

# High-Performance Data Centers Call for Innovative Cooling Techniques

*The conventional solution can be risky*

BY BRIAN DONOWHO

**M**ore than 80 percent of today's data center managers identify thermal management as their greatest challenge. This is no surprise considering the average heat load generated per cabinet by new equipment has doubled since 2000. The excess heat generated by equipment can concentrate within the cabinet and cause equipment to critically overheat and shutdown, costing companies time and money.

Contemporary thinking in data center thermal management promotes a hot aisle/cold aisle approach to segregate cold air in front of rows of equipment cabinets and hot exhaust air behind these rows of cabinets. This approach works well in low- to medium-density data center applications. Unfortunately, the hot aisle/cold aisle approach does not perform well in many medium-density applications and cannot begin to support high-density applications.



**Brian Donowho** is senior product manager for Chatsworth Products, Inc. (CPI). He has been with CPI for nine years, spending time in production management as well as product management.

Chatsworth Products, Inc. (CPI) offers a ducted exhaust cabinet that manages the exhaust airflow to overcome the capacity constraints of the hot aisle/cold aisle layout. Ducted exhaust cabinets control heat by allowing the equipment to draw the required volume of air through the cabinet, then directing the exhaust out of and away from the cabinet, completely eliminating the problem of hot air re-circulation and hot spots, delivering higher energy efficiency.

## **Thermal Management**

The primary goal of thermal management in the data center is to maximize the performance, uptime, and life expectancy of the active equipment. The goal is accomplished by delivering cold air to every piece of equipment so that the internal temperature of all equipment in the data center never exceeds the manufacturer's maximum allowable operating temperature. The cold air delivered to the equipment must be at or below the manufacturer's recommended temperature and in sufficient volume to meet the equipments' airflow requirements.

Delivering cooling with the lowest possible energy consumption is an important secondary goal. Eliminating wasteful air re-circulation and optimizing the return

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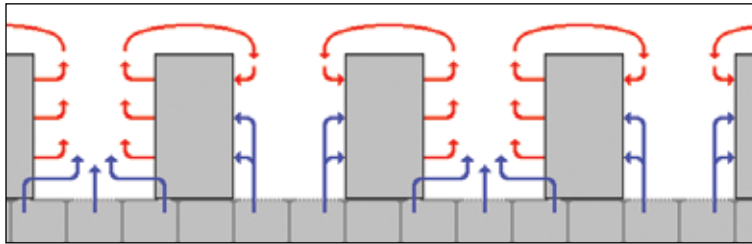


Figure 1. Hot aisle/cold aisle configuration, but the hot air recirculates

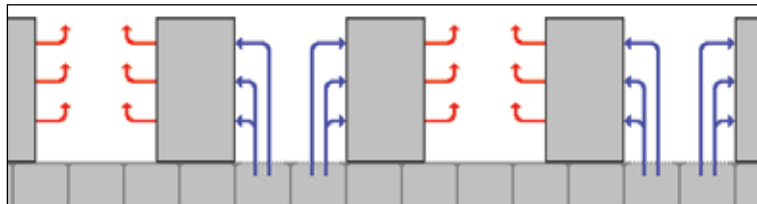


Figure 2. Proper airflow in a hot aisle/cold aisle layout.

air temperature to the computer room cooling units so that they perform at a higher efficiency than in a typical hot aisle/cold aisle data center are two methods to reduce energy use.

### Preventing Recirculation

Recirculation is defined as the condition when hot exhaust air travels back into the equipment intake air stream. This out-of-control exhaust airflow raises intake air temperatures and will cause equipment to run at higher operating temperatures.

Bypass airflow is another out-of-control condition that occurs when cold source air bypasses the active equipment and travels directly into the hot exhaust air stream. This situation wastes energy, contributes to humidity control problems, and can indirectly contribute to re-circulation.

Re-circulation and bypass airflow are often present because hot aisle/cold aisle data center environments typically do not operate under ideal conditions. When insufficient volumes of cold air are delivered in the cold aisle, air is pulled over the

tops of the cabinets from the hot aisle. This means that servers near the top of some cabinets may be ingesting air that is 20 or 30 degrees Fahrenheit warmer than the air being delivered through the access floor.

Figure 1 shows bypass airflow in the hot aisle reducing the amount of cold air that can be delivered in the cold aisle. Cable penetrations and perforated tile in the hot aisle reduce the static pressure under the access floor. This leads to less airflow through the perforated tile in the cold aisle. If the servers in the cabinet draw more air than is delivered through the access floor in front of the cabinet, then air will flow from the nearest source. This is usually hot air re-circulating over the top of the cabinets.

Under ideal circumstances, all recirculation and bypass airflow can be eliminated (see figure 2). Removing perforated tiles from the hot aisle and installing KoldLok raised-floor grommets in the cable cutouts in the rear of the cabinet eliminates undesired bypass airflow. A data center with ideal airflow will deliver cold air at the same temperature to every piece of equipment. Without recirculation, all the air in the cold aisle will be the same temperature.

Managed exhaust airflow allows the entire data center to be cold — no more hot zones.

Unfortunately, strict discipline and careful airflow balancing are required to maintain this ideal operating condition in higher density data center environments. While an initial installation may realize these ideal conditions, moves, adds and changes, along with the demands for constantly monitoring and rebalancing, frequently make maintaining this ideal operating condition impractical, if not outright impossible. This is why inlet air temperatures are never uniform across the front of a cabinet, let alone uniform throughout a data center (see figure 3).

### Hot Aisle/Cold Aisle Layout

Hot aisle/cold aisle is good data center architecture. Segregating the cold air in front of equipment cabinets and hot exhaust air behind them is well principled. But maintaining the segregation is difficult. In order to maintain proper segregation, the volume of air delivered to each cabinet must roughly equal the volume required by all of the active equipment (servers) in each cabinet.

With a 48-inch (in.) wide cold aisle (two 24-in. tiles wide), each cabinet only has one floor tile positioned in front of it. The other floor tile serves the cabinet in the



Figure 6 (hot) and 7 (cold). The basic cabinet can dissipate even more heat under appropriate circumstances.

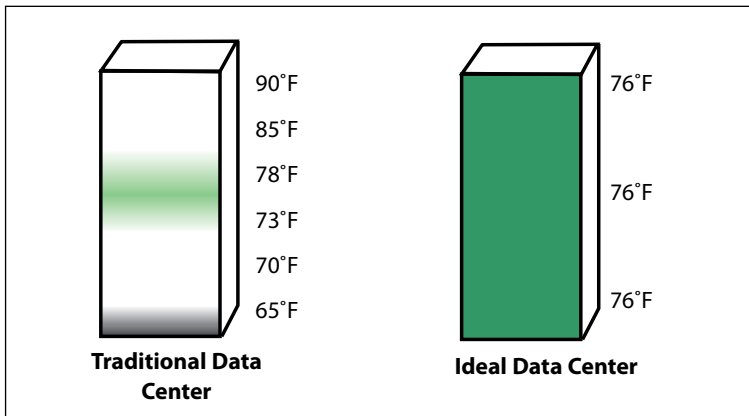


Figure 3. Inlet air temperatures are not uniform across the front of the serves, as is the ideal.

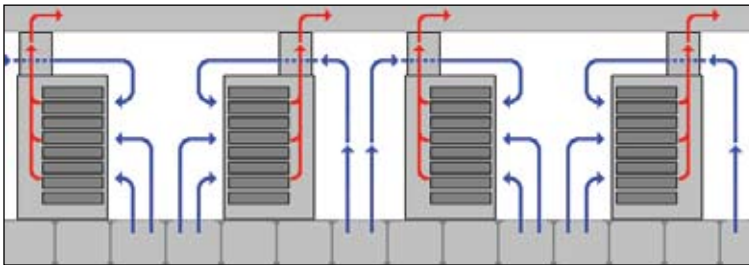


Figure 4. Managed exhaust airflow completely segregates the hot exhaust air by directing it up an exhaust duct at the top rear of the cabinet.

opposite row. Under optimum conditions, each tile will deliver 600-700 cubic feet per minute (CFM). That volume of cool air will only dissipate 4-8 kilowatts of heat. The actual heat dissipated depends on how the manufacturer has designed heat to transfer into the air moving through the equipment.

Server manufacturers design their products to consume an appropriate volume of air for the heat that they generate. However, not all manufacturers design around the same temperature rise across their components. A typical rule of thumb is that the temperature will rise 27 deg F (15 deg C) between the intake and exhaust of a server. But actual measurement of an IBM eServer BladeCenter under full load indicated a 42 deg F temperature rise ( $\Delta T$ ). The greater the normal temperature rise designed into the equipment, the greater the amount of heat transferred into a given volume of air.

### Going Beyond

Hot aisle/cold aisle starts with the correct premise--to segregate the cold source air from the hot exhaust air in the data center. The hot aisle/cold aisle philosophy of segregating airflows leads to managing exhaust airflow when the concept is applied at the next level. Managed exhaust airflow completely segregates the hot exhaust air by directing it up an exhaust duct at the top rear of the cabinet (see figure 4).

Typically, the exhaust duct is connected to a drop ceiling return air plenum. But this is not necessary where high ceilings can offer sufficient clearance for the return air to stratify above the cold air in the room.

Several benefits come from this architecture. One such benefit is that up to 100 percent of the exposed floor can be perforated. Perforated access tiles can be located anywhere in the room. Managed exhaust airflow allows the entire data center to be cold — no more hot zones. Cold intake air can be pulled from anywhere in the room. A cabinet no longer has to obtain all of the air required from the access floor tile directly in front or adjacent to it. CFM balancing issues practically disappear.

Managed exhaust airflow also creates the opportunity to deploy high-density applications in a non-access floor environment. Cold air can be delivered directly into the room. It does not require an access floor.

### Achieving High Performance

CPI has developed and tested a ducted exhaust cabinet that utilizes managed exhaust airflow. This design avoids any dependency on booster fans, with the accompanying concerns over additional heat loads, fan failure and redundancy, thereby qualifying the ducted exhaust cabinet for Tier three and Tier four criticality applications.

The basic cabinet configuration is similar to other CPI server cabinets (see figure 5). The most obvious feature is the large, low-restriction exhaust air duct at the top rear of the cabinet. The front door is high-flow perforated metal. The rear door is solid.



Figure 5. The basic cabinet configuration.

The design assumptions were confirmed in third-party testing at extreme heat load densities. This testing demonstrated that the ducted exhaust cabinet can easily support 22 kW of heat load in the proper data center environment. It also indicated that the cabinet could dissipate even more heat under appropriate circumstances (figures 6 and 7).

Subsequent data center installations around the world have confirmed the theory and early test results. Multiple high performance data centers are successfully using the ducted exhaust cabinet to support average heat loads of 17-25 kW. Many of these users have demonstrated their confidence in the ducted exhaust cabinet by designing future installations with planned heat loads up to 30 kW per cabinet. ■