Unified Physical Infrastructure^{SM} (UPI) Strategies for Smart Data Centers

Deploying a Vertical Exhaust System to Achieve Energy Efficiency and Support Sustainability Goals

WHITE PAPER

Introduction

Business management applications and rich collaboration software for both employees and customers require increasingly complex and large-scale database processing capabilities. Data center managers are under constant pressure to manage growth while reducing capital and operational expenses. With per-cabinet equipment densities increasing to meet these processing demands, network stakeholders need new and effective cooling conservation strategies for managing growth and the resulting high heat densities over the life of the data center.

Organizations are looking to Unified Physical Infrastructure^{SM} (UPI) solutions that take a holistic approach to the data center, turning to passive exhaust containment solutions to optimize energy efficiency and mitigate risk throughout the physical infrastructure. One such solution, the Vertical Exhaust System (VES), is a passive exhaust containment system that eliminates hot exhaust air recirculation to active equipment inlets throughout the data center. These systems channel heated server exhaust air directly into the hot air return plenum, separating hot exhaust air from cool supply air. This allows data center managers to operate the data center at higher supply air set point temperatures to achieve operational savings.

This white paper discusses thermal management considerations associated with deploying a Vertical Exhaust System in the data center, and its impact on the data center physical infrastructure. An example scenario is presented to demonstrate the cost savings that may be achieved by deploying a VES in a typical data center environment. Best practices include minimizing airflow impedance in the back of the cabinet and up through the vertical duct, and keeping the server exhaust area clear of airflow obstructions. When deployed in conjunction with infrastructure best practices, VES containment strategies achieve cooling efficiencies, support sustainability goals, and lower cooling system operating costs by 25% or more.

Reaching the Limits of Traditional Cooling Systems

Typically, airflow management in a data center is achieved by strategic placement of Computer Room Air Handling (CRAH) units and physical layer infrastructure elements, with equipment rows positioned in a Hot Aisle / Cold Aisle arrangement (see Figure 1) as defined in TIA-942 and in ASHRAE's "Thermal Guidelines for Data Processing Environments."

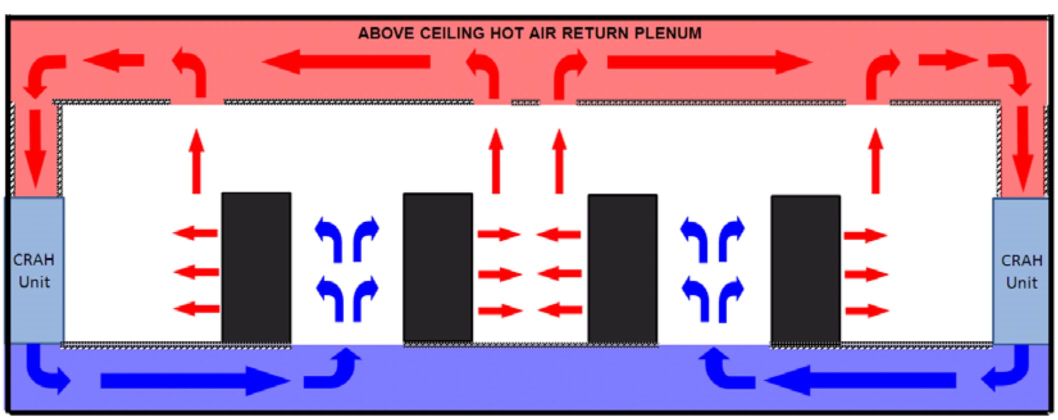

Figure 1. Traditional Raised Floor Hot Aisle / Cold Aisle Data Center with Ceiling Returns

In a raised-floor environment with ceiling returns, CRAH units distribute cool air underneath a raised floor, allowing air to enter the room through perforated floor tiles located in cold aisles. Active equipment within cabinets is positioned such that the equipment fans draw cool air through the equipment from the cold-aisle side and release exhaust into the hot aisle at the rear. Finally, the equipment exhaust air exits the room and returns back to the CRAHs via a ceiling plenum and return ducts.

The current trend in data centers is toward greater equipment densities, and these higher densities are pushing the capability of raised floor cooling systems to their limits. Raised floor systems with ceiling returns can typically deliver enough air to remove 7-8 kW of heat per cabinet, provided that the CRAH units have adequate thermal capacity and best thermal management practices are employed. These best practices include a 24-36 inch (60-90 cm) raised floor height, a hot aisle / cold aisle arrangement for cabinet rows, properly sized perforated floor tiles or grates, a proper return airflow path, proper positioning of power and data cables, and the use of raised floor air sealing grommets and blanking panels.

Data center consolidation and virtualization efforts are resulting in higher density cabinets with each cabinet holding several servers. These high server densities can generate heat loads of 8-12 kW per cabinet; and as equipment is added and upgraded, especially high heat-generating blade server configurations, cabinet heat loads can exceed 25 kW. Without effective thermal management strategies in place risks multiply quickly:

- Increased risk of downtime and lost revenue due to equipment failures
- Reduced Mean Time Between Failure (MTBF)
- Increased costs associated with maintenance
- Increased operational expenses due to overcooling

Innovative, Cost-Effective Improvements in Data Center Cooling

Budget constraints and escalating energy costs are forcing data center stakeholders to review all available heat removal options in order to improve operational efficiency and maintain business continuity. UPI-based cooling conservation solutions are finding increasing adoption in data centers as a reliable, cost-effective and eco-friendly option for addressing high heat loads. These innovative solutions use precision cooling techniques to optimize airflow and protect active equipment without adding power-hungry cooling units that drive capital costs up and introduce additional operational costs (see Table 1 for a quantitative comparison).

Table 1. Comparison of Supplemental Cooling Methods in the Data Center

Method	Capital Costs	Operational Costs	Points of Failure
Passive Systems	$	None	None
In-Cabinet Fans	$$	✓	✓
Overhead Cooling Units	$$$	✓	✓
Rear Door Heat Exchanger	$$$	✓	✓
Boost CRAH Capacity	$$$	✓	✓

As part of a holistic UPI-based approach, precision cooling elements can be planned and deployed from initial startup or modularly added when needed, enhancing agility by integrating with existing cabinet layouts to allow cooling capacity to scale as business requirements change and grow. This flexibility allows data center stakeholders to provision equipment as needed without adding CRAH units or overtaxing the raised floor cooling system.

One of the most efficient passive airflow management options for data center environments is exhaust containment such as the Vertical Exhaust System (VES), which channels heated server exhaust air directly to the ceiling return plenum via a vertical duct or "chimney" unit (see Figure 2). This ducting of hot exhaust air to the CRAH returns prevents hot air recirculation, ensuring availability of cool air at the equipment inlets. The VES exhaust containment system is capable of supporting high heat loads to enable high density equipment configurations such as blade server deployments.[1]

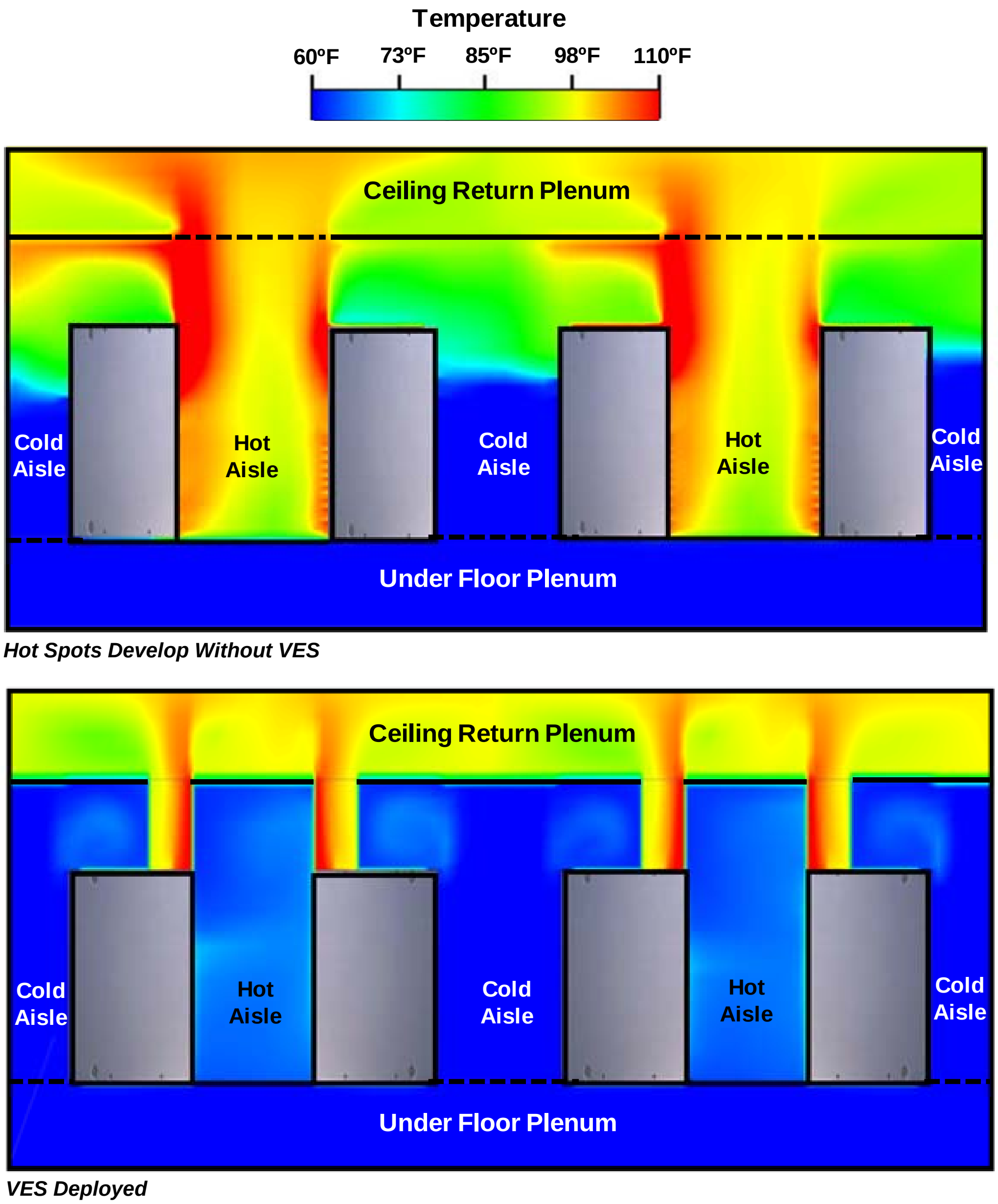

Figure 2. TOP: In a traditional Raised Floor with Ceiling Returns configuration (hot aisle/cold aisle) hot air can recirculate to the front of the enclosure, heating the top portion of the rack.
BOTTOM: The Panduit VES optimizes thermal efficiency by moving hot air through vertical ducts directly to the return plenum.

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[1] Intel white paper: "Air-Cooled High Performance Data Centers: Case Studies and Best Methods." November 2006.

The segregation of hot and cool air allows the data center to be operated at a higher temperature set point, which in turn reduces energy consumption by the cooling system. Directing hot air into the return plenum also reduces energy use by maximizing the difference in temperature between the return air and chilled water across cooling coils, which enables CRAH units to run at higher capacity. The deployment of a VES-based air containment system provides opportunities to lower CRAH fan speeds and observe fan power savings while maintaining the cabinet inlet temperatures within the desired range (e.g., ASHRAE-recommended temperature limit of 80.5ºF).

A VES enables significant energy savings in the data center by potentially reducing the number of CRAH units required to obtain desired thermal performance and by optimizing the work performed by those units, resulting in immediate and considerable energy and cost savings. For example, a 3,000 ft^2 raised floor data center with 68 server cabinets would require 6 CRAH units to manage 8 kW of heat per cabinet. As equipment is added, data center stakeholders face the challenge of managing the additional thermal load.

This hypothetical data center would require additional CRAH units to reliably manage up to 10 kW per cabinet, at a capital cost of $35,000 per unit. At an average electrical utility rate of $0.11 per kW-hr, the cost to operate a CRAH unit at maximum capacity runs about $9,000/yr[2], plus any other installation and maintenance costs to service the unit. By contrast, for less than the cost of one CRAH unit, a passive VES can be deployed on all heat-generating cabinets to manage thermal loads without additional ongoing operating costs (see Table 2).

All of these factors combine to reduce cooling system operating costs by at least 25%, with actual cost savings potentially increasing with layout configuration, equipment density, and maintenance savings. For all these reasons it is clear that VESs are the cost-effective (and green) choice to efficiently cool high heat-generating cabinets.

Table 2. Cost Savings Achieved Using Passive VES for Thermal Management (3,000 ft^2 Data Center with 68 Server Cabinets)

	Capital Costs*					Utility Costs**	
Thermal Management Option	**CRAH unit cost**	**# of CRAH**	**VES unit cost**	**# of VES**	**Total**	**Annual per CRAH**	**Total**
Option 1: Additional CRAHs	$35,000	8	$700	0	$280,000	$9,023	$72,184
Option 2: VES Cabinets	$35,000	6	$700	37	$235,900	$9,023	$54,138
Total Cost Savings Using VES					$44,100		$18,046
% Cost Savings Using VES					**16%**		**25%**

Assumptions:
* Does not include cost to install.
**Electricity rate of $0.11 per kW-hr.

Return on Investment (ROI) For VES Deployment
Payback period: 0.3 years
10-year ROI: 266%

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[2] Value calculated with the Liebert Power and Cooling Energy Savings Estimator, using an electricity rate of $0.11 per kW/hr at 90% motor efficiency.

VES Design Considerations

The decision to deploy a VES has multiple implications for layout of other data center elements. First, data center stakeholders need to analyze the layout of the entire physical infrastructure (both facilities-related and cabling-related elements) to determine how best to keep overhead room space free from obstruction. Second, stakeholders should maximize system performance by optimizing cable management within the cabinet: in-cabinet airflow can be hampered by poor cable management in server cabinets where power and data cable congestion can block server exhaust fans and obstruct airflow through the VES.

Optimize Room-Level Layout

Several room-level factors need to be considered for effective VES deployment. Designers should route data cable pathways overhead at the front of cabinet enclosures, leaving the rear of the cabinet open for physical placement of the vertical duct above the hot exhaust area. Only the front area above the cabinet should be used for overhead copper and fiber cabling pathways. This should be carefully designed to ensure sufficient cabling capacity for the entire row of cabinets (see Figure 3a).

An additional challenge for data center stakeholders is integrating the VES layout with lighting and fire detection/prevention systems. Infrastructure layout decisions are commonly made during the data center design phase in consultation with facilities experts, with lighting and fire systems positioned to attain maximum coverage throughout the room and in compliance with local codes. In retrofit applications the VES must be integrated with existing lighting and fire suppression designs to maintain the effectiveness of those key systems.

Once the vertical duct unit is placed in position, it should be sealed at the points of transition (i.e., ceiling plenum and cabinet) to prevent hot exhaust air from being released into the data center and recirculating (see Figure 3b). Cable entry points at tops of cabinets also should be sealed to prevent hot air leakage and recirculation.

Figure 3a. Effective Location of Overhead Cabling Pathways in Relation to Panduit VES

Figure 3b. Solid Rear Doors Prevent Hot Air Recirculation

To realize the full potential of a Vertical Exhaust System and for effective separation of cabinet exhaust air from the room ambient air, use blanking panels in empty cabinet spaces and properly seal all cable pass-through openings. These best practices eliminate the bypass of cold air, recirculation of hot exhaust air, and unwanted airflow leakage. This also enables server inlets to draw uniformly cool air at the front of the cabinet, eliminating the need to oversupply cool air to achieve desired thermal performance.

Keep the Exhaust Area Open

The VES functions by containing and channeling hot exhaust air. A slightly lower pressure in the ceiling return plenum than in the room helps draw hot exhaust air from the cabinet and into the plenum. The VES should be properly sized, sealed, and free from obstructions to avoid introducing choke points that impede the continuous flow of exhaust air and limit system effectiveness.

The impact of chimney size on system performance is fairly straightforward-- the larger the channel and less obstruction, the less impedance to server fan airflow and hence the greater the volumetric airflow through the vertical duct. The more critical limiting factor for VES effectiveness is the size of the space behind servers, as the back pressure on the exhaust side of the cabinet may adversely affect the cooling of IT equipment. To minimize the back pressure effect on server fans and to optimize VES effectiveness, the space behind the servers should be free from obstructions and sized to avoid any substantial back pressure.

The free space behind servers is also a critical parameter to control, as server cabling density can have a significant impact on the ability of hot exhaust air to exit the cabinet. For example, in a standard 24-inch-wide server cabinet, the effective open space behind servers is often reduced by improper cabling and horizontal cable management (see Figure 4).

Figure 4. Poor in-cabinet cable management practices introduce clutter and choke points in the exhaust area that limit cooling system effectiveness.

As shown in Figure 5, data cables behind servers in a 24-inch-wide cabinet are forced to occupy valuable exhaust area space, with data cables positioned to one side of the rear of the enclosure and power cables on the other. Cable management arms also extend approximately four inches into the exhaust area, blocking that space with cables and reducing the effective size of the exhaust area by 33%. (Loose or poorly managed cabling can add clutter to this area, reducing cooling system effectiveness even further.)

In contrast, a 32-inch-wide cabinet adds 8 inches of width to the exhaust area without sacrificing depth: cables are routed into vertical spaces to the sides of the servers to keep the entire exhaust area clear. Data and power cabling can be managed outside the exhaust area to maximize the airflow channel and maintain optimal cooling system performance. The result is an effective doubling of the open exhaust area (see Figure 5), dramatically increasing airflow capacity while observing best cable management practices to ensure system performance.

Cross-Sectional Exhaust Area	186 sq. in. (1200 sq. cm)	372 sq. in. (2400 sq. cm)
Cabinet Width	~24 in. (600 mm) Cabinet with Cable Mgmt Arms	~32 in. (800 mm) Cabinet
Effective Free Space Behind Servers	~8 in. (200 mm)	~12 in. (300 mm)

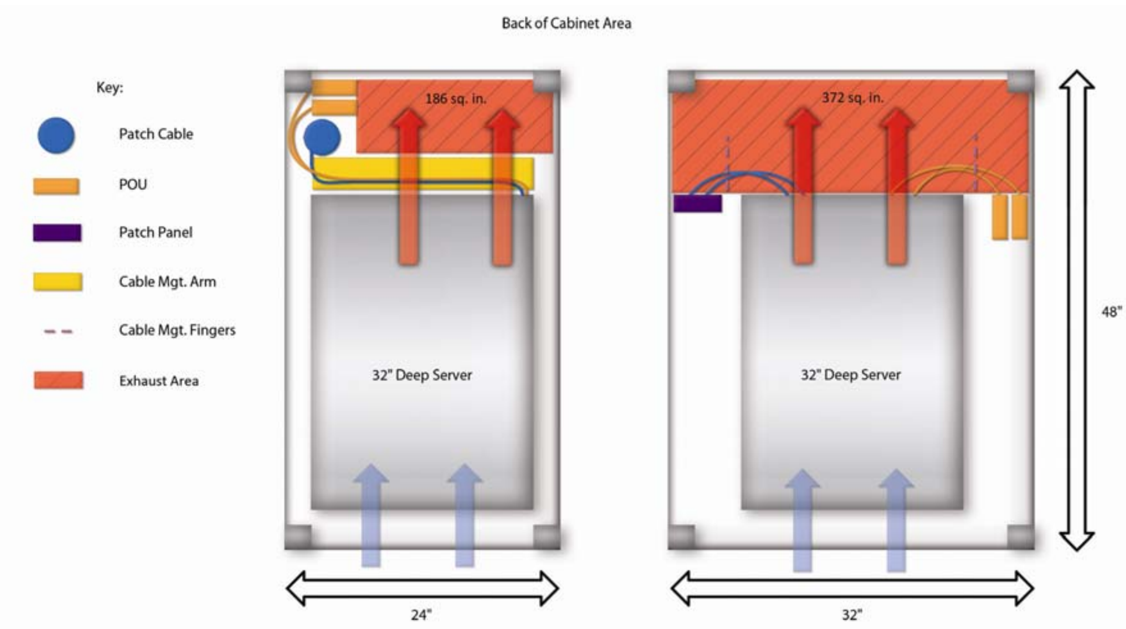

Figure 5. Top View Showing Impact of Cabinet Width and Cable Management on Exhaust Area Space

Cable Management Considerations

Panduit has identified several best practices to follow in order for data center stakeholders to maximize VES effectiveness while maintaining optimal network performance. In general, the exhaust area should be kept as free from obstruction as possible to enable the unimpeded flow of hot exhaust air from the cabinet into the vertical duct. Installers should route data and power cables toward cabinet side walls and away from server exhaust areas. Also, the use of cable management fingers is preferred over cable management arms, as the arms create an obstruction that impedes airflow.

The following best practices address specific areas within the cabinet where optimal airflow should be observed.

- **In-cabinet exhaust area**. The most critical area of the in-cabinet exhaust area is the upper four to six rack unit spaces. Although cabling-related obstructions below this point can impede airflow, obstructions above this point present a direct risk to cooling system performance as they block the vertical duct channel and directly inhibit the ability of air to exit the cabinet (see Figure 6). For example, server cabinets provisioned with Top of Rack (ToR) switching architectures are prone to this type of risk, as dense fiber and copper cable bundles (as well as equipment) may protrude several inches into the exhaust area.

Because fiber enclosures can extend beyond cabinet mounting rails, a flush-mount fiber enclosure is recommended to prevent fiber tray overhang into the exhaust area. For patching environments, the use of a flush-mount vertical patching system is recommended to route patch cords from server ports directly to adjacent patching locations, leaving the exhaust area free from large cable bundles that block the vertical duct channel opening (see Figure 6). For ToR switching deployments, cable bundles can be efficiently routed up vertical side channels to minimize the amount of space these bundles occupy in the exhaust area.

- **Power Outlet Units (POUs) and associated cabling**. Power outlet units and cabling should be aligned with data cabling by placing POUs in opposite vertical spaces and positioning power cables away from IT assets (see Figures 5 and 6). Cables should be sized at minimal lengths (18-24 inches) to minimize cable slack and increase available space in the exhaust area.

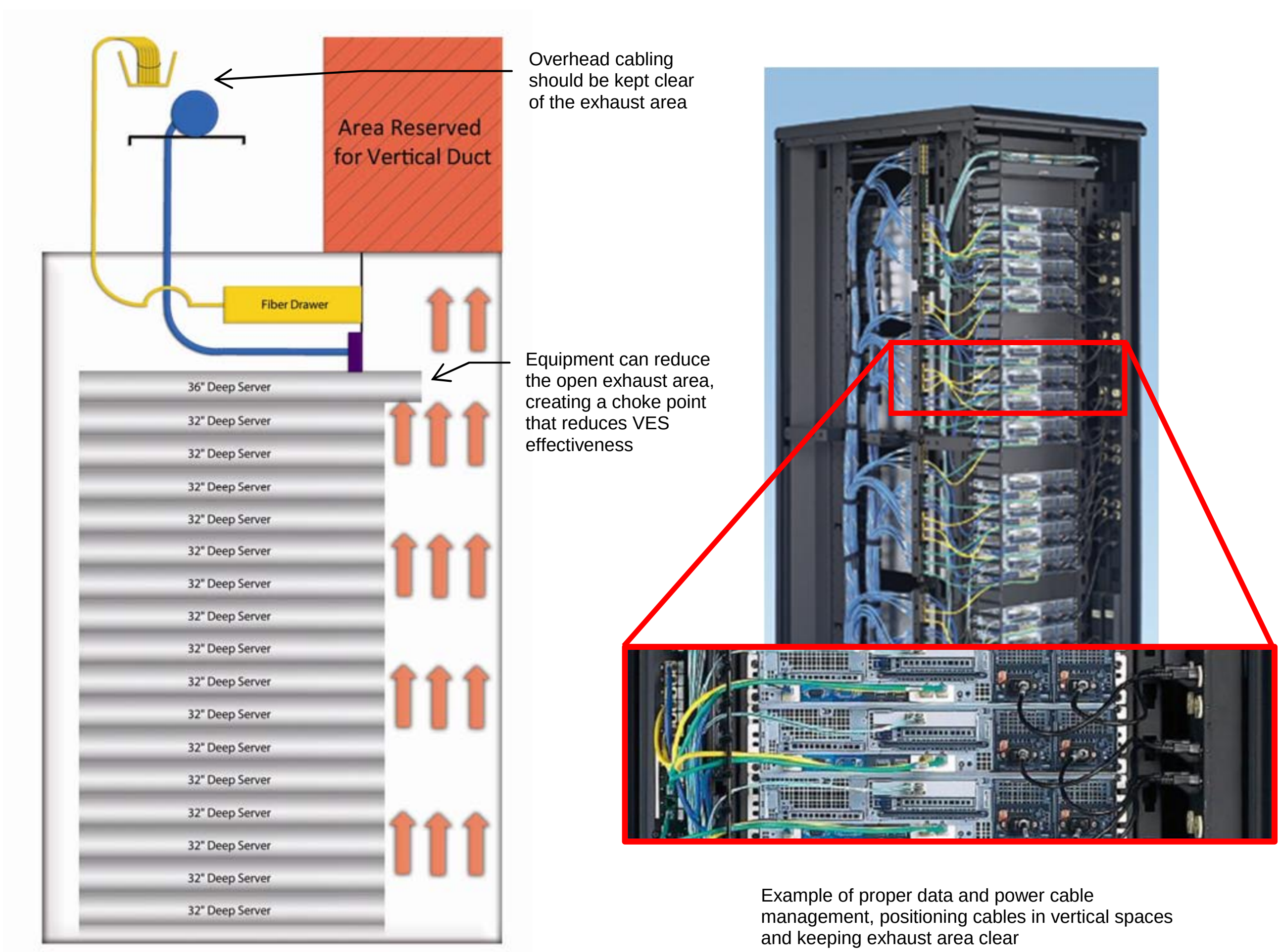

Figure 6. Maximize VES Effectiveness by Properly Managing Overhead Pathways and In-Cabinet Patching

- **Passive air-blocking devices**. Blanking panels should occupy empty rack spaces and air sealing grommets should be used to seal raised floor tile cutout openings to maintain hot and cold air separation.

- **Cable pathways**. Data center designers should deploy overhead cabling pathways at the front of cabinets in order to ensure enough clearance at the rear of the cabinet for vertical duct units to be directly positioned above the exhaust area. Also, in-cabinet cable managers provide pathways allowing cables to run vertically in cabinet side areas; cables are managed out of the path of hot exhaust airflow and are distanced from equipment chassis.

Retrofit Cases

Although many data center designers incorporate VESs into an initial room design, these systems can be deployed in conjunction with existing cooling systems to address high heat-generating cabinets that emerge over time. Room layout conditions under which the VES can be deployed in retrofit applications include adequate room above the cabinet to fit a vertical duct unit and a hot air return path such as a dropped ceiling return plenum. The retrofitting of VESs provides additional cooling efficiency at minimal operating cost. A VES can be integrated with existing hot aisle / cold aisle cooling layouts, whether the data center is a raised floor or concrete slab type.

Conclusion

High heat loads in the data center are best managed by deploying UPI-based solutions that support uptime goals, prolong the life of active equipment, and enable the continued support of “green” IT goals. Organizations cannot afford to waste money on inefficient cooling practices, so data center stakeholders need to be confident that the thermal management solutions they deploy will achieve cooling goals at minimal cost.

These goals can be realized by the deployment of passive exhaust containment systems. The modular, passive Vertical Exhaust System (VES) channels heat from the server exhaust directly into the hot air return plenum, isolating hot exhaust air from equipment cooling air to eliminate data center hot spots due to hot exhaust air recirculation. Best cabling practices to observe include keeping the in-cabinet exhaust area behind servers as free from obstructions as possible to enable the unimpeded flow of hot exhaust air into the vertical duct. In particular, installers should route data and power cables toward cabinet side walls and away from server exhaust areas, leaving the exhaust area free from large cable bundles.

Panduit’s expertise in the data center space and consultative approach to determining customer requirements deliver physical infrastructure solutions that optimize the thermal efficiency of the data center infrastructure. Our comprehensive UPI-based data center solutions include thermal management systems, High Speed Data Transport (HSDT) systems, cabinet systems, and physical infrastructure management software. This unique solutions approach enables enterprises to confidently meet broader business objectives for agility, availability, integration and security.

For more information on comprehensive Panduit data center solutions, or to view the Net-Access Cabinet brochure featuring the VES, visit www.panduit.com/datacenter.

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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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