UNIVERSAL APPLICATION AND BENEFITS OF AIR CONTAINMENT: A PRACTICAL GUIDE

A Dell™ Technical White Paper

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Introduction

To operate more efficiently and at higher densities with the ability to predictably deploy IT hardware with less thermal risk, implement containment. Embrace containment aggressively; the approach to containment is a bit like the approach to virtualization. If you experiment with it lightly, you might only see minor benefits like rack density increases. Like virtualization, it takes a strong commitment. You need to contain most, if not all, of the data center in order to tap into large efficiency benefits. Both Liebert™ and APC® have good papers[1,2] on containment. Although they do show some bias for their own solutions, they agree on major benefits such as:

- An increase in coil capacity accompanying the higher return temperatures associated with containment
- Near or absolute 100% sensible operation (no energy lost to condensation and humidification)
- The opportunity to raise temperatures and save energy in the chilling process

In addition to these benefits, it should also be mentioned that the elimination of hot spots would result in the immediate lowering of IT equipment fan power in the affected areas. For a more detailed example of containment-related energy savings, please refer to *The Energy Advantages of Containment Systems*[3] Dell whitepaper.

The goal of this paper is not to come to an absolute conclusion as to which solution is the best. What is ideal for one facility will not be ideal for another. However, this paper will point out some of the key considerations to explore in determining the best solution for your facility. The following points are addressed in this paper:

- Greenfield vs. Brownfield?
- Supply (intake) vs. return (exhaust) containment
- Materials and flexibility
- Rack level vs. row level containment
- Closely coupled vs. loosely coupled

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[1] Focused Cooling Using Cold Aisle Containment, Emerson Network Power, 2009; http://www.liebert.com/common/ViewDocument.aspx?id=1295
[2] Hot Aisle vs. Cold Aisle Containment, John Neimann, 2008; http://www.apcmedia.com/salestools/DBOY-7EDLE8_R0_EN.pdf
[3] The Energy Advantages of Containment Systems; David Moss; 2009; http://content.dell.com/us/en/corp/d/business~solutions~whitepapers~en/Documents~dci-energy-advantages-of-containment-systems.pdf.aspx

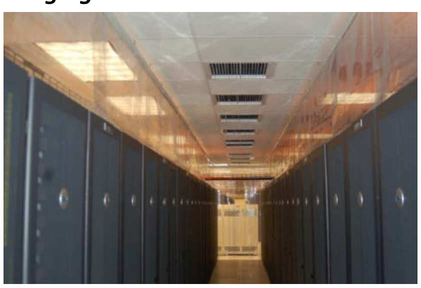
Nomenclature

For the purposes of this paper, we will attempt to categorize and name different types of containment.

Stationary

Aisle containment like the APC Hot Aisle Containment (HAC) or Liebert Cold Aisle Containment (CAC) is a hard-paneled structure assembled in place that contains integral attachment points to the IT racks. These solutions contain multiple racks. APC's solution is designed specifically around their InRow coils, and it contains the hot aisle. Liebert's solution contains the cold aisle and can be designed to contain raised-floor venting and Liebert XD systems. In each solution, hard-paneled construction includes doors and a ceiling structure. This type of containment is typically more stationary and requires more effort to refresh new racks or additional cooling units in comparison to other solutions that are not as integrated.

Hanging Partitions



Hanging partitions are often referred to as meat locker curtains. Vendors of these products have both hard and flexible material versions. They are typically hung from ceiling structures and lightly touch the racks (if they touch at all). They often are intentionally hung with gaps at the ceiling to allow smoke to pass horizontally and activate fire prevention systems as well as the fuse links used to hang the partitions themselves. Since the partitions are not tied to the IT racks, it is generally easier to refresh individual racks. The containment is looser than with stationary solutions. This picture in one of Dell's data centers depicts cold aisle containment with both floor and overhead delivery. Hanging partitions can also be used effectively as hot aisle containment.

Rack Chimneys

Rack Chimney solutions add ductwork to each rack. With the rear of the rack closed up, this rack is tightly coupled to the IT systems. The chimney is typically extended to a false ceiling which is used as a return plenum and also ducted to the CRAC units. Unless the chimney contains fans or the CRAC units pull air through the return plenum to aid the flow through the rack, the rack and chimney add pressure to the IT systems. This either slows the flow rate through the systems or causes them to speed up to maintain proper airflow. There is some debate in the industry as to whether chimneys should be deployed with serial fan units that help the IT fans to evacuate the rack.

Greenfield vs. Brownfield

If you have the luxury of a Greenfield opportunity, your options are obviously less limited. Some containment solutions are less invasive in the installation process. Since hanging partitions are not structurally tied to the racks, they tend to be an easier solution to use in a retrofit situation. As a retrofit, a chimney may require server downtime, especially for servers located high in the rack. Stationary solutions require attachment to existing racks and possibly drilling holes; this might make some owners uncomfortable. Even if you prefer a more substantial containment system like a stationary HAC or CAC, you might consider the hanging partition products for the retrofit portion of the data center and use your preferred choice for all new racks. The partition products are inexpensive and might be eventually switched out with your preferred choice as IT product is refreshed. Whatever solution you choose, your goal should be to get the entire data center contained so you can reap full efficiency benefits.

Supply vs. Return

HVAC vendors often have strong opinions that favor their own products, and suggest sharp contrasting density limitations specifically for cold aisle containment. However, both Cold Aisle Containment (CAC) and Hot Aisle Containment (HAC) can be set up for high density. Hot aisle may offer more flexibility to apportion more density in one area at the detriment of another. In either case, the goal is to provide an adequate compliment to the air consumption rate of the IT equipment. It is the volumetric delivery of the facility that establishes any density limitation that might exist for each rack. This is why hot aisle containment may offer a local advantage. With a cold aisle solution there is a finite number of vent tiles. Since the aisle containment captures the vent tiles, the number of vents cannot be increased; it is typically no more than a single vent per rack. In contrast, a hot aisle containment solution does not capture the vents. Venting outside the perimeter of the pod can actually supply the pod with additional airflow.

APC makes a similar argument regarding the limitations of cold aisle delivery[4,5]. The APC papers go one step further; they make assumptions about typical raised floor limitations, arguing that a maximum of approximately 600 CFM on average can be delivered through a single vent. APC equates this to a limitation of 6 kW per cabinet which takes their argument past the differences between HACs and CACs, resulting in an argument between raised floor delivery and their InRow products. It can be argued that this as an artificial limitation used to support the claim of superiority of the row cooling product. Higher CRAC-to-vent ratios allow a raised floor to easily achieve higher flow rates. A data center lab at one of the Dell facilities averages twice that value (1200 CFM) per vent. The APC argument of 100 CFM per kW is a good rule of thumb for generic legacy hardware. Today's Dell servers, however, have much more efficient thermal designs and typically operate closer to 80 CFM per kW. If you combine higher vent flow rates with the fact that newer IT consumes less than 100 CFM per kW, an argument similar in approach to that in the aforementioned APC paper can be made in support of greater than 10 kW per rack.

Consider this high-density example computed using Dell's Energy Smart Solutions Advisor (http://www.dell.com/calc). A 1U server with high-end processors and 32 GB of memory consumes 324 watts and uses 25.6 CFM, which amounts to just 79 CFM per kW. Assuming 80 CFM per kW and an average of 1200 CFM per vent, the raised floor would support 15 kW per vent if that flow rate is delivered effectively to the rack. Containment is one way to ensure that the 1200 CFM supplied gets consumed effectively to achieve the full 15 kW.

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[4] Hot Aisle vs. Cold Aisle Containment, John Neimann, 2008; http://www.apcmedia.com/salestools/DBOY-7EDLE8_R0_EN.pdf

[5] Cooling Strategies for Ultra-High Density Racks and Blade Servers, Neil Rasmussen, 2006; http://www.apcmedia.com/salestools/SADE-5TNRK6_R5_EN.pdf

The decision whether to use hot or cold aisle containment should probably not be made on the basis of a perceived density advantage. Ultimately, the data center is limited by the total amount of flow available from all the CRAC units. If a hot aisle containment enables an incremental advantage in one area because it can take advantage of adjacent vents outside of the perimeter of the pod, it uses up more of the aggregate CRAC flow rate, and other areas will be slighted. The HAC/CAC decision is more likely based on whether or not the facility already has a return ceiling plenum. It might also just be made on the basis of human comfort, since a HAC renders the personnel space comfortable in terms of temperature, and a CAC essentially uses the entire data center as a return plenum.

Materials and Flexibility

Aesthetics are important to many data center owners. Some may not have considered hanging partitions for that reason. These systems are gaining in popularity quickly, and their appearance is not as terrible as some people may think. Hard plastic versions are available; they are a bit more expensive than the meat-locker type material, but they are generally perceived as more attractive. Besides their cost advantage over other containment products, some Dell customers find more flexibility with this type of product. The stationary aisle containments typically tie the racks into a pod. Any reconfiguration that entails breaking up the pod will be easier with a hanging partition solution. Hanging partitions are readily available from a variety of vendors, and you can engage Dell Energy Optimization Services for assistance as they can install these types of products for you. Hanging partitions work well as either hot or cold aisle containment. Interestingly, in talking to the vendors of these products, the majority of their deployments have been cold aisle containment. Presumably, this is due to the absence of an existing ceiling return plenum. An additional consideration when contemplating flexible curtains is that, depending upon the criticality of the data center, the data center's insurance company may have reservations about the flexible material. Even if a fire marshal has signed off on the product, the insurance company may be more conservative and oppose the flexible curtain material.

Tightly Coupled vs. Loosely Coupled Containment

There are varying degrees of coupling between coil products and IT racks. The minimum goal behind containment is to separate supply and return paths. Above and beyond this minimum goal is an opportunity to more closely match coil flow rates to rack consumption (minimizing waste). The ability to achieve a flow match is proportional to the physical tightness of the coupling between the racks and coils.

Hanging Partitions Stationary Rack Level

Greatest Air Over-Provision Least Air Over-Provision

With looser coupling, more air overage is required from the coils. Hanging partitions are arguably the loosest since they typically have designed gaps (for example, at the ceiling). The exhaust chimney appears to be the tightest common form of containment. Stationary containment systems range in between the two. Because aisle containment spans many racks, it is quite difficult to make it as "airtight" as a rack chimney. Gaps in the construction, under or between racks, are likely to exist. Any mismatch in flow rate between the coils and the racks will find these leaks. Stationary systems probably require more over-provision of air from the coils than a tightly coupled chimney but not as much as with hanging partitions.

A downside to a tightly coupled containment solution exists especially as it applies to the IT equipment. Any form of external pressure added to a server, storage, or networking product elicits one of two responses—the airflow slows and component temperatures climb, or the IT fans respond with additional fan energy to boost the flow rate back to its intended design point. What is meant by external pressure? A small amount of external pressure is added, for instance, when IT is put into a standard front-to-rear cooled rack and the front and rear perforated doors are closed. As a result, some negative pressure is applied to the front of the IT system and some positive pressure to the back of the system. Similarly, contained systems, like rack chimneys or door coils, typically impart two to three times the external pressure as a standard “flow through” rack due to their added airflow resistance.

The IT system’s thermal design will determine whether or not its response to pressure is an increase in component temperature, an increase in fan power, or some compromise of the two. Newer systems will likely tend toward a fan speed increase. They have more components enabled with temperature sensors that contribute to the system’s fan response algorithms. If the system design is optimized, it will respond to even small pressure changes that would otherwise have resulted in a component temperature increase. Older IT systems have less discrete component temperature measurement capability and are typically designed more conservatively with higher thermal margins. They typically respond with less of a fan speed increase unless the pressure is large. The IT manufacturer should be able to advise you as to the impact of pressure on his or her system. Dell has historically designed with enough margin to handle the pressure added by a standard rack (two perforated doors) and a full cable management apparatus (translating arm).Therefore, even if the fans do not spin up due to pressure, minor component temperature increases do not exceed specification limits. More details of how Dell systems respond to external pressure can be found in the *IT Equipment Response to External Pressure* Dell whitepaper[6].

More on Rack Level Containment

Chimney systems are not the only form of rack containment, although they are probably the most widely used. Enclosed racks with side-car coils also could be considered contained solutions since they separate the hot from the cold. Rear door coils are another product which could technically be considered contained. Any of these systems may have impacts on the IT fan response as mentioned in the paragraphs above.

Passive Chimney Systems

Care should be used when deploying passive chimney systems. A good design should impart little to no external pressure on the IT systems within the racks. While in some cases the air handlers may facilitate the flow through the racks and chimneys by creating a significant negative pressure in the ceiling return, a test should always be carried out to determine the presence of negative pressure in the chimneys and rack rears. If the air handlers do not improve the flow through the chimney, an increase of IT fan energy may occur. In addition, you may risk a pressure build-up at the back of the rack because the IT equipment is pushing the air up the chimney, which will cause a larger recirculation between the IT systems. This may not be a concern with larger systems such as blades where there are only a few chassis per rack. However, the 20 to 40 small gaps between 1 and 2U systems can add up. Increased recirculation could raise inlet temperatures and limit the extent to which you raise the overall data center temperature, thus limiting savings at the chiller.

New Dell Rack Containment

Dell is currently working on another form of containment—a rack-level containment product that alters the normal front-to-rear flow pattern and converts it to bottom-to-rear. The strategy is scheduled for release late next year. Like other containment solutions, it enables similar energy savings opportunities. It will be a tightly coupled

[6] IT Equipment Response to External Pressure, Robert Curtis/David Moss, 2009

system; as such, it will enable a more ideal match of facility flow and rack flow. Since the system is tightly coupled to the floor and not the ceiling, it is more of a plug-and-play solution than most other containment solutions. The rack can be rolled up with no connections other than the vent underneath. Since that coupling surrounds the vent, it has the ability to affect the flow exiting the vent. Up to a certain rack density, the floor tends to dominate and actually aid the IT system's flow rate; it may lower the IT fan energy as the IT systems try to throttle down flow rates. Above that density, the IT systems in the rack tend to dominate, extracting a greater volume than normal out of the floor. There is no specific density limit with this rack. High densities mean higher airflow which typically translates into increased IT equipment fan energy. This energy increase is in line with the increases cited for other rack solutions in *IT Equipment Response to External Pressure*[7]. A slight increase in IT fan energy may be acceptable in order to achieve facility energy savings like those detailed in *The Energy Advantages of Containment Systems*[8].

There are further advantages to this rack level containment strategy. Due to the tight coupling with the floor, the rack has the ability to affect the pressure under the floor. In the case where multiple racks have spun up and increased their air consumption, a constantly supplied raised floor would normally see a decrease in under-floor pressure and a drop in the flow rate through other vents. Air handlers (CRAH units) can be configured to adjust their flow rates based on under-floor pressure. Rather than link airflow control with return or supply temperature (as is more common), variable speed fans in the air handlers speed up or slow down to maintain a specific pressure under the floor. This control strategy typically allows data centers to deploy new hardware with less concern about the adequacy of airflow delivery. As new racks are added, vents are installed as well. The increase in the number of vents would normally drop the pressure and the flow through all vents. The CRAH units, however, compensate to correct the pressure. As long as the CRAH unit flow rates are not at their maximum, the addition of new IT racks is accompanied by an increase in the CRAH unit flow rates.

Similarly, as IT equipment dynamically drives rack flow rates up or down, a tightly coupled rack like the Dell containment rack could have a dynamic coupling to the CRAH units. This would be accomplished indirectly through their common pressure connection, the raised floor. Others companies have attempted to achieve similar results by much more complicated means (for example, a competitor introduced a dynamic service with a multitude of sensors feeding into a server to control the floor's CRAH units).

With the Dell solution, a company can have a data center set up such that whenever new racks are added, the CRAH units adjust their flow rates to compensate. Throughout the day, when the IT load changes and the rack airflow fluctuates up and down, the CRAH units also adjust up and down, supplying a near ideal match of air delivery versus rack consumption. The only task the company has is to monitor the Variable Frequency Drive (VFD) settings on the CRAH units to verify how close they are getting to 100%. At some point prior to the unit nearing 100%, another CRAH unit would have been scheduled for bulk airflow infusion into the floor. This situation is comparable to a type of "air buss" where multiple air handlers feed a common buss (the floor plenum) and multiple racks tap into and consume what they need from that buss. In addition to the energy and density advantages obtained with containment solutions, this dynamic coupling with the air handlers specific to the Dell containment rack offers a significant advantage.

[7] IT Equipment Response to External Pressure, Robert Curtis/David Moss, 2009
[8] The Energy Advantages of Containment Systems; David Moss; 2009; http://content.dell.com/us/en/corp/d/business~solutions~whitepapers~en/Documents~dci-energy-advantages-of-containment-systems.pdf.aspx

Non Hot/Cold Aisle Facilities

There are still plenty of facilities that have not converted to hot/cold aisle orientation. Aisle containment strategies rely on the fact that there is already hot/cold aisle orientation. Some of the rack level containment strategies actually do not require hot/cold aisle orientation. Chimneys, self-contained racks, the door coil, and Dell's new rack containment would all work in a front-to-back oriented facility.

Summary

Regardless of the type, containment solutions should be considered in almost any data center setting. The two major areas for reductions in cooling energy are at the chiller and air handler fans. Both of these energy reductions are aided by containment. Containment should be applied to as much of the data center as possible. With the main goal being an increase in overall data center temperature, it may be difficult to achieve without comprehensive containment. Rack densities are also improved with containment. Rack and associated costs are reduced by installing equipment in fewer racks. Finally, some tighter forms of containment, such as the new Dell rack, offer additional benefits in terms of coupling with facility airflow systems to set up a near ideal match of airflow and one that scales with IT load and IT additions.

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