WHITE PAPER

Reducing Room-Level Bypass Airflow Creates Opportunities to Improve Cooling Capacity and Operating Costs

By
Lars Strong, P.E., Upsite Technologies, Inc.

505.798.0200
upsite.com

Reducing Room-Level Bypass Airflow Creates Opportunities to Improve Cooling Capacity and Operating Costs

Executive Summary

Based on field data on the amount of excess cooling capacity running in data centers, there is vast unrealized opportunity to reduce operating expenses and increase cooling capacity. At the root of the considerations is room-level bypass airflow.

The data center industry is seeing a lot of emphasis on airflow management (AFM) solutions as a way to improve reliability, reduce operating costs, and increase cooling capacity. It is well known that installing grommets to seal cable openings in the raised floor and blanking panels in cabinets are best practices for eliminating hot spots and prerequisites for the efficient operation of any computer room cooling configuration. However, this fundamental step is often overlooked or unfinished before sites begin installing AFM solutions such as hot or cold aisle containment.

Despite the multitude of AFM and containment solutions available today, data centers, on average, still have nearly four times the capacity they need. Therefore, the full potential benefits of these best practices remain largely unrecognized.

The misconception is that managing the openings of a raised floor, or even installing full containment solutions, will eliminate bypass airflow. The truth is that while these solutions solve intake air temperature problems, and may reduce operating costs of IT cooling fans, the volume of bypass airflow in the room remains unchanged. Detecting and correcting this room-level issue lies in a broader understanding of bypass airflow.

The Evolution of Bypass Airflow

The Uptime Institute published the first paper on bypass airflow nearly 10 years ago. That research, conducted by engineers from both the Uptime Institute and Upsite Technologies, quantified the ratio of bypass openings to intentional openings, such as perforated tiles, in raised floors. The concept of bypass airflow was developed with a focus on unmanaged openings in the raised floor. While unmanaged openings release bypass air, they are not the cause of bypass airflow.

The definition of bypass airflow is any conditioned air supplied by a cooling unit that does not pass through IT equipment before returning to a cooling unit. In addition, air that passes through IT equipment multiple times is defined as IT equipment exhaust air circulation. The ideal for airflow in a computer room is for every molecule of conditioned air supplied by cooling units to pass through IT equipment just once before returning to a cooling unit. Any volume of air delivered by cooling units that is greater than the volume of air consumed by IT equipment becomes bypass airflow.

The original Uptime Institute research revealed that on average 60% of computer room cooling capacity was escaping through unsealed cable openings and misplaced perforated tiles. Recent research by Upsite Technologies of 45 computer rooms reveals that on average 48% of conditioned air is escaping from unsealed openings and misplaced perforated tiles. These statistics indicate surprisingly poor improvements in AFM over the last decade. It is also clear that there is a need for a broader understanding of AFM fundamentals. For example, many of the sites in Upsite's research had installed either hot or cold aisle containment without completing management of the raised floor bypass open area.

Misunderstandings About Bypass Airflow

The importance of managing openings in the raised floor is obvious, as conditioned air then only leaves the raised floor through intentional openings such as perforated tiles or grates. However, there are several misconceptions about the benefits of managing the raised floor open area.

There is a common misconception in the industry: if a cable opening is sealed and perforated tiles are properly managed, the amount of bypass airflow is reduced. This may indeed happen, but in most computer rooms where there is an excess of running cooling capacity, and therefore an excess volume of conditioned airflow, sealing cable openings and properly managing perforated tiles shifts the location of bypass airflow to the cold aisle.

The arrows and numbers in the following figures represent volumes and direction of air movement in computer rooms. The number of cabinets and cooling units are simplified for clarity but the ratios can be applied to rooms with many cooling units and rows of equipment.

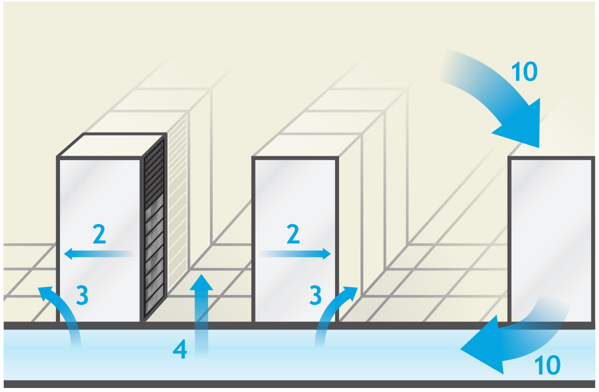

Figure 1: Typical Airflow Volumes

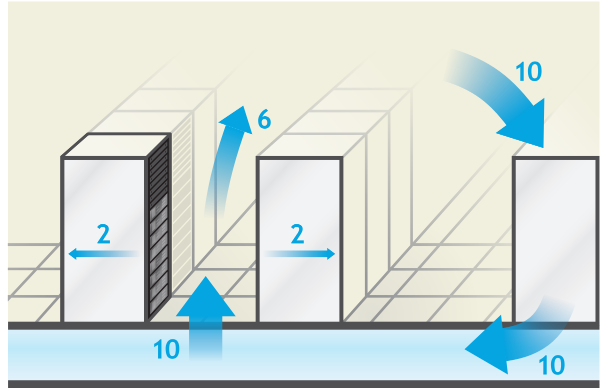

Figure 2: Airflow After Sealing Raised Floor

Figure 1 illustrates a typical computer room that has not completed raised floor open area management. The cooling unit is supplying 10 units of cooling airflow volume. Unsealed cable openings are releasing a total of 6 units of volume, and perforated tiles in cold aisles are releasing 4 volumes of conditioned airflow. The IT equipment consumes a total of 4 units of volume. In this case the volume of air supplied by perforated tiles equals the volume of air consumed by IT equipment. The only bypass airflow in the room is air escaping from the unsealed cable openings.

Figure 2 illustrates the situation after the raised floor open area has been completely managed. Now the 6 units of conditioned air volume that were escaping through unsealed cable openings is also coming out of the perforated tiles properly placed in the cold aisle. So now a total of 10 units of cooling capacity from the cooling unit reaches the cold aisle, but since only 4 units are needed by the IT equipment, 6 units of conditioned air volume leave the cold aisle as bypass airflow. This simplified example shows that changing the volume of conditioned air supplied by cooling units is the only way to change the volume of bypass airflow in a room.

It is also misunderstood that sealing cable openings and other obvious sources of bypass airflow increases return air temperatures to cooling units and cooling unit efficiency.

As shown in the figures above, sealing the openings in the raised floor that release bypass airflow increases the volume of conditioned air from perforated tiles and grates. This will likely eliminate hot spots and increase the IT load that can be cooled, however, the return air temperature to cooling units will not change. The return air temperature to cooling units, and therefore their efficiency and capacity, is a function of airflow volume, heat load, and the thermostatically controlled return air temperature set points of the units. Raising the cooling unit return air temperature set points is the only way to increase the efficiency and capacity of cooling units and realize the full benefits of AFM efforts.

Many sites have implemented AFM best practices and seen some or all of the following benefits:

- Improved IT intake air temperatures
- Improved IT equipment reliability
- Increased volumes of cooling airflow delivered by perforated tiles
- Ability to add more perforated tiles and cool more cabinets to the room without compromising raised floor static pressure

However, most of these sites have not changed cooling unit return air temperature set points, reduced fan speeds, or turned off excess cooling units. So they have not realized the potential additional benefits:

- Increased cooling unit efficiency
- Increased cooling unit capacity
- Reduced operating expense

Four Steps to Improve Bypass Airflow

By understanding the broader definition and sources of bypass airflow, data center managers can identify significant opportunities to increase cooling capacity and reduce operating costs. This comes down to four basic steps.

Note: To ensure that IT equipment is not damaged by excessive temperatures and that downtime does not result, it is extremely important that any changes to AFM and the cooling infrastructure only be made while carefully monitoring the IT equipment, as part of a comprehensive cooling optimization plan. The appropriate Cooling Capacity Factor (CCF) for each room is dependent on many factors, such as, but not limited to: cooling unit size, cooling unit number and placement, room configuration, heat load distribution, raised-floor height, and ceiling height.

First Step

Measure a computer room's existing CCF to get a context for opportunities to improve. If cooling units have fixed speed fans, or fans are running at full speed, then the CCF is a good indicator of the bypass airflow ratio in the room.

CCF can be calculated by dividing the total cooling capacity (kW) by 110% of the IT critical load (kW). Once your know your room's existing CCF, you can take steps to make improvements.

Supporting Tool: Upsite's Online Cooling Capacity Factor (CCF) Calculator

To help users get started, Upsite has created an online CCF Calculator (http://www.upsite.com/cooling-capacity-factor-calculator). Data center managers can enter some simple site data to have their site's estimated CCF calculated. While this is not intended to replace an onsite assessment, determining the CCF is the first step in understanding the utilization of existing cooling capacity and opportunities to improve the environment, reduce operating costs, and increase server density. CCF and potential cost savings are calculated. A summary of data and calculations is also emailed to users.

Second Step

Improve AFM by making the necessary changes at each of the following three levels in the proper sequence. A good mnemonic are these three R's, which should be carried out in this order: Raised floor, Rack, and then Row.

1. Manage the open area of the horizontal plane of the raised floor. Seal cable openings and manage perforated tile placement. Check the perimeter walls below the raised floor for unsealed wall or partition penetrations. Sealing these penetrations often requires fire-rated materials.
2. Close all open space of the vertical plane of IT equipment intakes. Install blanking panels, seal under cabinets, and seal between mounting rails and sides of cabinets.
3. Fill open spaces where IT equipment cabinets are missing or where there are gaps between cabinets. In some situations when cabinet densities are high enough or the highest possible efficiency is desired, hot or cold aisle containment is an option.

Third Step

Next, change the cooling infrastructure.

- Raise cooling unit return air temperature set points. Raise set points as high as possible without exceeding the IT equipment intake air temperature maximum.
- Turn off cooling units or reduce fan speeds for units with variable frequency drives (VFD) or install VFDs.

Fourth Step

Lastly, repeat the process above to ensure your cooling infrastructure is optimized.

After each adjustment to cooling unit set points or airflow volumes, it may be necessary to adjust the number and location of perforated tiles or grates to maintain IT intake temperatures as low and even as possible.

The goal is to raise cooling unit temperature set points as high as possible and have as few cooling units running as possible or reduce fan speeds as much as possible without IT intake air temperatures exceeding maximum limits. Keep in mind that it is important to have redundant cooling units operating so that when a cooling unit fails there is sufficient running capacity to support the load. The number of redundant cooling units required is dependent on many factors such as: the height of the raised floor, blockages under the floor, layout of cabinets, quality of AFM, variation in room load, size of the room, etc.

Also, after implementing each AFM improvement, it will likely be possible to raise cooling unit temperature set points and or reduce fan speeds further. For example, after a thorough review and adjustment of perforated tile number and placement, it may be possible to raise temperature set points a couple of degrees. Then, after installing grommets and blanking panels and filling spaces in equipment rows, it may be possible to raise set points a few more degrees.

Conclusions

Based on the amount of excess capacity in data centers today, operators and managers are often challenged to quantify bypass airflow and capacity issues at their sites. Indeed, the commonality of bypass airflow problems is prevalent throughout the industry.

Solutions ranging from sealing grommets and blanking panels to aisle containment are necessary enhancements, but to realize greater financial benefits from improving cooling capacity, changes need to be made in the cooling infrastructure: change set points, reduce fan speeds, or turn off cooling units.

If bypass airflow is seen not just as "leaks" or "holes" in the data center raised floor, a great opportunity exists to quantify, understand, and improve cooling infrastructure and reduce operating expenses. We should think of bypass airflow as any cooling airflow volume greater than IT equipment airflow volume. This is true regardless of the configuration of the room, including full aisle containment. Considering bypass airflow from this broader room level introduces a perspective that brings more financial benefits and savings opportunities easily within grasp.

Glossary of Terms

Raised floor bypass open area (RFBOA)

The total area of all openings that release conditioned air into hot aisles or open spaces (unsealed cable openings + misplaced perforated tile and grate open area).

Total open area of raised floor

The sum of all openings in the raised floor (open area of all perforated tiles and grates + all unsealed cable openings).

Percent raised floor bypass area

The RFBOA divided by the total open area of the raised floor.

Bypass airflow

Any conditioned air supplied by a cooling unit that does not pass through IT equipment before returning to a cooling unit.

Cooling Capacity Factor (CCF)

Total nameplate rated cooling capacity of all running cooling units (kW) divided by 110% of the IT critical load (kW).

Airflow management (AFM)

Encompasses all process, procedures, monitoring and controls, and physical infrastructure devices involved in controlling the conditioned supply and exhaust return air flow.

PN 84003 Rev A