle (which is counter productive to an air tight seal, costly, and not recommended). You can also use a fire activated horizontal ceiling (uses intelligence from fire / smoke monitoring to open ceiling panels in a fire while maintaining an air tight seal at all other times). This is the recommended approach. There are practical methods for addressing obstructing cable and piping access with the application of vertical walls.

Thermal Image of Chimney Removing Hot Air from Room
(Figure Six)



Rack containment eases the containment road map when the chimneys deployed are natively upgradeable in order to add fans. Chimneys address the human factor by removing hot air from the room and the equation (see Figure Six), leaving a cool, comfortable work environment even working up close in front and behind the racks.

Prove Containment with Leakage Testing

The containment package should include vendor testing to confirm that no more than three-percent air leakage remains. The testing method should pressurize the aisle with .001-inches of water and gauge air leakage under those conditions.

A maximum three-percent air leakage enables the data center to match the cooling supply so closely to the power consumption in the aisle that 53 kW of cooling can effectively cool an aisle drawing 50 kW of rack equipment power.

Recommendations

- Accommodate varying rack vendors and sizes by selecting flexible, vendor-neutral containment components that are suitable for a mix of racks and equipment.
- Consider the risks that come with using multiple vendors. Using multiple vendors can lead to vendor blame shifting and slowed support for issues in areas of overlapping service between two or more vendors.
- Ease vendor management by selecting a single vendor. Using a single vendor that can handle all containment needs leads to standard, cohesive solutions and quick, effective support. There is only one vendor to go to when there are support issues and the data center will always know who will take responsibility for it.

Summary

Containment should not be an afterthought. It is at the heart of data center planning, deployment and scalability. The large data center operator cannot afford to ignore the sizeable savings it can realize by increasing compute densities inside containment solutions.

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