White Paper

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Maximizing Cooling Energy Efficiency with Effective Cabinet Sealing

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Introduction

Driven by explosive growth in data processing demands, data center managers face multiple, competing priorities: reducing operational costs, improving energy efficiency, and optimizing available capacity, all while maintaining network availability/reliability. To meet these demands, data center space is often underutilized and overprovisioned with power and cooling capacity.

A typical data center consumes an average of 5-7kW of power per cabinet. However, it also has individual cabinets or zones with significantly higher thermal loads. This can lead to overcooling of the entire data center and an inflation in energy costs.

Anticipating the impact of the trend toward higher densities, data center managers are increasingly using air containment systems to manage higher thermal loads. In an air-cooled data center, containment systems are used to effectively separate cold air from hot exhaust air to reduce the cooling system energy consumption. Containment systems such as cold aisle containment and hot air containment (vertical exhaust ducts) prevent mixing of cold and hot air streams and enable cooling system energy savings of up to 40%. This allows chillers to operate more efficiently, which reduces energy consumption. A properly sealed cabinet is critical to obtaining this level of energy efficiency savings and achieving maximum cooling system performance with a containment system.

Space utilization can also be improved by utilizing cabinets and containment systems that optimize the separation of hot and cold air. Cabinets can be provisioned for thermal loads of 15kW or more per cabinet if power and cooling are managed effectively. As energy and construction costs continue to rise, over-provisioning and under-utilization are no longer sustainable and result in higher operating expense (OpEx) and capital expense (CapEx).

This white paper compares air leakage characteristics for three Vertical Exhaust Duct (VED) cabinets (a type of hot air containment) from different manufacturers and explains how the difference in sealing level between Panduit's Energy Efficiency Cabinet System and these competitors' cabinets translates into energy reductions that result in OpEx savings of as much as $780USD per cabinet per year while enabling densities of 15kW and higher per cabinet.

Cabinet Leakage Challenge

Leakage is air that escapes through structural gaps and holes between and through mounting rails, cable management devices, blanking panels, and equipment. Cabinet leakage can adversely affect thermal efficiency by increasing cooling energy usage and its associated costs. In a Cold Aisle Containment (CAC) system, leakage paths can result in cold air bypass whenever a sufficient pressure differential exists between the cold aisle and the hot aisle side of the containment system. The bypassed cold air mixes with the cabinet exhaust air and reduces the cooling unit return air temperature and its efficiency. In a VED cabinet, leakage paths can allow recirculation of hot exhaust air whenever there is a pressure differential that forces the hot exhaust air through the various gaps into the cold aisle. The recirculated hot exhaust air warms the cold aisle air to a temperature above the targeted room set point and can force the data center operator to lower the room set point temperature to maintain the desired equipment inlet temperature.

This type of recirculation within the cabinet is different from the row-level recirculation where hot aisle air recirculates to the IT equipment inlet over the top of the cabinet or around the end of a row, common in traditional hot/cold configurations. The net result is the same – higher inlet air temperatures. However, while

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containment solutions eliminate the room and row level recirculation issues, they do not eliminate in-cabinet recirculation. One way to reduce the effect of cabinet air leakage is to use fan-assisted VEDs but this solution increases the complexity of the data center airflow design and has higher initial costs, making it less efficient than passive approaches. It also increases the points of failure and the overall data center cooling energy cost. A simpler solution is to effectively seal all the gaps, holes and openings that can result in air leakage in a cabinet structure.

To minimize air leakage in the cabinet, Panduit's new energy-efficient cabinet system is engineered to completely separate hot exhaust air from cold supply air, which allows higher data center set points, resulting in reduced cooling energy usage. Panduit's new cabinet design eliminates gaps other than those needed to mount equipment. For example, the Net Access™ S-Type cabinet improves separation between cold and hot air over the previous generation server cabinet by closing gaps within the cabinet structure. An innovative vertical post design, in conjunction with integrated air dams block potential leakage paths between the front and back of the cabinet. Externally attached door hinges and door latch brackets reduce the number of large openings in the frame posts through which air can escape. Plugs designed especially for unused openings also contribute to the improved air sealing. This attention to detail gives S-Type cabinets an advantage in thermal efficiency over earlier generation server cabinets.

VED Cabinet Thermal Testing

To quantify the benefit of improved sealing at the cabinet level, a series of thermal and airflow tests was completed on the Net Access™ S-Type VED cabinet and on two other VED cabinets from different manufacturers.

This section describes cabinet leakage testing for three cabinets and shows how poor sealing results in higher IT equipment inlet temperatures, an effect that gets worse as the cabinet heat load and airflow increase. This difference is then translated into energy savings and OpEx savings.

The objective of the testing was to quantify the effects of improved cabinet sealing for a VED version of a Net Access™ S-Type (600mm x 45RU x 1200mm) cabinet against competitor A (600mm x 42RU x 1200mm) and competitor B (600mm x 48RU x 1200mm) VED cabinets. Each cabinet was tested individually.

First, we performed flow bench tests to characterize the air leakage through the three cabinets. These tests were done with an airflow test chamber (AMCA 210-99) setup that pulled air through the front of the cabinet.

All three cabinets were set up for the airflow leakage test in a similar manner, see Figure 1. Next, the front door was removed and the cabinet adapter assembly was attached to the flow bench, and sealed to the front external edges of the cabinet. Finally, the equipment mounting space (between the mounting rails) was sealed. The airflow testing over a range of pressures (0.005”-0.7” H_2O) showed significant differences in the level of sealing among the three cabinet manufacturers. The Net Access™ S-Type cabinet allowed on an average 20% less air leakage over a wide range of pressure differences than the competitor cabinets, as shown in Figure 2.

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Figure 1. Airflow testing setup. From left to right: the cabinet under test (black) cardboard adapter, cabinet adapter to airflow test chamber (white) and AMCA 210-99 (blue).

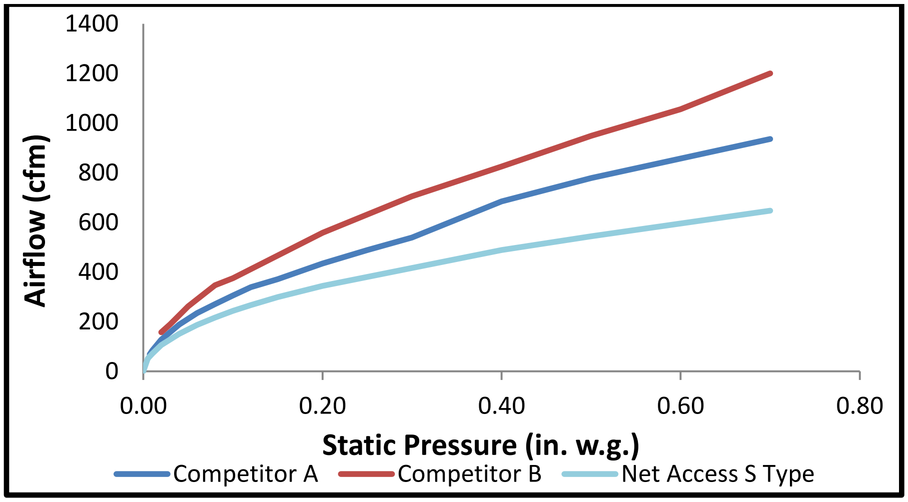

Figure 2. Flow bench test results showing cabinet leakage data.

To quantify the effect of cabinet leakage on data center efficiency, we tested all three cabinets in the Panduit thermal lab. We increased the cabinet IT load from 15 kW to 33 kW and observed the resulting elevated inlet temperatures caused by hot air recirculation through leaks.

The data center test lab is equipped with a Computer Room Air Handler (CRAH) that delivers cold air to a raised floor plenum that distributes the air to the test cabinet through perforated tiles. Each test cabinet was set up per the manufacturer's standard VED configuration. The tests were run with a supply air temperature of 68°F (20°C). Three to four perforated tiles were used, depending on the cabinet heat load and airflow requirements, as shown in Figure 3, top view. This was done to minimize the upward velocity of air supplied by tiles and to minimize the variation in under-floor pressure. The drop ceiling return plenum was maintained at approximately -0.02 inches of water. A total of three HP Proliant DL360 G5 servers were installed, one in the bottom, middle, and top RU locations, respectively, to study the effect of back pressure on server fans, if any. Four thermal load banks were placed between the servers to simulate additional IT equipment heat and airflow, see Figure 3, front

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view. Any open RU slots were filled with horizontal blanking panels and servers were operated at maximum power dissipation via burn-in code for all tests. The load banks generated sufficient heat load to represent a range of cabinet heat dissipations from 15 kW to 33 kW with an airflow rate of 100 cfm/kW. For each of the scenarios the CRAH supplied 10% more airflow than the cabinet airflow demand. Several temperature and pressure sensors were installed to capture the cabinet inlet/exhaust temperature profile and pressure distribution at the back of the cabinet.

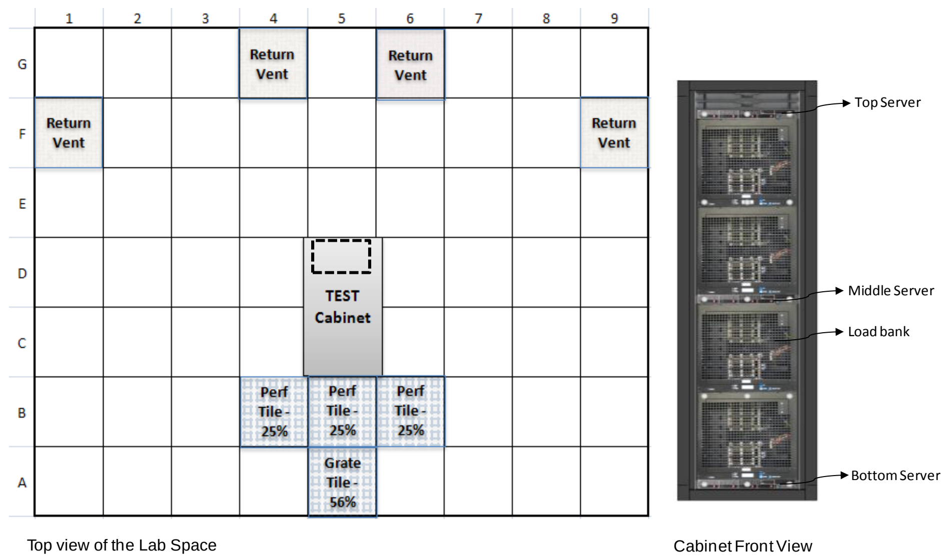

Figure 3. Data center test lab setup. From left to right: top view of the lab, cabinet front view showing the location of the load banks and the servers.

Thermal Testing Results

The results of the thermal testing are displayed as a thermal map (Figure 4) on the face of the cabinets. The thermal map provides a visualization of the inlet air temperature gradients resulting from in-cabinet exhaust air recirculation. In the Net Access™ S Type VED cabinet the maximum inlet air temperatures were all at least 1ºC below the ASHRAE recommended inlet temperature limit of 27ºC. However, due to in-cabinet recirculation the maximum inlet air temperatures on competitor cabinets were higher than the ASHRAE recommended limit (11ºC for competitor A and 6ºC for competitor B). With this configuration, the Net Access™ S Type VED cabinet can support a heat load of up to 33 kW and airflow up to 3300 cfm. Note that Panduit's new cabinet, because of the superior sealing, did have slightly higher back pressure versus one of the competitor cabinets, but its effect on the server fans was minimal. In fact, higher server inlet air temperature and higher server fan speeds were observed in the competitor cabinets.

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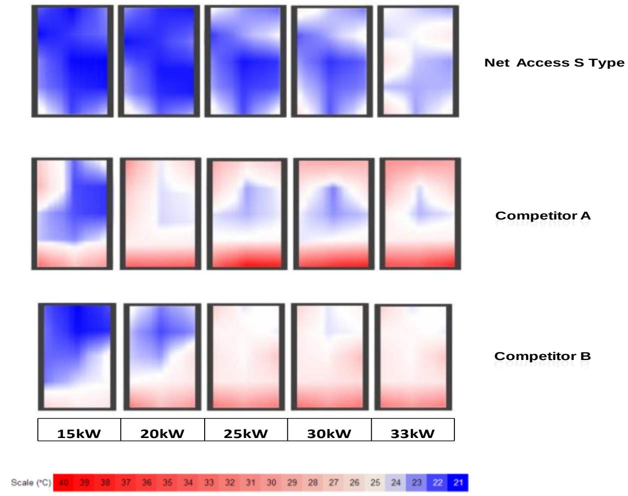

Figure 4. Comparison of inlet air temperature gradients at front of cabinets.

Energy Savings and Economic Analysis

Various data center containment solutions have flooded the market with claims of energy efficiency improvements designed to offset the additional first costs of the containment systems installation. The effectiveness of a containment system is determined by its ability to prevent hot air recirculation and cold air bypass. Containment systems can allow improvements in energy efficiency if cooling system set points can be modified. The magnitude of these energy savings depends on the degree to which the containment system is sealed.

From the collected data, a potential energy savings due to the Total Air Seal feature was calculated. Preventing hot exhaust air recirculation allows the room supply air temperature to be increased without exceeding ASHRAE limits at the IT equipment. This, in turn, allows the data center operator to increase the building chilled water temperature (assuming cooling is provided by a mechanical cooling system with a chiller). The efficiency of a chiller system increases with an increase in chilled supply water temperature (SWT). As a rule of thumb, for every degree Celsius increase in SWT the chiller efficiency increases by 3%-4% [2] A hypothetical data center layout with a chiller based cooling system was used to estimate the potential cooling energy savings. We extrapolated the 20 kW single cabinet thermal test data to a 1.6 MW data center with multiple cabinets, resulting in 41% less cooling energy consumed.

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Table 1. Economic analysis with 20kW per cabinet.

Example Data Center Characteristics	
Total IT Load (kW)	1600
Number of Cabinets	80
Per Cabinet IT Load (kW)	20
Centrifugal Chiller System	0.67 kW/Ton @ 5.6°C SWT, SWT can be raised up to 18°C

Table 1 shows the results of the economic analysis with 20 kW per cabinet. Here, the ASHRAE allowable inlet air temperature limit of 32°C is used as a threshold for the IT equipment inlet air, which then determines the maximum supply air temperature (SAT). Similar to the single cabinet thermal tests, we assumed 10% excess facility cooling airflow beyond the cabinet airflow demand. Also, it has been assumed that the IT equipment inlet air temperature scales up and down linearly with the supply air temperature. For example, a 6.5°C decrease in supply air temperature would lower the maximum IT equipment inlet air temperature by 6.5°C. The cooling chain components (such as CRAH units, fixed flow rate pumps, cooling tower, etc.) that are fixed for all three cabinet scenarios are not considered in the analysis. The improvement in cooling allows significant cooling energy cost savings, as shown in Table 2.

Table 2. Chiller Annual Energy Cost Comparison for 20 kW VED cabinets

	Competitor A	**Competitor B**	**Panduit Net Access S Type**
Experimental Supply Air Temp., Deg. C	20	20	20
Experimental Maximum IT Inlet Air Temp., Deg. C	33.4	33.7	27
SAT to maintain max IT inlet of 32°C, Deg. C	18.8	18.5	25
SWT (assuming 7.2°C approach), Deg. C	11.6	11.3	17.8
Chiller Annual Power Consumption (kW)	237	241	170
Chiller Annual OpEx ($0.10 per kWh)	$207, 811	$211,182	$148,859
% Increase in Annual Chiller Energy Usage	39%	41%	baseline
Annual Savings per Cabinet over Competitor B			$780

Figure 5 shows the comparison of chiller annual energy costs for the different heat load scenarios (assuming that the total data center IT load remains ~1.6MW).

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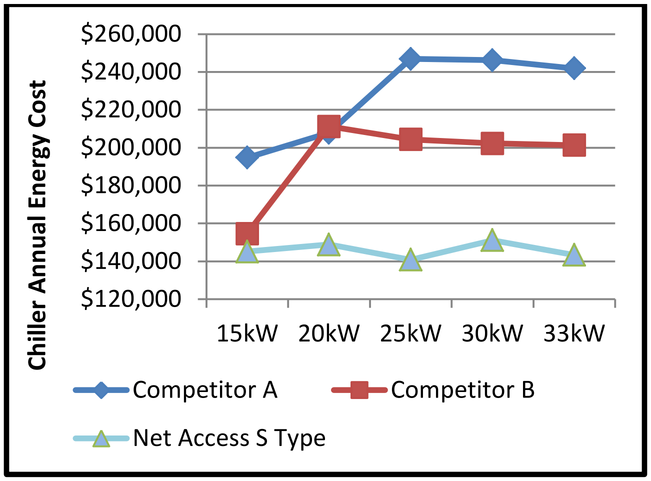

Figure 5. Chiller Annual Energy Cost Comparison for different heat load VED cabinets.

For data centers with an economizer system (airside or waterside), a higher room air set point temperature allows more hours of free cooling, and therefore reduced cooling energy. For example, a data center located in Chicago with an airside economizer that can be operated with 25°C supply air would be able to use free cooling for 88% of the time (~7700 hours out of 8760 hours) in a year[2], which translates to approximately $156,000 in annual cooling energy savings (for a 1.6MW data center) over a chiller based cooling system

Conclusion

Through airflow bench testing we have demonstrated that the integral cabinet sealing features of Panduit's Net Access™ S Type VED cabinet reduce air leakage by up to 20% over the competitors' cabinets. The improved sealing has a significant impact on hot air recirculation and IT equipment inlet temperatures, as the VED cabinet IT loads increase from 15 kW to 33 kW. This study clearly demonstrates the economic benefit of using a well-sealed cabinet in containment applications.

References

1. Average Data Center Energy Usage Allocation, Lawrence Berkeley National Laboratory 2007
2. Design Considerations for Datacom Equipment Centers ASHRAE 2009, Second Edition. Page 138.

About Panduit

Panduit is a world-class developer and provider of leading-edge solutions that help customers optimize the physical infrastructure through simplification, increased agility and operational efficiency. Panduit's Unified Physical Infrastructure℠ (UPI)-based solutions give enterprises the capabilities to connect, manage and automate communications, computing, power, control and security systems for a smarter, unified business foundation. Panduit provides flexible, end-to-end solutions tailored by application and industry to drive performance, operational and financial advantages. Panduit's global manufacturing, logistics, and e-commerce capabilities along with a global network of distribution partners help customers reduce supply chain risk. Strong technology relationships with industry leading systems vendors and an engaged partner ecosystem of consultants, integrators and contractors together with its global staff and unmatched service and support make Panduit a valuable and trusted partner.

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