WHITE PAPER

Two-Dimensional Computational Fluid Dynamics Analysis of Blanking Panel Solutions

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Executive Summary

Because air-intake temperature is a known significant factor in IT equipment reliability and availability, Upsite Technologies, Inc. commissioned an independent, third-party organization to study the effect of blanking (filler) panels on airflow patterns and IT equipment intake temperatures within equipment (server) cabinets. This study was conducted, in part, to expand on work previously completed by Robert F. Sullivan, Ph.D. with the Uptime Institute, Inc.

Innovative Research, Inc. performed the study using two-dimensional, computational fluid dynamics (CFD) modeling. In this study, three server cabinet configurations were modeled:

- Model 1: No blanking panels on the mounting rail in the gaps between adjacent servers were installed.
- Model 2: Blanking panels with horizontal air gaps of 1.6 mm (1/16 inch) between adjacent blanking panels and also with horizontal air gaps of 3.2 mm (1/8 inch) between blanking panels and servers were installed.
- Model 3: Blanking panels with no horizontal gaps between adjacent blanking panels or between blanking panels and the IT equipment were installed.

The major results of this study are summarized as follows:

- The use of blanking panels had a significant impact on the amount of unwanted hot exhaust air from the equipment that recirculated toward the front of the cabinets and mixed with cool conditioned air available at the equipment air intakes.
  - ✓ The servers in the cabinet without blanking panels drew in 40 percent of their total required airflow volume from the hot exhaust air originating in the back of the server cabinet.
  - ✓ Blanking panels with horizontal gaps between adjacent blanking panels and between blanking panels and IT equipment reduced the volume of hot exhaust air recirculation to 19 percent (a 53 percent improvement over a server cabinet with no blanking panels).
  - ✓ Blanking panels with no gaps reduced the volume of hot exhaust air recirculation to 0 percent (a 47 percent improvement over a server cabinet with blanking panels that have horizontal gaps, and a 100 percent improvement over a server cabinet with no blanking panels).
- When hot exhaust air recirculation occurs, installing higher flow perforated tiles or grates, installing additional cooling units, or reducing the cooling unit set points will not necessarily reduce server intake-air temperatures.
- More important, the result of using blanking panels to reduce unwanted bypass air within the cabinet significantly reduced and stabilized the temperatures at the server air intakes.
  - ✓ Blanking panels with horizontal gaps reduced the average temperature by 20 percent over the use of no blanking panels.
  - ✓ More significant, blanking panels with no horizontal gaps reduced the average temperature by 37 percent over the use of no blanking panels. The average air temperature at the air intake was the same as the conditioned air from the floor grate. All air drawn into the equipment was conditioned air. Under this condition, adjusting cooling set points and conditioned air volumes have a direct effect on conditions at the equipment air intakes.

This white paper will describe the study results in detail and present some conclusions and implications. The work previously conducted by Dr. Sullivan will be summarized and compared to the results of this study. Also, plans for future research will be summarized.

Introduction

- Increasing computing densities have raised IT equipment intake temperatures and increased failure rates, triggering awareness about the importance of effective and efficient conditioned airflow management in computer rooms. The importance of controlling airflow in these environments has been explored in numerous research papers, including:
- *2005-2010 Heat Density Trends in Data Processing, Computer Systems, and Telecommunications Products (Brill)*[1]
- *Alternating Cold and Hot Aisles Provide More Reliable Cooling for Server Farms (Sullivan)*[2]
- *Reducing Bypass Airflow Is Essential for Eliminating Computer Room Hotspots (Sullivan, Strong, and Brill)*[3]

In considering these prior white papers, computer room airflow can be examined in terms of three zones: below-the-floor; through-the-floor; and above-the-floor. Each zone presents specific challenges to the management of conditioned airflow.

- Significant below-the-floor airflow and static pressure management factors include the height of the raised floor; airflow obstructions resulting from infrastructure piping; poor power and data cabling layout and management; poor perimeter opening sealing; and the distances between cooling units and the IT load.
- Significant through-the-floor management factors include the type, number, and location of perforated tiles or grates; and bypass airflow openings such as cable openings, inadequate sealing between the floor and perimeter walls, and around structural columns. Bypass airflow is any volume of conditioned air that doesn't directly contribute to the cooling of IT equipment by passing through the IT equipment. The Uptime Institute recommends that bypass airflow be limited to 10 percent or less of the total volume of conditioned air being supplied.
- Significant above-the-floor circulation factors include server cabinet layout, such as Hot aisle/Cold aisle; ceiling height; server cabinet height; cooling unit placement and orientation; server cabinet design; and internal server cabinet circulation.

Perhaps the least understood problem related to airflow circulation patterns is the above-the-floor condition of internal server cabinet recirculation. Unsealed openings in a server cabinet can allow the recirculation of hot exhaust air from the equipment within the server cabinet or from equipment in adjacent server cabinets or aisles. In previous work, Dr. Sullivan measured the volume of air being drawn into equipment air intakes in server cabinets not furnished with blanking panels. Dr. Sullivan found that as much as 20 percent of the total air volume measured at the equipment air intake was hot exhaust air recirculated within the server cabinet. His study showed that this situation is especially true with server cabinets that are more than 50 percent populated and that effect is increased on equipment located toward the top of the server cabinet. These findings indicate that the recirculation of hot exhaust air significantly increases equipment inlet air temperatures, causing hotspots that can reduce IT equipment reliability and increase operating expenses. The maximum IT equipment intake temperature recommended by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) is 25˚C (77˚F). Above this temperature IT equipment failure rates increase significantly.

Because it is evident that the open spaces between IT equipment within a server cabinet are the most significant cause of internal server cabinet air recirculation, Upsite Technologies commissioned the two-dimensional CFD modeling study to deepen industry knowledge of internal server cabinet air recirculation and temperatures, and to examine the effect of using blanking panels to manage air recirculation and air-intake temperatures within server cabinets. The study clearly demonstrated the importance of using blanking panels to seal these openings.

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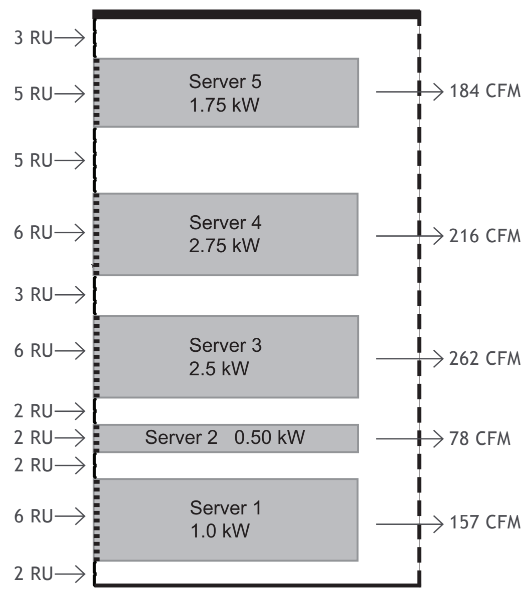
[1]Found on upsite.com
[2]Found on uptimeinstitute.org
[3]Found on upsite.com

Two-Dimensional CFD Study

In conducting the study, Innovative Research used two-dimensional CFD models to simulate airflow and temperatures around and within a server cabinet. The study simulated a server cabinet partially filled with servers by using a raised-floor grate tile in front of the server cabinet and a full solid tile behind the server cabinet. Conditioned air was supplied through the raised-floor grate. The cabinet contained five servers with the characteristics listed in Table 1 below. The server cabinet modeled was 42 rack units (RU) in height. The servers accounted for a total of 25 RUs. Therefore, the server cabinet was 60 percent populated.

Table 1
Cabinet-Server Configurations



Total Height (RU)	*Total Heat Load (kW)*	*Total Airflow Demand*
42 RU	**8.5 kW**	**897 CFM**

All assumptions and dimensions are based on data collected in operational computer rooms. Recognizing the large variations in cabinet configuration, power density, and conditioned airflow that exist in computer rooms, Innovative Research selected a configuration that would best represent a typical high density configuration. Data points and assumptions in the study were as follows for all models:

- Total server cabinet heat load was 8.50 kilowatts (kW).
- Total server airflow volume demand was 25.4 cubic meters per minute (CMM) or 897 cubic feet per minute (CFM).
- Conditioned airflow volume through the grate was 27.95 CMM (987 CFM) (representing 110 percent of the total server demand).
- Conditioned air supply temperature was 15.5°C (60°F).
- Computations were made on a non-uniform grid comprising 60 control volumes in the X direction and 100 control volumes in the Y direction.
- Server cabinet design prevents recirculation between the server cabinet side panels and equipment mounting rails.
- Server cabinets were modeled without front doors.
- A 60 percent perforated back door was modeled. There were no significant differences in the results of models run without back doors compared to those with back doors.

The study investigated three models of server and blanking panel configuration.

- Model 1 simulated a server cabinet in which no blanking panels were used.
- Model 2 simulated a server cabinet with blanking panels that had horizontal gaps of 1.6 mm (1/16 inch) between adjacent blanking panels and 3.2 mm (1/8 inch) between each blanking panel and server.
- Model 3 simulated a server cabinet using blanking panels with each blanking panel having a compressible edge that left no gaps between blanking panels or between any blanking panel and the server.

The Results

First, the results of the CFD models corroborate the work done by Dr. Sullivan, which shows that as much as 20 percent of the intake air into the IT equipment is composed of recirculated hot exhaust air. The CFD model in this study shows that, under a different set of assumptions, 40 percent of the intake air into the IT equipment is composed of recirculated hot exhaust air. Specifically, the CFD model revealed the internal server cabinet recirculation air volumes for each of the three server cabinet configurations.

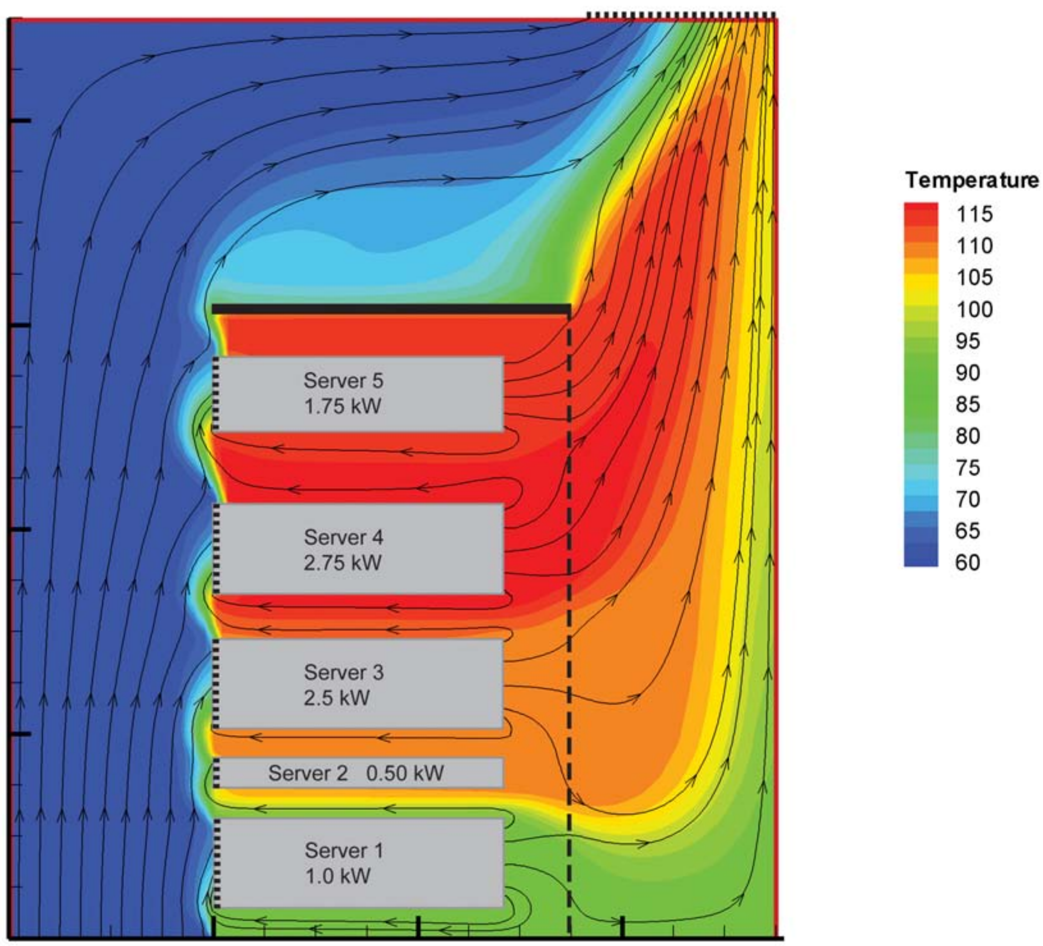
- Model 1: The servers in the server cabinet without blanking panels drew in 10.0 CMM (354 CFM) of the hot exhaust air from the back of the server cabinet, which is 40 percent of their total required airflow volume.
- Model 2: Blanking panels with horizontal gaps between adjacent blanking panels and between blanking panels and IT equipment improved recirculation over a server cabinet with no blanking panels by reducing the volume of hot exhaust air being draw in by the servers to 4.73 CMM (167 CFM), which is 19 percent of the total required volume. This represents a 53 percent improvement over a server cabinet with no blanking panels.
- Model 3: Blanking panels with no gaps eliminated recirculation by blocking all exhaust air. Recirculation was 0 CMM (0 CFM). This represents a 47 percent improvement over a server cabinet with blanking panels that have horizontal gaps, and a 100 percent improvement over a server cabinet with no blanking panels.

Second, the models provided important information about the amount of conditioned air reaching the air intakes of the servers in the cabinet.

- In Model 1, no blanking panels were deployed on the equipment mounting rails in the space between the servers. As seen in Diagram 1, hot exhaust air from the back of equipment and from the hot aisle recirculated to the front of the server cabinet because no blanking panels were installed to prevent the recirculation. Notice

Diagram 1

Model 1: Cross-Section of Airflow in Server Cabinet Without Blanking Panels Installed

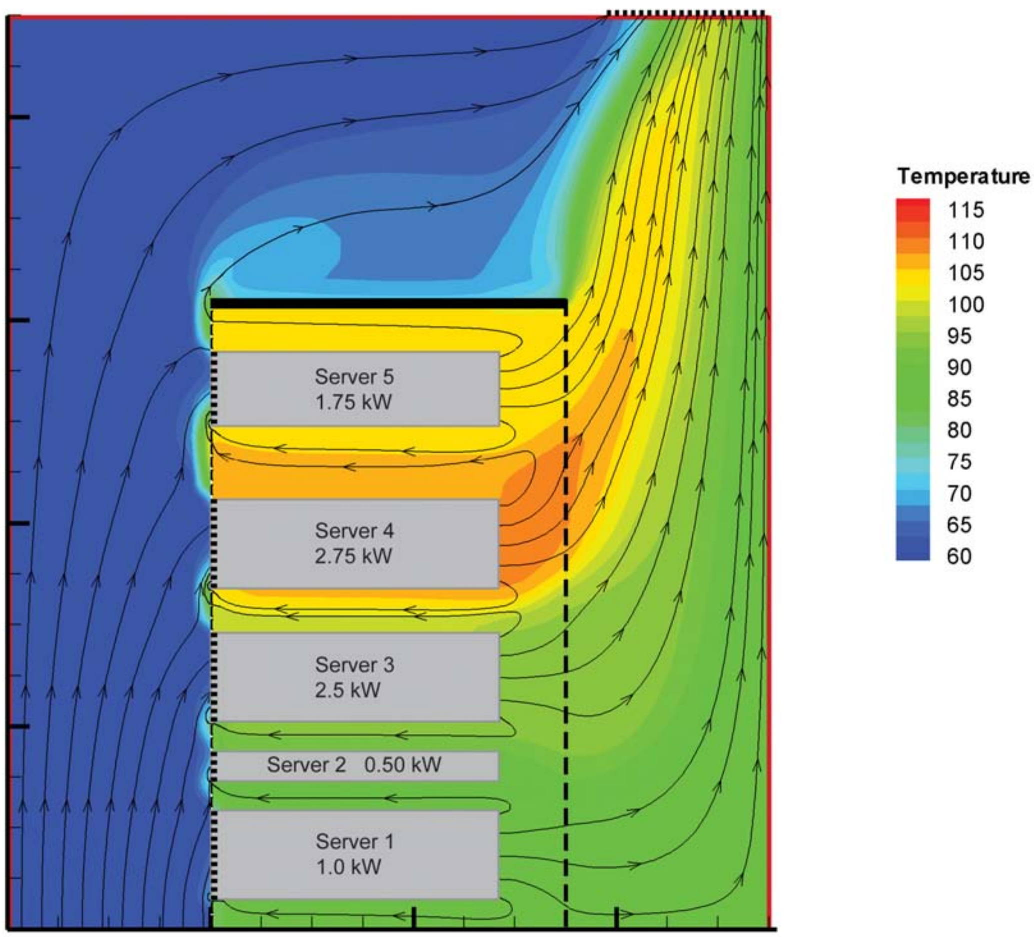


that in Diagram 1, compared with Diagrams 2 and 3, approximately half of the airflow paths leaving the raised floor grate pass by the server air intakes. This shows that an insufficient volume of conditioned air from the perforated tiles in the cold aisle is not causing the high intake temperatures. Thus, installing higher flow perforated tiles or grates, installing additional cooling units, or reducing the cooling unit set points, would not necessarily reduce server intake-air temperatures.

- In Model 2, the server cabinet had blanking panels installed, but with horizontal air gaps of 1.6 mm (1/16 inch) between adjacent panels and also with horizontal air gaps of 3.2 mm (1/8 inch) between blanking panels and servers. The temperatures and airflow results of Model 2 are shown in Diagram 2, again, as a cross-section of the server cabinet. As in Model 1, recirculation occurred despite the existence of excess conditioned air volume of 110 percent of the total server demand (e.g., airflow through the grate of 27.95 CMM (987 CFM) versus a total server airflow demand of 25.40 CMM (897 CFM)). Notice in Diagram 2 that there is less air recirculation compared with Diagram 1, and that more conditioned air is being taken into the server air inlets as indicated by the blue airflow arrows. Again in Model 2, installing higher flow perforated tiles or grates, installing additional cooling units, or reducing the cooling unit set points would not necessarily reduce server intake-air temperatures below the recommended maximum of 25°C (77°F).

Diagram 2

Model 2: Cross-Section of Airflow in Server Cabinet With Blanking Panels With Gaps Installed
Installed blanking panels are modeled with horizontal air gaps of 1.6 mm (1/16 inch) between adjacent blanking panels and also with horizontal air gaps of 3.2 mm (1/8 inch) between blanking panels and servers.



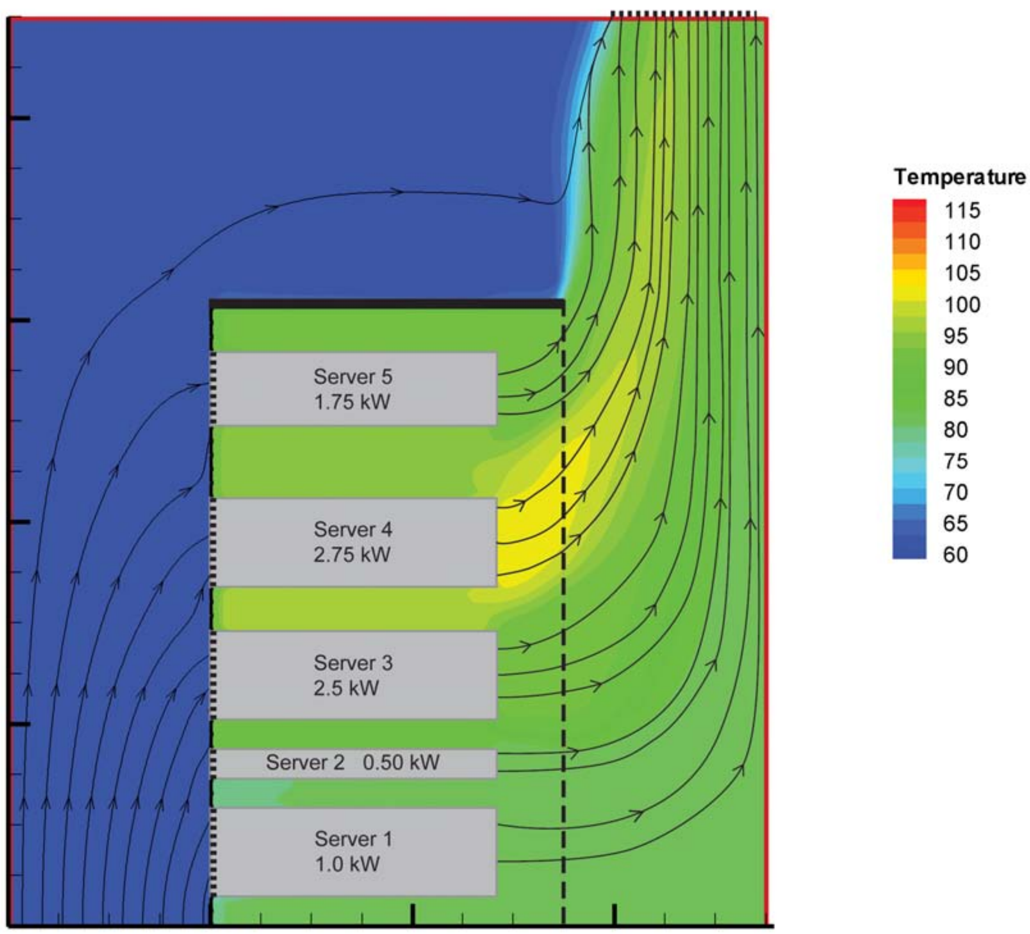
- In Model 3, the server cabinet was populated with blanking panels that had a compressible edge. There were virtually no air gaps between adjacent blanking panels or between blanking panels and IT equipment. This eliminated internal server cabinet recirculation. The temperatures and airflow results of Model 3 are shown in Diagram 3, again, as a cross-section of the server cabinet. Notice in Diagram 3 that there is no hot exhaust air recirculation being drawn into the air intakes. Only conditioned air is being taken into the server air inlets as indicated by the blue air flow arrows. The results indicate ideal delivery of conditioned air. Under this condition, adjusting cooling set points and conditioned air volumes have a direct effect on conditions at the equipment air intakes.

In Model 3, with internal server cabinet recirculation eliminated, the server inlet-air temperatures were all equal to the temperature of the conditioned air being supplied. The results indicate ideal delivery of conditioned air. As shown in Table 2, the server cabinet using blanking panels with no gaps between adjacent blanking panels or between blanking panels and servers achieved an intake-air temperature reduction of up to 15.6˚C (28˚F) compared with the server cabinet with unsealed openings (this indicates a 32 percent improvement). Also, the server cabinet using blanking panels with effective sealing produced an improvement in inlet-air temperatures of up to 14 percent as compared with the server cabinet using blanking panels with gaps of 1.6 to 3.2 mm (1/16 to 1/8 of an inch) between adjacent blanking panels and between blanking panels and the servers.

Third, and most significant, the models provided important information about the server air-intake temperatures in the cabinet. Tables 2-4 show the details of the server air-intake temperatures for the three models. Heat load and airflow demand for the five servers in the server cabinet remained consistent under all test conditions.

Diagram 3

Model 3: Cross-Section of Airflow in Server Cabinet With Blanking Panels With No Gaps Installed
Installed blanking panels are modeled with no horizontal air gap between adjacent blanking panels or between blanking panels and servers.



- In Model 1, no blanking panels were deployed on the equipment mounting rails in the space between the servers. As seen in Table 2, the average air-inlet temperature was 26.3°C (79.4°F). The average air-intake temperature in three of the five servers is above the ASHRAE-recommended maximum of 25°C (77°F). Finally, Table 2 shows the average maximum air-inlet temperature was 35°C (95.2°F) and that all five servers exceeded the ASHRAE-recommended maximum temperature of 25°C (77°F).

TABLE 2

Model 1: Server Cabinet Without Blanking Panels Installed (Fahrenheit)

Server No.	Heat load (kW)	Airflow Demand (CFM)	Min Inlet Temperature (F)	Max Inlet Temperature (F)	Average Inlet Temperature (F)	Delta T vs No Panels (F)	% Temperature Drop	% Improve-ment over Metal Panels
5	1.75	184	67	104	83	NA	NA	NA
4	2.75	216	62	99	76	NA	NA	NA
3	2.5	262	65	101	79	NA	NA	NA
2	0.5	78	85	94	88	NA	NA	NA
1	1	157	65	78	71	NA	NA	NA
			Average	95.2	79.4	NA	NA	NA

Model 1: Server Cabinet Without Blanking Panels Installed (Celsius)

Server No.	Heat load (kW)	Airflow Demand (CFM)	Min Inlet Temperature (C)	Max Inlet Temperature (C)	Average Inlet Temperature (C)	Delta T vs No Panels (C)	% Temperature Drop	% Improve-ment over Metal Panels
5	1.75	184	19.4	40.0	28.3	NA	NA	NA
4	2.75	216	16.7	37.2	24.4	NA	NA	NA
3	2.5	262	18.3	38.3	26.1	NA	NA	NA
2	0.5	78	29.4	34.4	31.1	NA	NA	NA
1	1	157	18.3	25.6	26.7	NA	NA	NA
			Average	35.1	26.3	NA	NA	NA

- In Model 2, the server cabinet had blanking panels installed, but with horizontal air gaps of 1.6 mm (1/16 inch) between adjacent panels and also with horizontal air gaps of 3.2 mm (1/8 inch) between blanking panels and servers. Table 2 shows the average air-inlet temperature was 19.4˚C (67˚F) and that the average air-inlet temperature on all five servers was below the ASHRAE-recommended maximum temperature. Model 2 achieved an average improvement in inlet-air temperatures that was 15 percent over the server cabinet with unsealed openings as shown in Table 3. While a definite improvement over Model 1, when the maximum air-inlet temperatures in Model 2 are examined, two of the five servers exceed the ASHRAE-recommended maximum temperature with the maximum air-inlet temperature of the top (Server 5) being 32˚C (90˚F). This is the result of recirculation through the horizontal gaps between adjacent blanking panels and between the blanking panels and servers. Notice that the two servers with maximum excessive air-intake temperatures are at the top or the cabinet, consistent with the findings in Dr. Sullivan's earlier study.

TABLE 3

Model 2: Server Cabinet With Blanking Panels With Gaps Installed (Fahrenheit)

Installed blanking panels are modeled with horizontal air gaps of 1.6 mm (1/16 inch) between adjacent blanking panels and also with horizontal air gaps of 3.2 mm (1/8 inch) between blanking panels and servers.

Server No.	Heat load (kW)	Airflow Demand (CFM)	Min Inlet Temperature (F)	Max Inlet Temperature (F)	Average Inlet Temperature (F)	Delta T vs No Panels (F)	% Temperature Drop	% Improve-ment over Metal Panels
5	1.75	184	62	90	72	11	13%	NA
4	2.75	216	61	82	67	9	12%	NA
3	2.5	262	62	72	64	15	19%	NA
2	0.5	78	66	70	69	19	22%	NA
1	1	157	61	66	63	8	11%	NA
			Average	76	67	12	15%	NA

Model 2: Server Cabinet With Blanking Panels With Gaps Installed (Celsius)

Installed blanking panels are modeled with horizontal air gaps of 1.6 mm (1/16 inch) between adjacent blanking panels and also with horizontal air gaps of 3.2 mm (1/8 inch) between blanking panels and servers.

Server No.	Heat load (kW)	Airflow Demand (CFM)	Min Inlet Temperature (C)	Max Inlet Temperature (C)	Average Inlet Temperature (C)	Delta T vs No Panels (C)	% Temperature Drop	% Improve-ment over Metal Panels
5	1.75	184	16.7	32.2	22.2	6.1	13%	NA
4	2.75	216	16.1	27.8	19.4	5.0	12%	NA
3	2.5	262	16.7	22.2	17.7	8.3	19%	NA
2	0.5	78	18.9	21.1	20.6	10.6	22%	NA
1	1	157	16.1	18.9	17.2	4.4	11%	NA
			Average	24.4	19.4	6.7	15%	NA

- In Model 3, with internal server cabinet recirculation eliminated, both the average and maximum air-intake temperature, as well as the airintake temperature of all five servers was 15.6˚C (60˚F) as shown in Table 4. The server inlet-air temperatures were all equal to the temperature of the conditioned air being supplied. The results indicate ideal delivery of conditioned air.

TABLE 4

Model 3: Server Cabinet With Blanking Panels With No Gaps Installed (Fahrenheit)
Installed blanking panels are modeled with no horizontal air gap between adjacent blanking panels or between blanking panels and servers.

Server No.	Heat load (kW)	Airflow Demand (CFM)	Min Inlet Temperature (F)	Max Inlet Temperature (F)	Average Inlet Temperature (F)	Delta T vs No Panels (F)	% Temperature Drop	% Improve-ment over Metal Panels
5	1.75	184	60	60	60	23	28%	14%
4	2.75	216	60	60	60	16	21%	9%
3	2.5	262	60	60	60	19	24%	5%
2	0.5	78	60	60	60	28	32%	10%
1	1	157	60	60	60	11	15%	4%
			Average	60	60	19	24%	9%

Model 3: Server Cabinet With Blanking Panels With No Gaps Installed (Celsius)
Installed blanking panels are modeled with no horizontal air gap between adjacent blanking panels or between blanking panels and servers.

Server No.	Heat load (kW)	Airflow Demand (CFM)	Min Inlet Temperature (C)	Max Inlet Temperature (C)	Average Inlet Temperature (C)	Delta T vs No Panels (C)	% Temperature Drop	% Improve-ment over Metal Panels
5	1.75	184	15.6	15.6	15.6	12.8	28%	14%
4	2.75	216	15.6	15.6	15.6	8.9	21%	9%
3	2.5	262	15.6	15.6	15.6	10.6	24%	5%
2	0.5	78	15.6	15.6	15.6	15.6	32%	10%
1	1	157	15.6	15.6	15.6	6.1	15%	4%
			Average	15.6	15.6	10.6	24%	9%

Conclusions and Implications

The results of this study indicate the following:

- Internal server cabinet air recirculation significantly impacts the intake-air temperature of IT equipment when no blanking panels are deployed in the spaces between IT equipment.
- Blanking panels significantly improve IT equipment intake-air temperatures and are therefore an effective solution for the problem of hot exhaust air recirculation within a server cabinet.
- Blanking panels with gaps as little as 1.6 mm (1/16 inch) in the horizontal space between adjacent blanking panels leave IT equipment vulnerable to damaging intake temperatures.
- Delivering an excess volume of conditioned airflow does not prevent the harmful effects of server cabinet internal recirculation when no blanking panels are deployed in the spaces between IT equipment or even when blanking panels with gaps are deployed.
- The most significant gains can be realized with blanking panels that have no air gaps in the horizontal space between adjacent blanking panels or between blanking panels and IT equipment, hence the importance of blanking panels with compressible edges that provide a near-perfect seal.
- Eliminating internal server cabinet air recirculation allows for significantly more efficient delivery of conditioned air to the equipment inlets.

The study implies that using blanking panels may have a noticeable impact on reducing IT equipment failure rates, replacement costs, and operating expenses

For Further Study

A three-dimensional CFD model has been commissioned to further clarify internal server cabinet air recirculation. Separately, a study of the energy usage and financial impacts of these conditions will be published.

About Upsite

Upsite Technologies, Inc. develops energy-efficient, high-availability solutions specifically designed to optimize your data center's critical physical infrastructure and ensure site uptime, reliability, and flexibility.

As the innovator of the LOK familly sealing solutions, Upsite continues to research and develop products and services to complement and enhance the already extensive lines of patented KoldLok® and HotLok products and EnergyLok℠ services. Our inventions optimize thermal load capacity, target hotspot remediation, reduce intermittent equipment failures, improve equipment reliability, minimize bypass airflow, and diminish capital costs associated with installing additional cooling equipment.

Upsite's well-engineered solutions are employed by data centers worldwide to help reduce their carbon footprint and minimize energy and operating costs. Upsite's products and services currently optimize more than 6 million ft^2 (550,000 m^2) of data center space.

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