Reducing Data Center Cooling Costs through Airflow Containment

Implementing a containment solution in the data center costs much less than the alternatives of adding air handlers or other supplemental cooling equipment.

Data center managers often configure cabinets in open hot/cold aisles and oversupply the room with cool air to keep equipment at operating temperature ranges. But that hurts efficiency and greatly inflates the energy bill.

By DAVID KNAPP
Chatsworth Products
Agoura Hills, CA

Data centers are one of the most energy-hungry facilities out there, and as computing processors become more advanced, the average heat load per cabinet is rising. A traditional approach many data center managers take is to configure cabinets in open hot/cold aisles and oversupply the room with cool air to keep equipment at operating temperature ranges. This, however, minimizes ef-

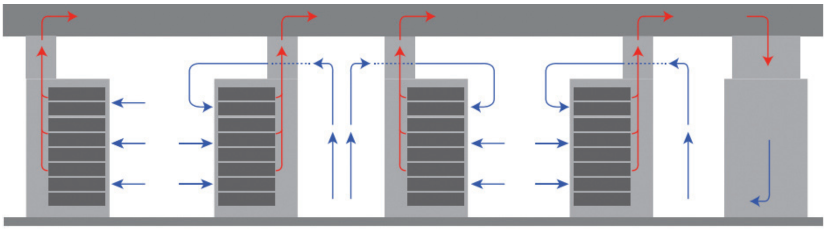

Figure 1. Sectional view of several ducted exhaust cabinets with Vertical Exhaust Ducts showing airflow through the cabinets and through the room. Note: Hot exhaust air is isolated and removed from the room through the Vertical Exhaust Ducts.

An 18-year veteran with Chatsworth, the author is a product marketing manager focused on data center, enterprise networking, and power management solutions.

ficiency and adds thousands of dollars in the energy bill.

Using a containment system with perimeter cooling is still an excellent solution for today's average rack densities and the anticipated densities over the next decade. Furthermore, containment systems support retrofit from hot aisle/cold aisle, economizer applications and free air cooling.

"Free cooling" refers to the number of hours that the economizer can be used instead of the chiller. "Free cooling" is not free, but economizers generally cost less to operate than chillers. The economizer rejects heat outdoors when the outdoor temperature is lower than the temperature of the chilled water loop. So, when the chilled water loop temperature increases, there are typically more hours that the economizer can be

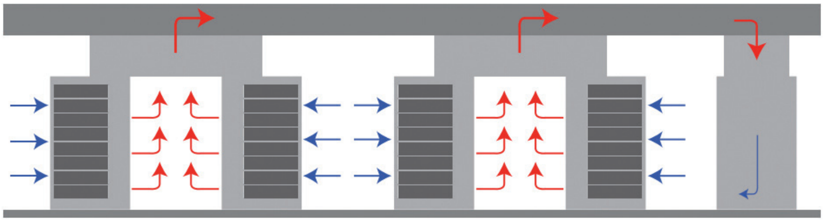

Figure 2. Sectional view of a HAC solution with ducts constructed over the hot aisles, showing airflow through the contained aisles and the room. Note: Hot exhaust air is isolated and removed from the room through the ducts over the contained hot aisles.

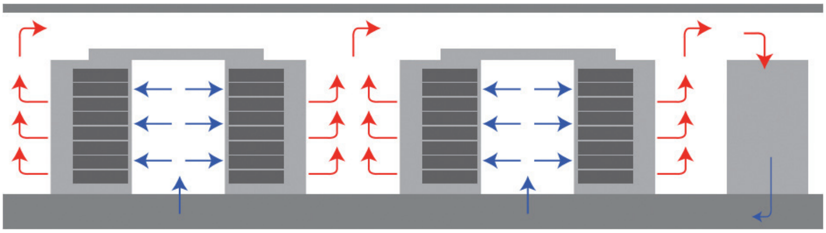

Figure 3. Sectional view of a CAC solution with ceilings constructed over the cold aisles showing airflow into the contained aisles and through the cabinets and back to the cooling units through the room. Note: Hot exhaust air is isolated within the room by the ceilings over the contained cold aisle.

		Net Sensible Cooling in MBH for Various Return Air Temperatures *for down flow unit, includes motor heat @ rated CFM and ESP, At 50°F EWT, 0% Glycol Solution, 14°F ΔTw*		
Capacity kW	**Stulz Model Number**	**75°FDB/62.5°FWB 50%RH, 55°FDP**	**80°FDB/64.2°FWB 42%RH, 55°FDP**	**85°FDB/65.9°FWB 36%RH, 55°FDP**
60	CFD-060-C1	124	185	242
90	CFD-090-C1	141	208	270
120	CFD-120-C1	167	254	332
150	CFD-150-C1	171	251	327
180	CFD-180-C1	223	324	416

Table 1. Summary of 2015 Thermal Guidelines from ASHRAE Datacom Series 1, Thermal Guidelines for Data Processing Environments, Fourth Edition, (RP-1499). Refer to the guideline for the complete environmental recommendation. Note: Maximum elevation is 10,000 feet (3,050 meters) above sea level, and maximum rate of change is 9°F over 36 hours (5°C over 20 hours)

operated instead of the chiller. As an added bonus, higher chilled water temperature also typically improves chiller efficiency.

Three Methods of Containment

There are three basic methods of complete containment, and regardless of which method you choose,you will improve the efficiency of a chilled water perimeter cooling system.

- **Ducted exhaust cabinets** are enclosed server rack cabinets with an attached Vertical Exhaust Duct. As pictured in Figure 1, the hot exhaust air given off by the servers is enclosed within the cabinet, completely isolating the air from the room. The hot air exits the cabinet through the overhead vertical exhaust duct, which directs the hot air into a plenum above the drop ceiling and back to the cooling units (shown) or to outside vents.
- **Hot aisle containment** (HAC) is the most popular type of containment solution used today. In this method, a configuration of duct work and baffles are set up over the hot aisle, with doors blocking the aisle entrances at either end. As shown in Figure 2, the HAC solution contains and isolates the hot exhaust air from the room, preventing it from reaching the adjacent cold aisles and mixing with the cold air. The hot exhaust air in the hot aisles is then returned to the cooling units, usually through drop ceiling plenums.
- **Cold aisle containment** (CAC) configurations are typically used to retrofit data center environments where a raised floor cooling system already exists. As seen in Figure 3, a roof and/or partitions are set up over the cold aisle, with doors at either end. This isolates the cold intake air within the cold aisle, keeping it separate from the hot air in the neighboring hot aisles. The hot exhaust air rises up freely in the hot aisles, and returns through the room to the air handlers.

Prevent Recirculation, Bypass Airflow

Effective airflow management and cooling cost reduction also requires the elimination of bypass airflow within or through the cabinet, utilizing the following best practices, as shown in Figure 4:

- Use proper racking techniques to block airflow around rack-mount equipment;

Equipment Environmental Specifications For Air Cooling, Operating Conditions, 2015				
Class	Low °F (°C)	High °F (°C)	Humidity Range	Max Dew Point °F (°C)
Recommended (A1-A4)	64.4 (18)	80.6 (27)	15.8°F (-9°C) DP to 59°F (15°C) DP and 60% RH	
Allowable A1	59 (15)	89.6 (32)	15.8°F (-9°C) DP and 8% RH to 80.6°F (27°C) DP and 80% RH	62.6 (17)
Allowable A2	50 (10)	95 (35)	10.4°F (-12°C) DP and 8% RH to 80.6°F (27°C) DP and 80% RH	69.8 (21)
Allowable A3	41 (5)	104 (40)	10.4°F (-12°C) DP and 8% RH to 80.6°F (27°C) DP and 85% RH	75.2 (24)
Allowable A4	41 (5)	113 (45)	10.4°F (-12°C) DP and 8% RH to 80.6°F (27°C) DP and 90% RH	75.2 (24)

Table 2. Table comparing the cooling capacity of chilled water cooling units as the return air temperature increases (left-to-right). Note: Values are in MBH (thousand BTU/hr), so 124 MBH is 124,000 BTU/hr. For conversion: 12 MBH (or 12,000 BTU/hr) = 3.5 kW (or 3,516 W) = 1 ton (refrigeration). Source: STULZ CyberAir CW Engineering Manual.

- Use blanking panels to seal all unused rack-mount spaces to block airflow between rack-mount equipment;
- Use air dams and seals around rack-mount equipment to prevent recirculation of hot air around the sides of the equipment;
- Use seals around cable openings in the cabinet body and raised floors;
- Use seals between cabinets to block airflow between cabinets into the contained space;
- Use panels to block airflow under the cabinet into the contained space.

An Effective Seal is Critical

When selecting a containment solution, you should take seal into account. Containment vendors typically describe system seal performance in terms of leakage, typically a percentage based on a particular volume of airflow to each cabinet under a specific operating pressure. When comparing these values, be aware that conditions may not match. The volume of airflow should be the maximum sustainable volume across the entire room at the planned static pressure during operation. For example, an optimal containment system performance is 3000 CFM (5097 CMH) of exhaust airflow per cabinet at .05 inches of water (.01 kPa) with less than 5-percent leakage.

Managing Pressure

Establishing a "good seal" in your containment system is not just a matter of having containment barriers without leaks. It also requires total pressure management of the contained environment, particularly with CAC. A complete containment architecture should include an effective pressure differential management system. This may include updating or introduction of HVAC controls.

Reducing Temperature Variations

The first noticeable effect when implementing a complete containment system is the change in room temperature. Containing hot exhaust air reduces or eliminates hot spots by blocking the recirculation and preventing the mixing of supply and exhaust air. As a result, the temperature variation across the front of racks is reduced, as shown in Figure 5.

Reduce Volume of Supply Air

Complete containment also typically allows the volume of air delivered to equipment to be reduced. Traditional hot aisle/cold aisle systems are often oversupplied in an attempt to overcome bypass airflow over and around cabinets. The volume of airflow can typically be reduced once containment is in place.

In existing sites with air handlers that do not have variable speed fans, this means turning some units off, resulting in some savings from reduced energy consumption. In sites with units that have variable speed fans, the fan speeds can be reduced to take advantage of fan affinity laws. Fans use less overall energy when running at reduced speed (partial capacity) because they are moving less air.

Essentially, all units are run at low partial capacity instead of several units at full capacity. This configuration still provides capacity for N+1 redundancy or better, if needed, while maintaining reduced energy costs.

Increase Supply Air Temps

Because containment results in less temperature variation in supply air, operators can reliably increase room temperatures closer to required inlet temperatures on equipment. The *ASHRAE Datacom Series 1, Thermal Guidelines for Data Processing Environments, Fourth Edition (RP-1499)* defines recommended and allowable equipment environment specifications for air cooling in data center computer rooms, see Table 1.

When complete isolation between hot and cold aisles is achieved, recirculation of hot return air is eliminated. Much lower temperature air is no longer necessary to overcome air mixing, and it is possible to safely raise the temperature of the supply air up to the recommended 64.4°F to 80.6°F (18°C to 27°C) range. The advantage of increasing the temperature of supply air is improved cooling unit efficiency as a result of the corresponding higher return air temperatures and access to more "free cooling" hours when using economizers.

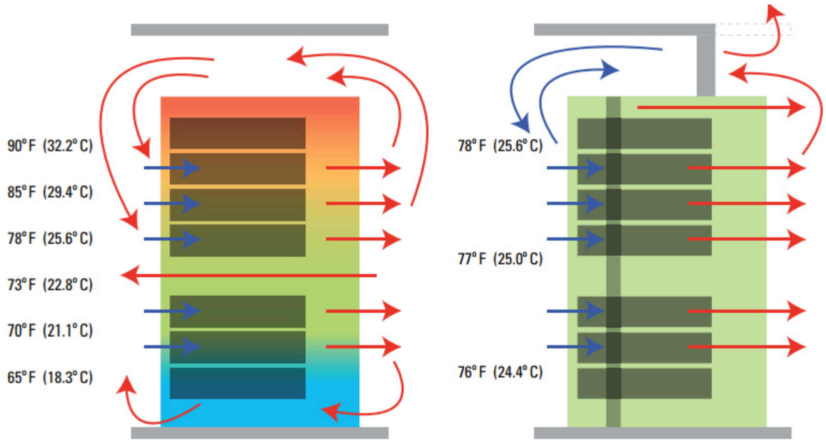

Figure 4. Sectional view of cabinets showing bypass airflow around equipment (left) and showing good airflow management guiding air through equipment and blocking recirculation (right). It is critical to utilize baffles and blanking panels within cabinets to seal openings that would allow air to bypass equipment. All air that passes through the cabinet should pass through equipment, and transfer heat away from equipment and out of the cabinet.

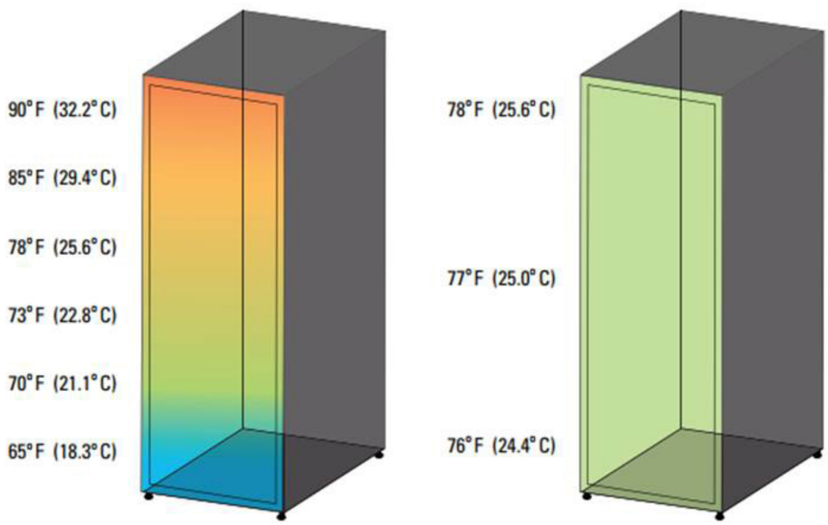

Figure 5. Containing hot exhaust air reduces or eliminates hot spots by blocking the recirculation and preventing the mixing of supply and exhaust air. As a result, the temperature variation across the front of racks is reduced.

Increase Chilled Water Temps

In chilled water systems, fluid is used to transfer heat between air handlers and chillers and/or economizers. Depending on required conditions and system design, it may also be beneficial to raise the temperature of the chilled water (fluid).

The advantage of increasing the temperature of chilled water is im-

As long as there is complete isolation between hot and cold air, and the necessary power, cooling and airflow, it is possible to run high-density server loads at higher temperatures.

proved chiller efficiency when using mechanical cooling and access to more "free cooling" hours when using economizers.

Improved Cooling Efficiency

With chilled water cooling units, increasing return air temperature generally results in increased sensible cooling. See Table 2.

In existing facilities, this relationship typically allows higher densities in the data center once containment allows reliable airflow separation and temperature control. In new construction, this relationship can be used to optimize the sizing of units for anticipated heat loads, reducing first cost and project capital expenditure.

Positive Bottom Line

For existing data center installs, effective airflow management with a containment system offers two overall benefits:

1. It lowers operational expenses (OpEx) by reducing the power consumption necessary to provide cooling to the data center environment.

2. It allows data center operators to increase server capacity in the data center. As long as there is complete isolation between hot and cold air, and the necessary power, cooling and airflow, it is possible to run high-density server loads at higher temperatures, while providing the servers with adequate cooling to prevent overheating and shutdowns.

As a final note, it is important to know the exact results of containment will vary for each site. Overall performance, the initial cost of the system (CapEx), the estimated operating cost (OpEx), resulting savings and return on investment will also vary. *To learn more about the economics of airflow containment, view this CPI white paper: http://pages.chatsworth.com/Economics-Of-Containment-White-Paper.html.* HPAC