White Paper

June 2012 • WP-20

Impact of Air Containment Systems

Reducing Energy Consumption in the Data Center

PANDUIT®

building a smarter, unified business foundation

Connect. Manage. Automate.

www.panduit.com

Introduction: The Importance of Maintaining Data Center Cooling Energy Efficiency

Data centers are mission-critical facilities and the nerve center of successful business operations. Surging demand for processing power, work load virtualization and consolidation combined with pressure to reduce operating expenses (OpEx) and improve asset utilization are making the thermal management of data centers challenging. Thermal issues that were once ignored now must be addressed to reduce cost and increase capacity:

- Mixing of hot and cold air – results in a loss of cooling effectiveness
- Leakage – unintended hot / cold airflow paths
- Hot air recirculation – exhaust is pulled back into equipment inlets
- Airflow obstructions – increased resistance to IT equipment fan airflow

Data center operators typically respond to these thermal issues in one or more of the following ways:

- Lower the supply air temperature set point on the cooling equipment
- Oversupply cool air by increasing the cooling equipment fan speed, increasing the amount of bypass air
- Run more cooling equipment than necessary, underutilizing available cooling capacity
- Oversize the cooling system to address isolated high-density regions

These approaches to solving thermal issues lead to inefficiency and under-utilization of available cooling resources in the data center. Proper data center efficiency goes beyond achieving energy savings − it depends on careful planning and cost-effective choices. Data center efficiency involves getting the most out of the power distribution system, computing hardware, network and storage systems while minimizing the power, cooling, and space requirements for the infrastructure. A holistic assessment of equipment choices and effective design choices in the data center facility is critical for optimum efficiency

This white paper focuses on increasing the cooling efficiency of data centers using air containment systems, and identifies how Panduit's Net-Contain™ Cold Aisle Containment system and Net-Access™ Cabinets address thermal management issues for improved data center operational efficiency.

Types of Air Containment Systems

Isolating cooling air from exhaust air in the data center is an important energy savings strategy towards achieving data center optimization and reliability. Most modern energy-efficient data centers deploy some kind of containment system. In simple terms, a containment system provides a physical separation between the cold supply air and the hot return air, optimizing airflow distribution in the data center room by preventing mixing of cold and hot air streams. The separation of cold and hot air provides the opportunity to closely match supply cooling airflow to IT equipment airflow, thereby promoting a more uniform cabinet inlet temperature profile. It also allows the cold air supply temperature to increase (within the design range) which results in a higher return temperature to the cooling units, making them more efficient.

There are primarily two types of air containment systems: cold air containment and hot air containment. Both types of containment system offers advantages over the standard Hot Aisle/ Cold Aisle (HA/CA) configuration. Containment systems work in both raised floor and slab cooling environments. The achievement of physical separation can vary depending on the architectural constraints and the desired level of containment.

Although there are both passive and active types of containment systems, this white paper centers on passive containment systems and the importance of deploying proper cooling energy efficiency in the data center, focusing on the comparison of common cold air containment and hot air containment techniques: Cold Aisle Containment (CAC), Hot Aisle Containment (HAC), and Vertical Exhaust Duct (VED) or Chimney. Both HAC and VED are types of hot air containment systems and offer similar advantages. The VED system in particular, provides a large mass of cold air in case of a cooling system airflow failure and offers increased hours of economizer utilization due to high return air temperatures.

Cold Aisle Containment (CAC)

Cold aisle containment (CAC) provides a physical separation between the cold air and the hot exhaust air by enclosing the cold aisle. A CAC system such as the Panduit® Net-Contain™ Cold Aisle Containment System (see Figure 1) facilitates the supply of cool air to equipment air intakes at a uniform temperature. It offers a focused cooling approach where the equipment intake air temperatures are close to the supply air temperature. However, it also generates a high room ambient temperature and anyone working in or entering the data center is exposed to high temperatures.

Hot Aisle Containment (HAC)

Hot aisle containment (HAC) provides a physical separation between the cold air and the hot exhaust air by enclosing the hot aisle. The goal of a HAC system is to capture all of the cabinet exhaust air and return it to the cooling units. The rest of the room outside of the HAC becomes a cold room with ambient air temperature close to the supply air temperature.

Figure 1. Example of Panduit's Net-Contain™ Cold Aisle Containment System.

Vertical Exhaust Duct (VED) Chimney Cabinets

The primary goal of a Vertical Exhaust Duct (VED) system is to contain cabinet exhaust air and prevent mixing of cold and hot air streams in the data center room (see Figure 2). The VED system captures and channels the cabinet exhaust air to a drop ceiling plenum. This approach requires addition of a solid rear door and the exhaust duct for each cabinet that connects to a drop ceiling plenum or opens up high above the cabinet. This technique allows the room ambient temperature to be maintained close to the supply air temperature.

Similar to a HAC system, a VED system also results in a room ambient air temperature close to the supply air temperature. However, the VED offers a cooler environment for anyone working in the hot aisle when compared to the HAC system. Please refer to Panduit White Paper WP-09: *Deploying a Vertical Exhaust System to Achieve Energy Efficiency* for further information about achieving energy efficiency via a VED system.

The Importance of Sealing Cabinets

Containment systems require proper cabinet sealing and a proper cable management solution. Any leakage within the cabinet and poor cable management may adversely affect the performance of the containment solutions. Panduit® Net-Access™ Cabinets contribute to improved network reliability by providing space and integral cable management features that allow data and power cables to be routed away from equipment air flow, eliminating obstructions that inhibit efficient cooling. The frame design of the cabinet enables both open rack accessibility to cabling and equipment, as well as large pathways to enable future growth for the data center.

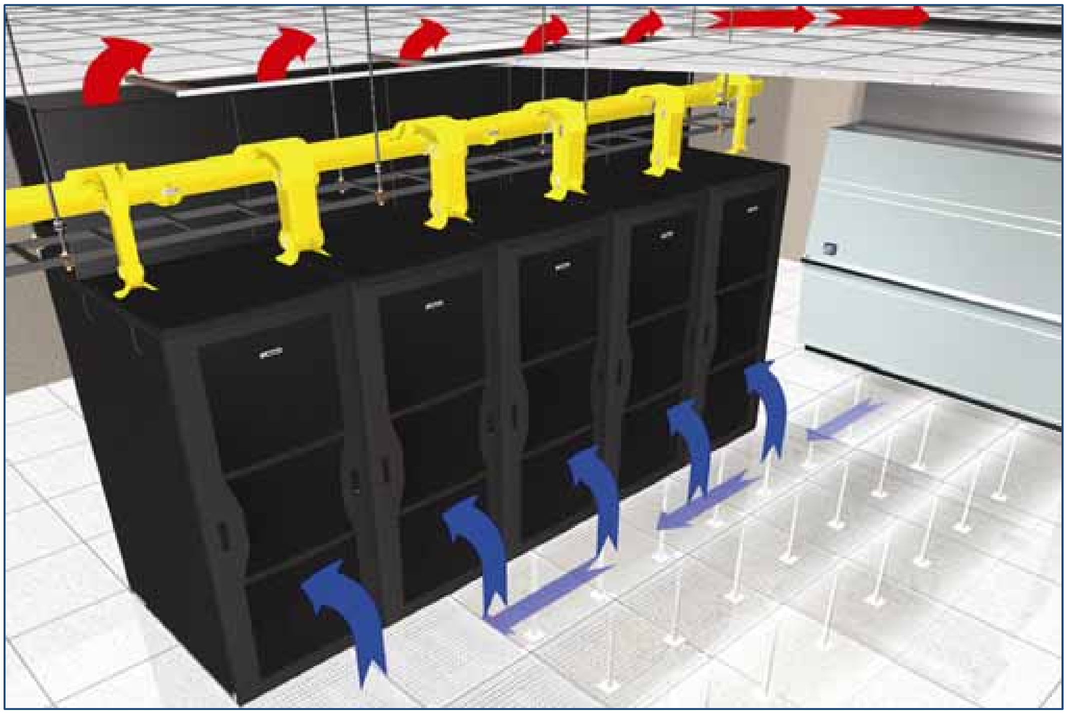

Figure 2. This figure illustrates how the cold and hot air are separated when using a VED system, allowing higher room set point and less bypass air. The cold air enters the perforated cabinet doors and is heated by the equipment while the hot air exhausts through the VED. The majority of the VED installations are connected to the return plenum through which the hot air enters the Computer Room Air Handler (CRAH) unit.

Data Center Case Study

The following sections of this paper present an illustrative case study to investigate the benefits offered by data center air containment solutions. This section of the paper investigates the energy savings associated with using a cold aisle containment system or a VED system vs. a standard hot aisle / cold aisle configuration with no containment. (Note that this study assumes a VED system and an HAC system to be thermally equivalent, and therefore does not include any data specific to an HAC system.)

For the case study, industry best practices were consulted (e.g. cabinets in hot aisle/cold aisle arrangement, blanking panels installed on unused rack unit spaces, etc.) to develop a reliable, scalable, high-performance and secure data center reference design which then was used for Computational Fluid Dynamics (CFD) modeling. A plan view (see Figure 3) of the CFD model shows the room layout and the location of the critical elements of the data center from a heat load and cooling capacity perspective. These elements include: the exterior walls, sub-floor, ceiling, the raised floor, perforated floor tiles, the CRAH (Computer Room Air Handler) units, and the cabinets with the data communication equipment. The cabinets and the perforated floor tiles are arranged in hot aisles and cold aisles.

This arrangement is advantageous since active data communication equipment fans typically pull air in the front of the unit and exhaust the heated air out the rear of the unit. The CRAH units (labeled D) are located on the “north” and “south” sides along the perimeter of the room and aligned with the hot aisles of the cabinet rows. These units draw the cabinets’ hot exhaust air from the room and supply cool conditioned air to the raised-floor plenum space. The cool air reaches the cabinet inlets through 25% open perforated tiles located in front of the cabinets.

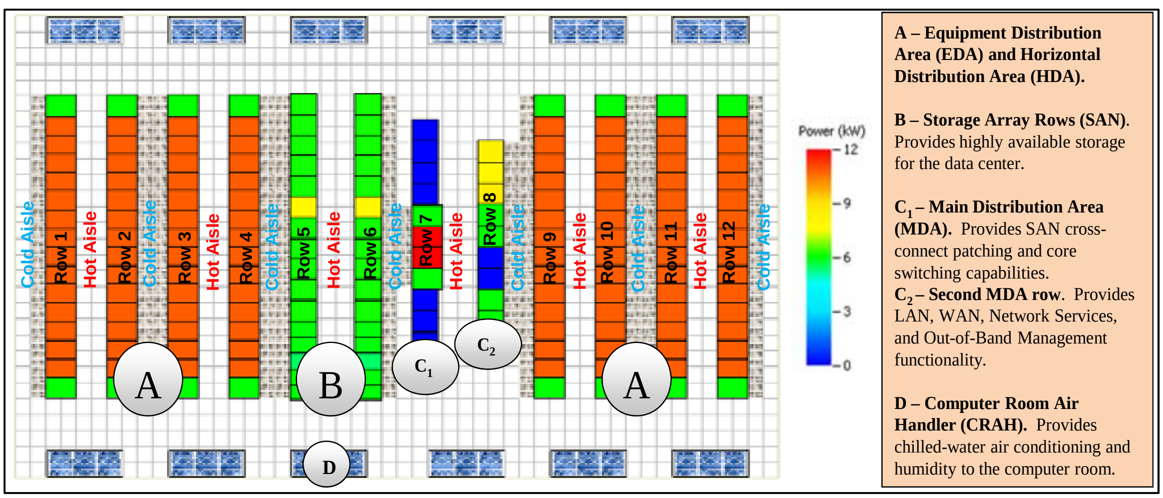

Figure 3. Data center layout. Cabinets are color coded based on the heat load.

Data Center Layout

In Figure 3, cabinet rows 1-4 and 9-12 consist of 14 server cabinets with a switch cabinet containing a single large access layer network switch on the ends of each of these rows. Each switch is sized to provide a sufficient number of ports to maintain A and B connectivity pathways. The server cabinets are 28″ wide and the switch cabinets are 32″ wide. The wider switch cabinet accommodates the large bundles of network cables necessary for the switch connections to the network.

The middle cabinet rows (5-8) contain the Main Distribution Area (MDA), switching, patching, the Storage Area Network (SAN) array, and network appliances. The total data communication equipment heat load and airflow for the room is estimated to be 1,592 kilowatts (kW) and 207,431 cfm, respectively. The twelve 40-ton CRAH units have sufficient cooling airflow and cooling capacity for the heat load of the room. The other room details are as follows:

- Area – 58 ft × 100 ft (17.7 m × 30.5 m) totaling 5,800 square feet (539.8 square meters)
- Raised floor height – 24 in (610 mm)
- Floor tiles mounted on pedestals – 24 in × 24 in (610 mm × 610 mm)
- Height of the room from the floor tiles to the ceiling – 12 ft (3.4 m)
- Total number of cabinets – 182
- Average heat load per cabinet – 8.7 kW
- Average airflow per cabinet – 1140 cfm
- Total number of CRAH units – 12
- Nominal Cooling Capacity per CRAH unit – 139 kW
- Nominal Airflow per CRAH unit – 24,000 cfm
- Number of 25% open perforated floor tiles – 208

Establishing Set Point Conditions

The following determines the cooling needs of the equipment and establishes associated set point conditions for the CRAH units using CFD analysis. The CFD models were created using the following assumptions:

- 3D Navier-Stokes steady state equations are solved using a commercially available CFD code.
- The κ-ε turbulence model is used to solve the turbulent fluid flow region.
- The data center is assumed to be located inside a building. No solar gains or heat gains from the other areas of the building are considered. The walls of the room are modeled as adiabatic.
- The CRAH units are modeled with a fixed airflow value based on the nominal airflow indicated on the manufacturer’s specification sheet.
- Secondary heat loads, such as lighting, IT personnel, etc. are ignored in the analysis.
- Over 19 million grid cells are generated to create the computational domain. The number of grid cells is determined using grid sensitivity analysis.
- All CRAH units are assumed to be running at the same speed and supplying cool air at the same temperature.
- Power Distribution Unit (PDU) and Uninterruptible Power Supply (UPS) systems are assumed to be located outside the data center room and are not included in the CFD model.

CFD Analyses

Baseline Scenario

CFD simulations were carried out on the example data center layout to establish baseline optimum set point conditions for the CRAH units (CRAH supply air temperature and CRAH airflow rate). Note that the baseline scenario is without any type of containment system (i.e., hot aisle/cold aisle only, see Figure 4). The optimum set points are defined as the maximum CRAH supply air temperature and the minimum CRAH airflow rate for which all cabinets' inlet air temperatures are within ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) recommended temperature limit (80.6°F).

The supply air temperature setting of 59°F and airflow rate setting of 24,000 cfm for each CRAH unit resulted in maximum inlet air temperatures close to 80.6°F for cabinets located at the row ends. This is due to wrap around recirculation of exhaust air for cabinets at the row ends. The mixing of the bypass cold supply air and the exhaust air resulted in an average CRAH return air temperature of 76.7°F.

Data Center with CAC System

A typical CAC deployment requires two rows (of equal lengths) of cabinets with inlets facing each other, sharing a common cold aisle. In this study we rotated all cabinets by 180º to form proper cabinet row pairs for CAC deployment. Also, filler panels are installed to make the two Main Distribution Area (MDA) rows of equal length.

The CAC system has been deployed on all cabinet rows except the SAN rows (see Figure 5). Similar to the baseline scenario, CFD simulations are used to establish the optimum settings for the CRAH units: 68°F supply air temperature; 19,600 cfm for each CRAH unit. The inlet air temperatures for cabinets in the CAC are close to 68°F (supply air temperature). However, a few cabinets in the SAN rows (with no CAC) are close to the threshold temperature (80.6°F) because of IT exhaust air recirculation and the high room ambient temperature. The average room air temperature and the average return air temperature to the CRAH units is 89.7°F. Note that custom CAC systems have been developed for attachment to storage cabinets for specific data centers.

Data Center with VED System (Chimney Cabinets)

To effectively deploy a VED system on the cabinets in the data center layout, we have assumed a 2ft drop ceiling. To take the full advantage of the VED system, a drop ceiling was necessary for this layout because of the low raised floor to ceiling height, 12ft. VEDs are deployed on the server and switch cabinets, EDA and MDA rows. There are no VEDs on the storage cabinets in the SAN rows. Note that custom adapters have been developed to mount standard VEDs on storage cabinets for specific data centers.

CFD simulations were performed to establish the optimum settings for the CRAH units: 77°F supply air temperature; 19,600 cfm for each CRAH unit (see Figure 6). The VED captures and returns the cabinet exhaust air back to the CRAH units, isolating hot exhaust air from the cool supply air. This makes the room air temperature and the inlet air temperature for these cabinets close to the supply air temperature (77°F). However, the storage cabinets that are without VEDs are still susceptible to hot air recirculation and the inlet air temperatures for a few of these cabinets are close to the threshold temperature (80.6°F). The average return air temperature to the CRAH units is 98.7°F.

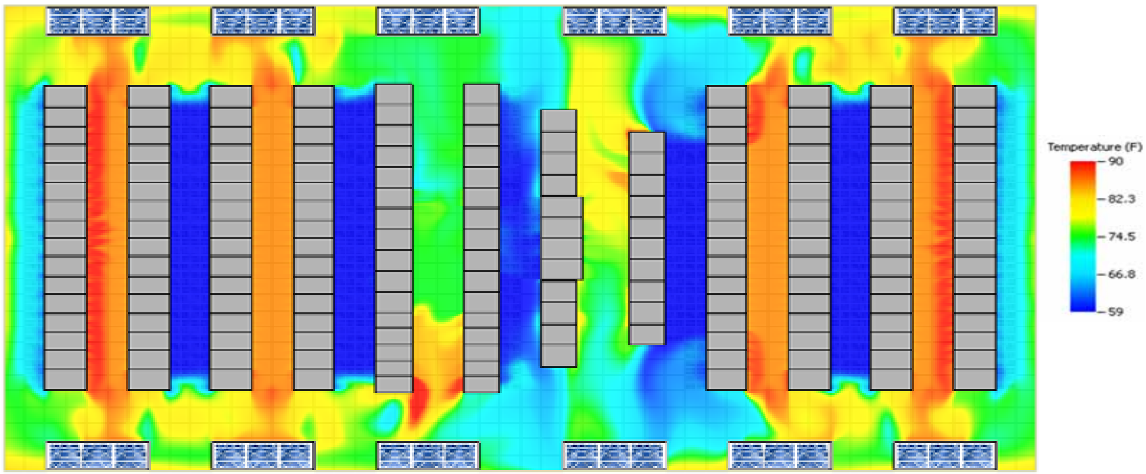

Figure 4. Hot Aisle/Cold Aisle (baseline): Temperature Plane (6 ft above raised floor).

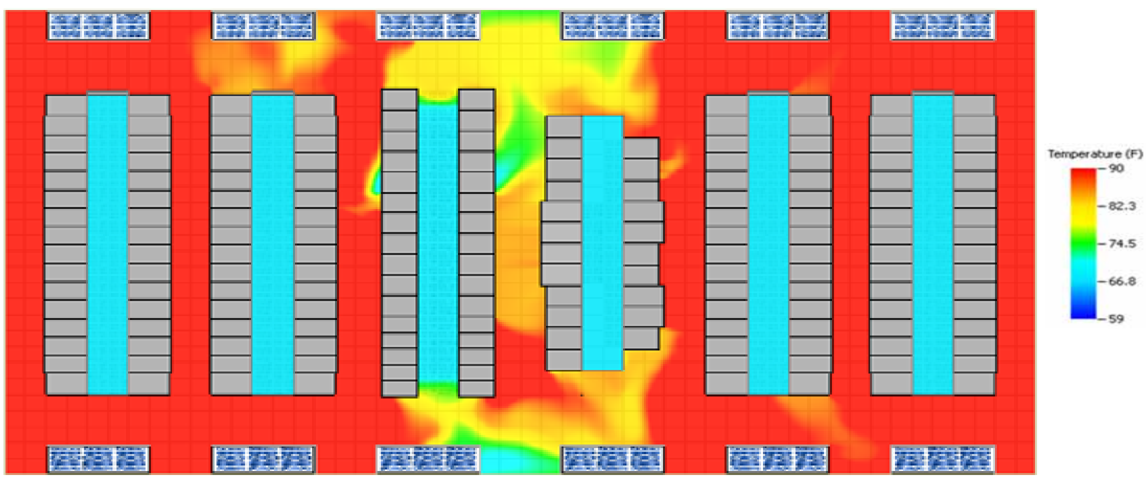

Figure 5. CAC System: Temperature Plane (6ft above raised floor).

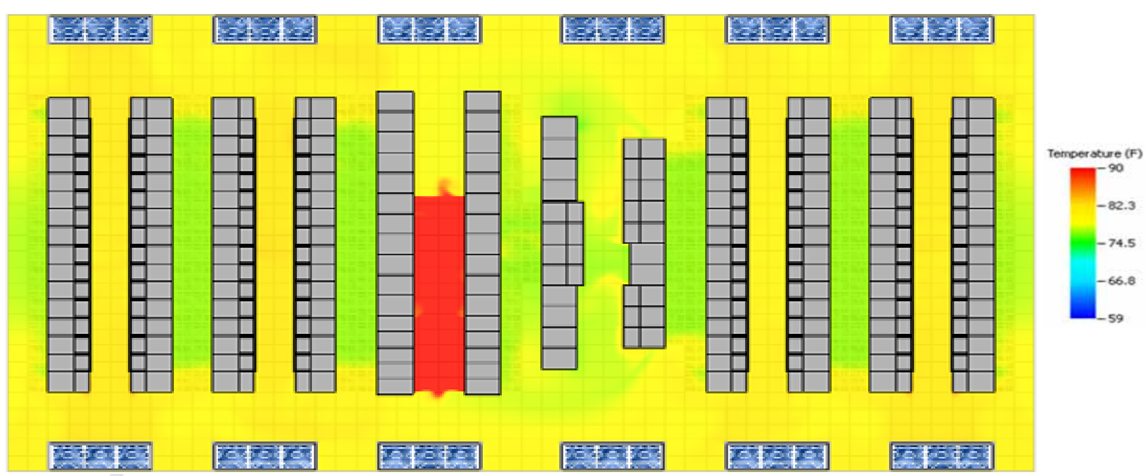

Figure 6. VED System: Temperature Plane (6ft above raised floor).

Containment on all Rows

For comparison purposes we have analyzed a scenario where CACs or VEDs were installed for all cabinets including the storage cabinets. In theory, we can match the CRAH airflow supply (17,276 cfm per CRAH unit) to the IT equipment airflow and raise the supply air temperature to 80.6°F. However, to have some margin and to ensure cabinet inlet temperatures do not run over the ASHRAE limit, we have limited the supply air temperature to 78°F.

Results of CFD Analyses

Table 1 summarizes the results of the CFD analyses conducted across the four different scenarios presented in this white paper. These results demonstrate that the application of containment, either hot aisle or cold aisle, enables a significant reduction in the amount of cooling air required to cool the IT equipment. The reduction of cooling air decreases the power consumed by CRAH fans. In addition, the analyses demonstrate that containment allows supply air and return air temperatures to be raised, which enhances the efficiency of the chiller system and reduces the power consumption of the chillers.

Table 1. Summary of CFD Results

	Baseline	CAC on Server Rows	VED on Server Rows	VEDs or CACs on all Rows
Total IT Equipment Load (kW)	1,592	1,592	1,592	1,592
IT Equipment Airflow (cfm)	207,317	207,317	207,317	207,317
Cooling Airflow (cfm)	288,000	235,200	235,200	207,317
Air Ratio (AR)	1.39	1.13	1.13	1.0
CRAH Supply Air Temp. (°F)	59	68	77	78
Av. CRAH Return Air Temp. (°F)	76.7	89.7	98.7	102.6
Av. Room Ambient Temp. (°F)	76.7	89.7	77.0	VED:78 | CAC:102.6

Notes:

- Total IT Equipment Load, kW – Sum of all heat loads for all cabinets. All IT devices are assumed to be running at 100% nameplate load.
- IT Equipment Airflow, cfm – Sum of airflows for all IT devices.
- Cooling Airflow, cfm – Sum of all CRAH airflows.
- Air Ratio (AR) – The ratio of the total cooling airflow to the total IT equipment airflow.
- CRAH Supply Air Temp. (°F) – The maximum supply air temperature to meet the ASHRAE recommended cabinet inlet air temperature (i.e., 80.6°F). Determined iteratively by CFD simulations.
- Av. CRAH Return Air Temp. (°F) – Calculated by averaging the return air temperature for all 12 CRAH units.
- Av. Room Ambient Temp. (°F) – Average bulk room air temperature.

Economic Analysis

The primary purpose of the CRAH units in a data center is to supply cold air to the room and extract the heated air from the IT equipment. In the previous section, we established the optimum set point conditions for the CRAH units for different containment options for the data center layout. This section of the white paper presents an economic analysis that compares three different water-based cooling system approaches to supply chilled water to the CRAH units − Mechanical Chiller System and Cooling Tower, Water-Side Economizer with Mechanical Chiller System and Cooling Tower, and Dry Cooler with Mechanical Chiller System and Cooling Tower. In this study Chicago has been selected as the data center location.

Mechanical Chiller System and Cooling Tower

Figure 7 shows the schematic of a cooling system with a mechanical chiller and a cooling tower. The waste heat load of the data center room is extracted through the CRAH units rejecting it to the chilled water loop and the chiller system. The chiller system transfers the heat load to the cooling tower through the cooling water loop. The cooling tower rejects the heat load to the ambient air.

The energy consumed by the chiller system constitutes a major fraction of the total energy consumed by the cooling system. A significant amount of cooling energy could be saved by operating the chiller system efficiently. The primary benefit of increasing the room supply air temperature is that it allows a higher supply water temperature. The efficiency of a chiller system increases with an increase in the supply water temperature. As a rule of thumb, for every 1°F increase in chilled water supply temperature the chiller efficiency increases by 2%. For the selected CRAH units for the layout, in order to have a proper heat transfer from the CRAH unit coils to the chilled water loop, a minimum approach temperature (temperature difference for required heat transfer) of 13°F needs to be maintained between the chilled water temperature and the CRAH supply air temperature.

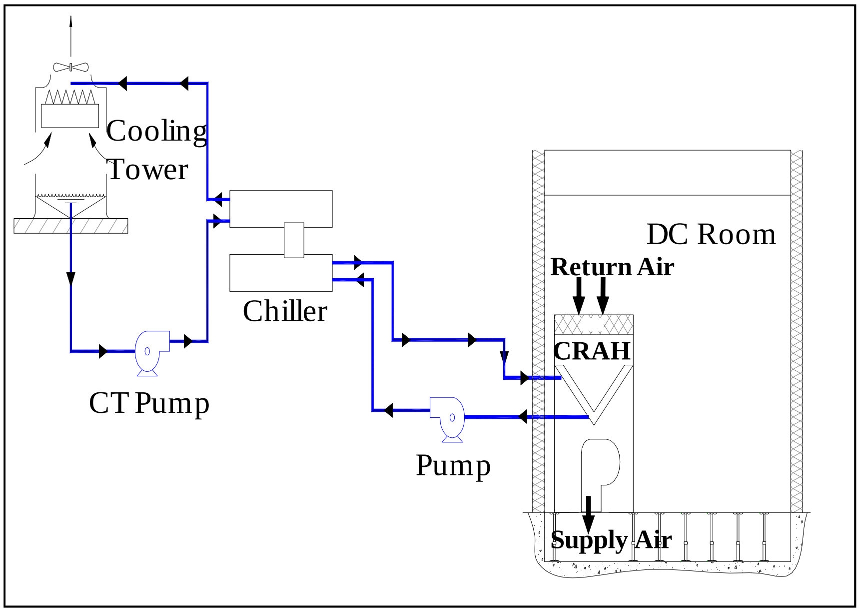

Figure 7. Schematic for the cooling system with a mechanical chiller and a cooling tower.

Table 2 compares the energy consumption of different containment options for the above cooling system. The higher set point supply air temperature requirement allowed us to increase the chilled water supply temperature for the CAC and VED scenarios. Also, the CAC and VED scenarios require less cooling airflow to maintain the cabinet inlet air temperatures below the threshold temperature (80.6°F). In this analysis, we have not included the cost of water consumption, water treatment and maintenance for the cooling tower, which we have estimated to be a small number compared to the total cooling energy cost.

Table 2. Economic comparison for a cooling system with mechanical chiller and cooling tower.

	Baseline	CAC on Server Rows	VED on Server Rows	VEDs or CACs on all Rows
Cooling Airflow (cfm)	288,000	235,200	235,200	207,317
CRAH Supply Air Temp. (°F)	59	68	77	78
Chiller Water Supply Temp. (°F)	46	55	64	65
Total CRAH Fan Power Consumption (kWh)	1,239,365	675,046	675,046	462,301
Chiller Power Consumption (kWh)	2,400,437	1,959,540	1,518,644	1,469,655
Pumps Power Consumption (kWh)	348,648	348,648	348,648	348,648
Cooling Tower Fan Energy (kWh)	262,800	262,800	262,800	262,800
Annual Cooling Energy Cost ($0.101/kWh)	**$429,376**	**$327,849**	**$283,319**	**$256,884**
Annual Energy Savings ($)	**NA**	**$101,527**	**$146,057**	**$172,492**

Notes:

- Cooling Airflow, cfm – Sum of all CRAH airflows.
- CRAH Supply Air Temp. (°F) –This is the maximum supply air temperature to meet the ASHRAE recommended cabinet inlet air temperature (i.e., 80.6°F). Determined iteratively by CFD simulations.
- Chiller Water Supply Temp. (°F) – This assumes that one can raise the chiller water temperature up to 65°F for optimum energy savings. This study considers the chiller system with a high supply water temperature capability. The majority of chiller systems operate at 42-46°F supply water temperature range. The chiller water temperature should be 13°F cooler than supply air temperature for the CRAH coil selected for this analysis.
- Total CRAH Fan Power Consumption (kWh) – calculated based on simulation results and fan laws.
- Chiller Power Consumption (kWh) – Sum of pump energy consumption. Two pumps are used: one for the chilled water loop that serves the CRAH units and another for the cooling tower water loop. In the above table, we have not included the pump energy savings due to reduced throughput requirement at higher return air temperature for the same cooling load, which we estimate to be 2-4% of the total cooling energy cost.
- Pumps Power Consumption (kWh) – Electrical energy used by pumps
- Cooling Tower Fan Energy (kWh) – Electrical energy used by the cooling tower
- Annual Cooling Energy Cost ($) – Electricity cost ($0.101/kWh) of running CRAH units, chiller system, and chiller pump.
- Annual Energy Savings ($) – Difference between annual cooling cost, annual baseline energy cost and annual cooling energy cost with VEDs or CACs.

Water-Side Economizer with Mechanical Chiller System and Cooling Tower

Figure 8 shows the schematic of the water-side economizer working in parallel with a mechanical chiller system on both the condenser (cooling tower side) and chilled water sides. The water-side economizer uses cool outdoor wet-bulb conditions to generate the chilled water for the CRAH units without using the chiller. The waste heat load of the data center is extracted through the CRAH units rejecting it to the chilled water loop and to the heat exchanger coils of the water-side economizer. The heat load from the water-side heat exchanger coils gets absorbed by the cooling tower water loop and the cooling tower where the heat load gets dissipated to the outside ambient air. In this study, we have considered a system where the chilled water is generated exclusively by the water side-economizer or exclusively by the mechanical chiller system (i.e. when the outside air conditions are appropriate to maintain chilled water supply temperature, the mechanical chiller system can be shut off). We have not considered a cooling system with the water-side economizer providing partial cooling.

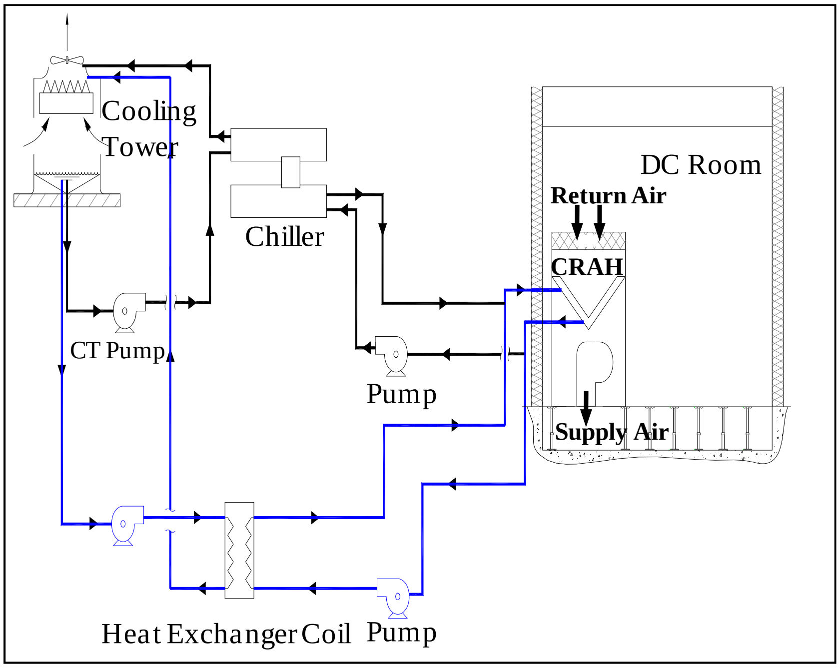

Figure 8. Schematic for the cooling system with a water-side economizer, a mechanical chiller and a cooling tower.

We have selected the water-side economizer with a heat exchanger with 3°F approach temperature (temperature difference for the required heat transfer). This means that the cool water in the cooling tower loop needs to be 3°F less than the chilled water going through the CRAH units. Also, there is an approach temperature (temperature difference for required heat transfer) requirement at the cooling tower which limits the lowest water supply temperature possible for a given outside wet-bulb condition.

For this analysis, we have selected a 7°F approach temperature (temperature difference for the required heat transfer) for the cooling tower. This implies that we could use the water side economizer only when the outside wet-bulb temperature condition is 10°F less than the chilled water temperature requirement. When this condition is not met, the chilled water would come from the chiller system.

Table 3 contains an economic comparison for a cooling system with a water-side economizer, mechanical chiller and cooling tower. Results indicate that, because of the higher allowable supply air temperature, the VED scenario offers more hours of free cooling (water side economization) than the CAC scenario.

Table 3. Economic comparison for a cooling system with water-side economizer, mechanical chiller and cooling tower.

	Baseline	CAC on Server Rows	VED on Server Rows	VEDs or CACs on all Rows
Cooling Airflow (cfm)	288,000	235,200	235,200	207,317
CRAH Supply Air Temp. (°F)	59	68	77	78
Av. CRAH Return Air Temp, ° (F)	77	90	99	103
Chiller Water Supply Temp. (°F)	46	55	64	65
Hours of Water-Side Economizer	2,642	4,024	5,410	5,557
Hours of Chiller Operation	6,118	4,736	3,350	3,204
Total CRAH Fan Power Consumption (kWh)	1,239,365	675,046	675,046	462,301
Chiller Power Consumption (kWh)	1,676,360	1,059,315	580,777	537,447
Pumps Power Consumption (kWh)	348,648	348,648	348,648	348,648
Cooling Tower Fan Energy (kWh)	262,800	262,800	262,800	262,800
Annual Cooling Energy Cost ($0.101/kWh)	**$356,244**	**$236,927**	**$188,594**	**$162,731**
Annual Savings ($)	**NA**	**$119,318**	**$167,650**	**$193,514**

Notes on new line items in Table 3, not covered on Tables 1 and 2.

- Hours of Water Side-Economizer - Hours in a year when outside wet-bulb temperature conditions (based on Chicago weather data are appropriate for water-side economization. For more information, refer to www.wunderground.com.
- Hours of Chiller Operation -Hours in a year when the chilled water temperature requirement cannot be met by a water-side economizer.

Dry Cooler with Mechanical Chiller System and Cooling Tower

Figure 9 shows a schematic of a dry cooler working in parallel with a mechanical chiller. A dry cooler consists of fans and heat exchanger coils. It rejects the data center waste heat to the ambient air flowing across the heat exchanger coils. This is a sensible heat transfer process (no heat lost through evaporation) as the air is sensibly heated to a higher temperature or the heated water from the data center is sensibly cooled to a lower temperature.

Similar to the other cooling systems, the dry cooler also has a minimum approach temperature requirement. For this analysis, we have selected a dry cooler with a 20°F approach temperature (temperature difference for required heat transfer) between the chilled water temperature and the outside dry bulb temperature. Table 4 contains an economic comparison for a cooling system with a dry cooler, mechanical chiller and a cooling tower.

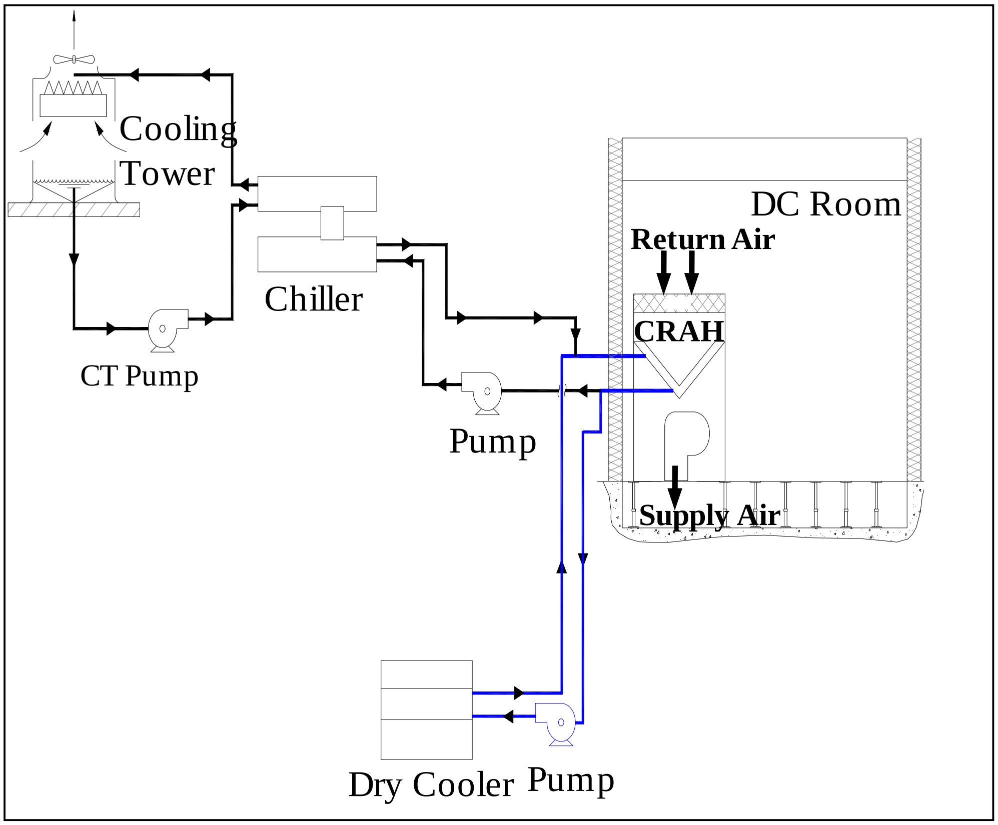

Figure 9. Schematic for the cooling system with dry cooler, a mechanical chiller and a cooling tower.

Table 4. Economic comparison for a cooling system with dry cooler, mechanical chiller and cooling tower.

	Baseline	CAC on Server Rows	VED on Server Rows	VEDs or CACs on all Rows
Cooling Airflow (cfm)	288,000	235,200	235,200	207,317
CRAH Supply Air Temp. (°F)	59	68	77	78
Av. CRAH Return Air Temp, (°F)	77	90	99	103
Chiller Water Supply Temp. (°F)	46	55	64	65
Hours of Dry Cooler	885	2,126	3,074	3,215
Hours of Chiller Operation	7,875	6,634	5,686	5,545
Total CRAH Fan Power Consumption (kWh)	1,239,365	675,046	675,046	462,301
Chiller Power Consumption (kWh)	2,157,927	1,483,971	985,731	930,278
Dry Cooler Fan Power Consumption (kWh)	66,375	159,450	230,550	241,125
Pumps Power Consumption (kWh)	334,559	314,802	299,710	297,465
Cooling Tower Fan Energy (kWh)	236,250	199,061	170,580	166,350
Annual Cooling Energy Cost ($0.101/kWh)	**$407,482**	**$286,061**	**$238,523**	**$211,849**
Annual Savings ($)	**NA**	**$121,421**	**$168,959**	**$195,633**

Notes on new line items in Table 4, not covered on Tables 1-3.

- Hours of Dry Cooler - Hours in a year when outside dry-bulb temperature conditions (based on Chicago weather data) are appropriate for dry cooling operation.
- Hours of Chiller Operation - Hours in a year when the chilled water temperature requirement cannot be met by a dry cooler.
- Dry Cooler Fan Power Consumption (kWh) - Dry Cooler fan(s) power consumption (75kW) for dissipating the heat from the heated water to the outside ambient air.

Results of Economic Analyses

Either a CAC or VED containment approach offers significant improvement in data center operations. Separation of hot and cold air by deploying a containment solution improves system scalability, operational reliability and efficiency. When hot and cold air cannot mix, uniform cabinet inlet air temperatures can be achieved and cooling units do not have to work as hard to supply cooling airflow at cabinet server inlets. This can allow raising the supply air and chilled water set point temperature as well as reducing the cooling unit fan speeds. It leverages a maximum number of hours of air-side or water-side economizer usage.

Either containment approach will address high heat density issues and improve cooling efficiency. However, CAC and VED approaches are characterized by significant functional differences that should be kept in mind when selecting a containment solution for the data center. Table 5 lists selection criteria that should be used in conjunction with an economic analysis when comparing thermal management options.

Table 5. List of selection criteria for Standard Hot Aisle / Cold Aisle (HA/CA) vs. VED vs. CAC

Selection Criteria	HA/CA	VED (Panduit® Net-Contain™)	Cold Aisle Containment (Panduit® Net-Contain™)
Return Airflow Path	It does not require any special provisioning for the return of hot exhaust air.	It requires either a high ceiling with tall chimneys or a drop ceiling for return airflow path.	Similar to HA/CA, it does not require any special provisioning for the return of hot exhaust air.
Water Cooled vs. Refrigeration Based Cooling System	Compatible with refrigeration and chilled water based systems because of the low return air temperatures.	Refrigeration based systems may not be compatible with very high return air temperatures that may be produced.	
Economizers	Compatible	Increased hours of economizer utilization due to high return air temperatures.	Increased hours of economizer utilization due to high return air temperatures.
Cooling System Failure Tolerance	Hot aisle air will be quickly drawn to the cold aisle. The average room temperature factors into the time to critical alarms in IT equipment.	Provides large mass of cold air in case of cooling system airflow failure.	Provides relatively small thermal mass in case of cooling system airflow failure.
Room Height	Requires sufficient height for raised floor or overhead supply ducting.	Needs high ceiling for chimney plus allowance for return plenum or hot air stratification.	Requires sufficient height for raised floor or overhead supply ducting.
Comfort	The hot aisle is relatively warm due to mixing of cold and hot air.	The entire room is within a few degrees of the supply air temperature (assuming VED on all cabinets).	All areas outside the cold aisle are typically at a very high temperature, which may not be an acceptable working condition.
Retrofitting / Brownfield	Minimal challenges, but limited thermal density.	May be challenging to fit VED into existing overhead pathways (power, structured cable, etc.). Addition of drop ceiling may be required.	Can be built on existing raised floors with minimal changes.
Fire Suppression	Depending on local codes, fewer sprinkler heads may be needed than for VEDs or CACs.	Depending on local codes, sprinkler heads may be needed in both the hot and cold aisles.	Depending on local codes, both fire detection devices and sprinkler heads might need to penetrate each containment system.
Lighting	Regular room lighting system is sufficient.	Chimneys will prevent light from travelling between aisles. Lighting fixtures are likely needed in both the hot and cold aisles.	Containment solutions may block light provided by overhead fixtures. Transparent roof sections or internal light fixtures may be required. Lighting fixtures are likely needed over each aisle.

Conclusion

A containment system reduces the overall cooling energy cost by preventing or reducing the mixing of cold and hot air streams. It also offers a significant opportunity for cooling energy savings regardless of its type or the type of cooling system used. This is due to the increase in allowable supply air temperature and an increase in return air temperature. As shown in the study, the progressively higher supply air temperatures and return air temperatures that can be achieved by using a CAC system, and then a VED system, and ultimately a 100% contained version of either, leads to increased savings over all the water-based cooling systems that were analyzed.

The data center study clearly demonstrates the impact that cold aisle containment systems have on the overall energy consumption in the data center. The Panduit ® Net-Contain ™ Cold Aisle Containment (CAC) System for Net-Access™ and Net-SERV® Cabinets isolates the cold supply air from the hot equipment exhaust, preventing hot air recirculation and effectively reduce energy costs, thereby contributing to the overall effectiveness of data center operations.

For typical data centers (e.g. storage area network cabinets) where some equipment in the room cannot be contained, the VED system has an advantage as it captures the exhaust air and prevents it from mixing with the cold supply air in the non-contained area. The Panduit Vertical Exhaust Duct (VED) is designed to channel the server or switch exhaust to the above-ceiling return plenum. Data center hot spots, server overheating, and air mixing can be eliminated, resulting in more efficient thermal management.

These containment systems enable Panduit cabinets to manage high thermal loads while optimizing data center cooling capacity and capital costs. Both systems are completely passive, with no moving parts that consume energy or require maintenance, improving network reliability and efficiency. Panduit owns and operates a state of the art thermal lab and is available to provide design specific analysis. For further information, please visit www.panduit.com/microdatacenter.

Referenced Standards

ASHRAE TC9.9, "2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance," www.tc99.ashraetcs.org.

About Panduit

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.

www.panduit.com · cs@panduit.com