Unified Physical Infrastructure (UPI) Strategies for Thermal Management

The Importance of Air Sealing Grommets to Improving Data Center Cooling Efficiency

WHITE PAPER

Introduction

One of the core issues affecting data centers is the ability to cost-effectively cool active equipment. Movement of cool air through the data center is achieved through strategic layout of air conditioning units and physical layer elements. In a conventional raised floor environment, cool air is distributed underneath the raised floor and the air enters the room through strategically placed perforated floor tiles in order to cool the active network equipment.

However, industry data indicates that up to 60% of available data center cooling capacity is wasted by airflow that bypasses the equipment it is intended to cool. Sources of “bypass air” include incorrect positioning of perforated tiles, poor placement of air conditioning units, and poorly sealed (or unsealed) cutout spaces in floor panels beneath racks and cabinets for underfloor cable routing. Whatever the source, this “bypass air” weakens the efficiency of the raised floor cooling system and has the potential to increase network downtime.

This white paper demonstrates how air sealing grommets can be used to close raised floor cutout spaces and improve data center cooling efficiency. Solutions that achieve the highest level of sealing effectiveness support network uptime goals by contributing to maximum cooling efficiency and providing superior cable management. Also, by saving energy in a measurable way, raised floor grommets are a reliable, effective component to green data center solutions.

Optimizing Data Center Airflow

The cooling system is critical to data center reliability and total cost of ownership (TCO). Therefore, this system requires careful design and constant oversight to maintain an acceptable level of performance at a reasonable cost. Active cooling system components can include computer room air conditioning (CRAC) and computer room air handling (CRAH) units, chillers, cooling towers, condensers, raised floors, ductwork, pump packages, piping, and supplemental rack- or ceiling-level cooling or air distribution devices.

The raised floor is often used to distribute cooled air, manage the cabling found within data centers, and enhance the appearance of the room. The CRAH units distribute cool air under the raised floor with the expectation that this air will enter the room through strategically placed perforated floor tiles. Above-floor computer room equipment rows follow the hot aisle/cold aisle layout defined in TIA-942 and in ASHRAE’s “Thermal Guidelines for Data Processing Environments”. Computer room servers and switches are positioned to face the cold aisles where these perforated floor tiles are positioned. This allows the cool air to transfer through racks and cabinets by equipment fans and be released as exhaust into hot aisles to the rear (see Figure 1). Other facilities and IT physical layer components (i.e., pipes, cables, power cords) can be deployed safely under the raised floor, in order to maximize the available space above-floor for cabling and active equipment subject to moves, adds and changes (MACs).

In a typical data center, a perforated tile with 25% open area and a cool air throughput rate of 150-200 cubic feet per minute (cfm) can disperse about 1 kW of heat. For loads much greater, or for heat loads that increase with active equipment loads over the life of the data center, several options are available to expand local cooling capacity. These options include increasing tile open area (from 25% to 40-60%), boosting CRAH capacity, deploying supplemental cooling units, and reducing air flow leaks.

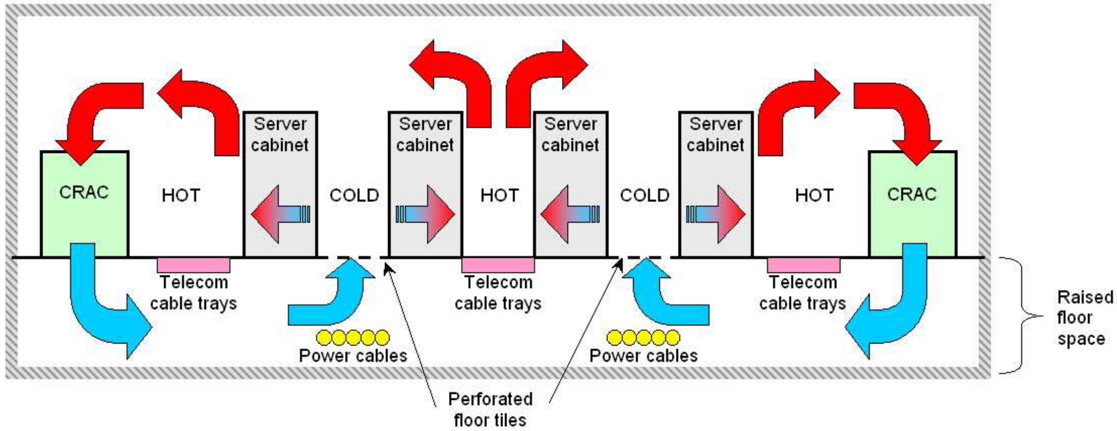


Figure 1. Placement of Data Center Equipment Cabinets in Hot Aisle/Cold Aisle Layout

The High Price of (Unsealed) Holes in the Floor

Every piece of equipment in a rack or cabinet has cords and cables transferring into overhead pathways or underfloor trays. The bulkiest of these (power cords, copper cables and patch cords) often are routed under the raised floor via cutout spaces in the raised floor tiles.

These cutout spaces are often left unsealed or with gaps that allow bypass air and a significant portion of the cool air is lost through the cutout spaces (see Figure 2). In addition, a significant amount of cool air can pass through improperly sealed spaces within the racks and cabinets and disrupt the efficient movement of cool (and hot) air throughout the room (see Figure 3). All of these disruptions to airflow have a quantifiable impact on cooling costs, and every piece of equipment that requires maintenance, repair, or replacement due to heat exposure reduces uptime and drives costs up.

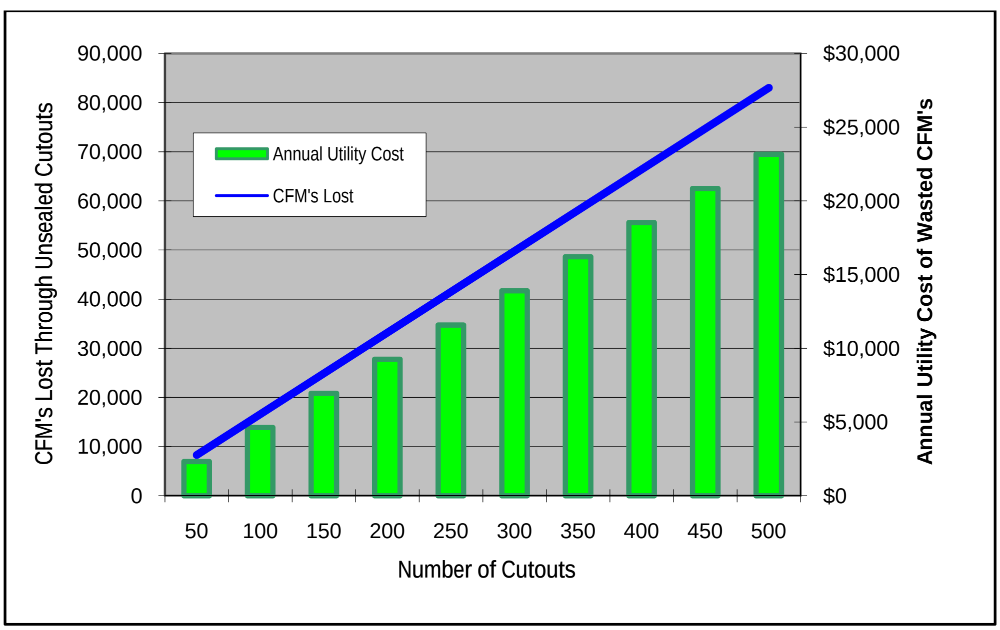
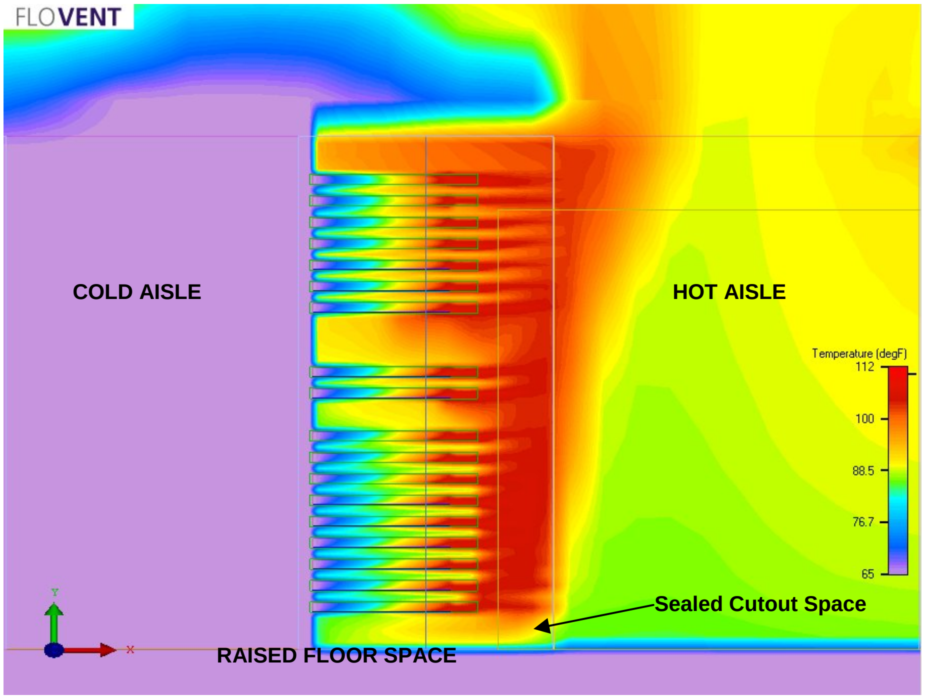


Figure 2. The Cost of Unsealed Cable Cutouts (assumes 4.5 in. x 6.5 in. cutout spaces)



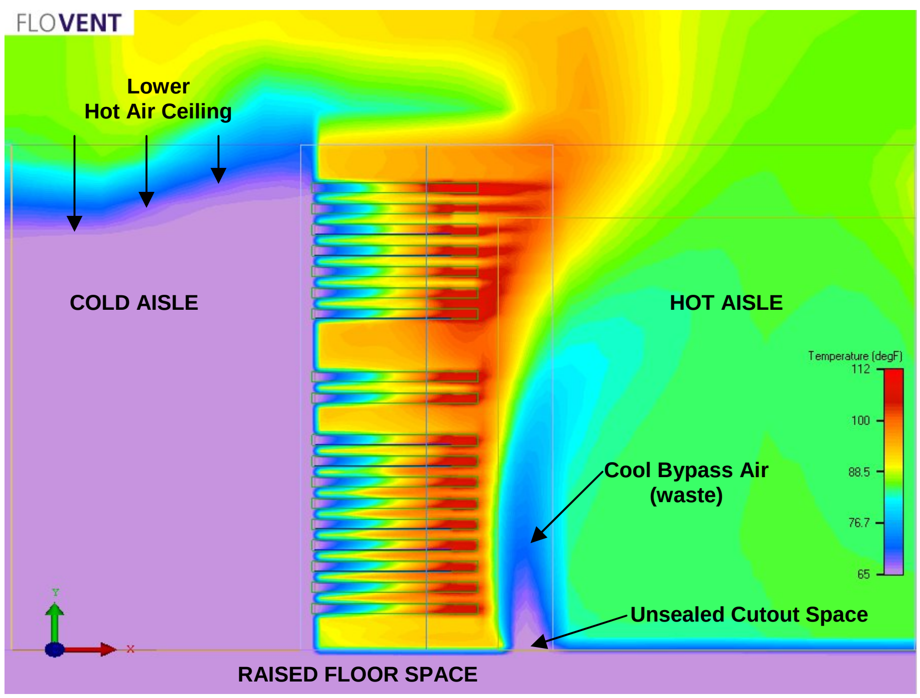


Figure 3. These cabinet cutaway views show how efficient cool airflow through cabinets (top) is disrupted when raised floor cutout spaces are left unsealed (bottom), resulting in cool air bypassing intake areas and a lower hot air ceiling.

Using Air Sealing Grommets to Optimize Energy Consumption

The unnecessary energy costs associated with bypass air are easily avoided by the installation of air sealing grommets, as described in the following examples.

Example 1: Maximizing Raised Floor Effectiveness

An organization is consolidating servers into a new data center with 5,000 ft^2 of raised floor space, and plans to deploy 120 standard density cabinets (7 kW per cabinet) and 30 high density cabinets (14 kW per cabinet) throughout the computer room for a total heat load of 1,260 kW. To disperse this heat load a total of 357 tons of cooling is required. This can be accomplished by using a combination of raised floor cooling for all 150 cabinets, plus supplemental cooling devices on the high density cabinets.

For the 30 high density cabinets, rear door heat exchangers can be used to remove 50% of the heat via water, leaving 7 kW of heat per cabinet to be handled by the raised floor system. For this remaining heat load, a traditional raised floor cooling system typically delivers enough air to disperse 7 kW of heat per cabinet, provided that the CRAH units have enough capacity and best practices are employed (e.g., hot aisle/cold aisle equipment layout, 24”-36” raised floor height, 25% opening through perforated tiles, proper return airflow path, and the use of rack filler panels).

Ten 30-ton CRAH units can be used to deliver 150,000 to 180,000 cubic feet per minute (cfm) of cooled air into the raised floor space and distribute it through perforated floor tiles. A computational fluid dynamics (CFD) study of this scenario shows that an arrangement of 150 perforated tiles (one tile per cabinet) will deliver 1,000-1,200 cfm per tile, enough to cool 7 kW per cabinet provided that the underfloor static pressure is maintained at 0.10 inches of water (see Table 1).

Achieving that pressure strongly depends on the degree to which cable cutout spaces beneath cabinets are sealed. The median size of a cutout space under standard density server cabinets is 4.5” x 6.5” (nearly 30 square inches), with spaces under high density cabinets potentially being larger to accommodate water hoses or greater cable volumes. If the 150 cutout spaces in this example are left unsealed, almost 25,000 cfm of cold supply air (166 cfm/cutout) will bypass cold aisles and follow a path to the CRAH unit return without removing any of the heat that is building up in the equipment cabinets. (By comparison, this is more airflow than a single 30-ton CRAH unit would deliver.)

Table 1. Summary of CFD Analysis for 5,000 ft^2 Data Center with 150 Cabinets

Treatment of Cable Cutout Spaces	Airflow Capacity (10 CRAH Units)	Airflow through 150 Perforated Tiles (25% Open Area)	Airflow through 150 Cutout Spaces (4.5 in. x 6.5 in.)	Underfloor Static Pressure (in.-H_20)
Fully sealed	158,850 cfm	158,850 cfm *1000 to 1200 cfm per tile* *(average 1059 cfm)*	0 cfm	0.10
Unsealed	158,850 cfm	133,914 cfm *780 to 950 cfm per tile* *(average 893 cfm)*	24,936 cfm *(average 166 cfm per cutout)*	0.07

As shown in Table 1, with cutout spaces left unsealed the underfloor pressure drops to 0.07 inches of water, and each perforated tile now delivers only 780 to 950 cfm to the front of the cabinet. Effectively, a cooling infrastructure designed for 7 kW per cabinet is now capable of only 5 to 6 kW per cabinet because the cable cutouts have not been properly sealed. In addition, the recirculation of hot air over cabinet tops is encouraged by inadequate delivery of airflow to the cold aisle, causing elevated inlet temperatures for equipment positioned at the top of the racks.

To maintain a static pressure of 0.10 inches to remove heat as designed, even with these 150 open cutout spaces, it would take the addition of two CRAH units, at a cost of $40,000 per unit and associated utility costs of roughly $4,600 per year to run each CRAH unit. When the capital costs are annualized over an eighteen-year useful life of the CRAH units, this could result in an additional $13,644 annual expense for the two new CRAH units alone (see Table 2). The dollar figures multiply even more quickly when the cost to maintain and replace heat-damaged active equipment, as a result of inadequate cooling, is factored in.

Table 2. Options for Maximizing Raised Floor Effectiveness in a 5,000 ft^2 Data Center with 150 Open Cutouts

Option	Cooling Impact	Financial Impact
Leave cutouts unsealed	• Bypass airflow is present (inefficient) • Airflow delivered to cabinets is inadequate for the designed cooling requirements • Only 5-6 kW removed even though CRAH capacity can remove 7 kW / cabinet	• $6950 wasted in annual utility costs due to bypass airflow • Increased risk of premature equipment failure
Add two CRAH units	• Bypass airflow is still present (inefficient) • Airflow delivered to cabinets now meets design goals	• $4,444 annualized capital costs • $9200 annual utility costs • >$6950 wasted due to bypass airflow
Seal the cutouts	• Bypass air is eliminated • Airflow delivered to cabinets meets design goals	• One-time modest investment in airflow sealing grommets • No longer wasting $6950 per year

Example 2: Optimizing Cooling System Power Consumption

A data center manager has been asked to analyze the energy efficiency of the raised floor cooling system and optimize the power consumption of the system. The 5,000 square foot computer room contains 150 cabinets, with 12 CRAH units deployed to deliver cooling through the raised floor at a rate of 7 kW per cabinet.

If the cable cutouts in this scenario are left unsealed, a significant portion of the CRAH airflow **(over 16%)** is lost through the cutout spaces. The cost of electricity required to deliver this unused airflow is significant: a typical CRAH unit blower will consume about 7,500 W to deliver approximately 16,500 cfm[1] of cold supply air (about 46 W / 100 cfm). At an average electrical utility rate of $0.07 per kW-hr, the cost of bypass air is $27.9 / 100 cfm per year, which adds up to nearly $8,900 of utility costs squandered annually (16% x 12 CRAH units x 15,500 cfm x $27.9 / 100 cfm).

One strategy to eliminate this waste is to deploy air sealing grommets and seal all cutout spaces in the computer room. By sealing all 150 cutouts, the data center manager in this scenario can turn off two entire CRAH units and still maintain adequate airflow and cooling capacity. Assuming that proper underfloor airflow

[1] Liebert Deluxe System/3™ Chilled Water *System Design Manual – 50 & 60 Hz*, p. 9.

distribution is maintained and the remaining CRAH chilled water coils have enough capacity to carry the heat load to the chiller plant, the annual savings will amount to $9200 (2 x $4600 per year).

A second strategy has the potential to deliver even greater savings but assumes that the CRAH units are equipped with variable speed fans in the blower units. The more porous the raised floor, the harder the CRAH blowers must work to maintain necessary static air pressure. However, once air sealing grommets are applied to the unsealed cutouts, the static pressure of the floor is increased and bypass air is recovered, allowing blower fan speed to be reduced by the same amount (about 16%). Fan power is proportional to the cube of the fan speed, so this reduction in fan speed translates to 42% less power consumed by the CRAH blower fans. **The savings across all 12 units will be $23,000/yr** (12 x 42% x $4600 per year per unit), which represents a quick return on investment for variable-speed CRAH units.

Grommet 101: Characteristics of Effective Solutions

The modeling data make it clear that air sealing grommets are an essential part of a complete data center physical layer solution. Sealing these cable cutouts is important, and the seal must be effective. These devices work with other passive components such as rack filler panels and cabinet ducts to route cool airflow past servers and switches and optimize hot and cool airflow throughout the room. Several grommet types are available on the market, ranging from brush-style grommets that block airflow with layers of thick bristles to the *PANDUIT*® *COOL BOOT*™ Raised Floor Air Sealing Grommet, which cinches securely around cables to create an effective seal.

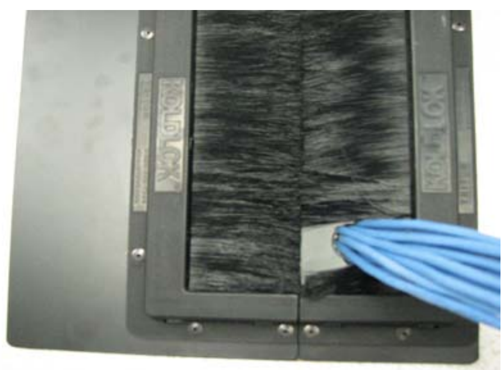


Figure 4. The position of cable bundles in brush-style grommets can move bristles out of position to reduce sealing effectiveness. In addition, bristles can sag, degrade, or break off over time.

Grommets with bristles achieve their maximum sealing efficiency when there are no cables passing through the opening or the cables are centered (optimally placed) within the grommet. However, care needs to be taken with positioning cable bundles every time MACs occur in order to maximize the sealing capabilities of the bristles. If the cables are located in the corner of the grommet (see Figure 4), or the grommet is not positioned properly, the user can expect sealing efficiency to be as low as 85%. Testing and CFD analysis indicate that when a cable cutout is sealed to 85%, it will still forfeit roughly 30 cfm of bypass air to the hot aisle. These gaps between the bristles prevent a raised floor cooling system designed to cool 7 kW per cabinet from achieving its optimum potential.

A more effective seal is needed in order to further eliminate this waste, and should add value beyond just sealing efficiency. For example, the grommet should allow two or more cable bundles to protrude through the same raised floor opening but in different locations or on different sides of the opening while maintaining its sealing effectiveness. This is particularly useful when the cable bundles are too rigid to be brought together, the slack is not available to allow these cable bundles to be brought to a central location, or the user intends to keep the power and data cables within the same opening yet as far apart as possible.

Solution: The PANDUIT® Cool Boot™ Raised Floor Air Sealing Grommet

The *PANDUIT*® *COOL BOOT*™ Raised Floor Air Sealing Grommet overcomes the weaknesses of brush-style grommets and other cutout sealing solutions by creating an effective, airtight seal no matter the quantity of cable bundles or where they are positioned in the cutout space.

This airtight seal is achieved by the fabric component of the assembly, which uses Hook and Loop type fasteners to form a complete seal around individual cable bundles, and can be sealed completely even when no cables are in place. This tight seal maintains greater raised floor static pressure than brush-style grommets for more effective cooling throughout the room. Also, where brush-style grommets lose air when cable bundles are positioned in the corners of openings, the *COOL BOOT*™ Raised Floor Air Sealing Grommet allows cable bundles to be segregated at opposite corners of the same opening (see Figure 5) without losing measurable quantities of cool air to bypass locations in the cabinet or hot aisle. In addition, the fabric component prevents cable scrap and other particles from falling underneath the raised floor.

Figure 5. Hook and Loop fasteners enable the *PANDUIT*® *COOL BOOT*™ Raised Floor Air Sealing Grommet to achieve maximum sealing effectiveness around multiple cable bundles.

The *COOL BOOT*™ Raised Floor Air Sealing Grommet adds further value by providing superior protection to cables from the sharp edge of the cut raised floor tile as the cable bundles pass through the cutout space. (Abrasion protection is a requirement according to Article 645 Section 5(D)(4) of the 2005 National Electrical Code.) *PANDUIT*® *COOL BOOT*™ Raised Floor Air Sealing Grommets also include a flexible gasket component that eliminates the labor intensive job of installing “L molding” around the perimeter of each cable cutout. The gasket is manufactured from a soft material that conforms to the natural bend of the cable to help keep cables from exceeding the specified minimum bend radius as they transfer from vertical to horizontal pathways.

Other advantages of the *COOL BOOT*™ Raised Floor Air Sealing Grommet include the low vertical profile of rigid components, which allows the opportunity for installation and adjustment under vertical cable managers (see Figure 6) and within restricted cabinet spaces. This low profile enhances the ability to make MACs and enables ease of retrofit installation because often holes are cut and cabinets are positioned before grommets are considered as a sealing solution. Also, when installed with screws the *COOL BOOT*™ Raised Floor Air Sealing Grommet provides a conductive path from the cable to the raised floor for the discharge of static electricity created as cool air rushes past cables. This pathway to ground helps protect network equipment by reducing the chance of damage due to electrostatic buildup.

Figure 6. The low height of the rigid components of the *PANDUIT*® *COOL BOOT*™ Raised Floor Air Sealing Grommet fits under vertical cable managers for faster, more efficient MAC's.

Conclusion: Pulling It All Together

Raised floor grommets act as part of a complete data center cooling solution, working with rack/cabinet hardware as part of a structured cabling system. Raised floor grommets help support data center uptime goals by improving efficiency of the cooling system and decreasing overall energy costs. In particular, grommets achieve better sealing effectiveness, greater flexibility of deployment, and superior cable management than brush-style grommet solutions.

About PANDUIT

PANDUIT is a leading, world-class developer and provider of innovative networking and electrical solutions. For more than 50 years, *PANDUIT* has engineered and manufactured end-to-end solutions that assist our customers in the deployment of the latest technologies. Our global expertise and strong industry relationships make *PANDUIT* a valuable and trusted partner dedicated to delivering technology-driven solutions and unmatched service. Through our commitment to innovation, quality and service, *PANDUIT* creates competitive advantages to earn customer preference.

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