Data Center White Paper

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Cold Aisle Containment System Performance Simulation

Executive Summary

With a goal of reducing inlet temperatures, BayCare Health System, a major, non-profit, healthcare network in the Tampa, Florida area, installed a cold aisle containment system (CACS) in one section of its data center. The initial data showed improvements in some areas, but the results were inconsistent. In a few areas, inlet temperatures actually increased.

To understand these results, Eaton, a global provider of airflow management solutions, simulated the performance of the data center using Future Facilities' 6SigmaDC computational fluid dynamics (CFD). Eaton captured airflow and temperature measurements within the BayCare data center. When the results of the measurements were compared to the simulation results, it was discovered they closely matched. It was then determined that the CFD software could be used to study and diagnose the data center's cooling problems.

The resultant diagnosis identified two broad airflow management issues: (1) An airflow deficit and (2) Several rear fan doors were installed in racks with side-to-side airflow breathing equipment, which caused cold air to escape through the rear of the racks.

Eaton, using CFD simulation, developed recommendations that demonstrated how to achieve the full potential of the cold aisle containment system. The CFD Simulation showed that the recommended strategy reduced the magnitude and variation of inlet temperatures. It also substantially reduced energy consumption.

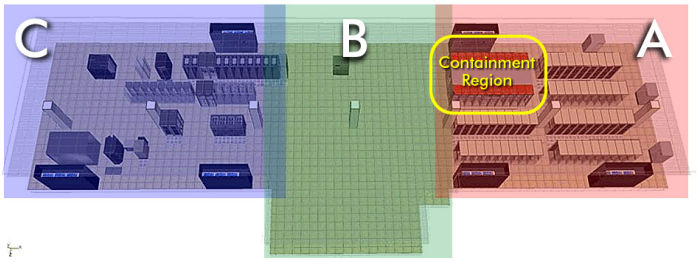

Figure 1. Overhead view of data center

The 8600 square foot data center facility is divided into three dedicated regions as shown in Figure 1. Regions A, B and C are areas of a single non-partitioned room. Region A uses 80 Eaton cabinets with Class 1 EIA-310 rack-mounted server equipment.

The data center previously used best practices including hot and cold aisles, as well as hot aisle ceiling-mounted egg crates that exhausted air into the ceiling plenum. The computer room air conditioning (CRAC) units with collars joined to the plenum provided a direct path for rejecting heat from the whitespace. BayCare contacted Eaton because it was interested in achieving further efficiency gains.

Installation of Cold Aisle Containment

With a goal of preventing hot air from recirculating and ensuring that cold air could reach equipment inlets, Eaton suggested a cold aisle containment system, which closed off the cold aisle, capped the ceiling, and added doors on the end of the aisle.

BayCare opted for cold aisle containment because the approach was simple to install, inexpensive to maintain and did not disrupt existing services. Cold aisle containment was first installed on 20 racks in Region A, as a test case.

Measurements taken before and after the installation of the cold aisle containment system showed improvements in some areas, but mixed results in others. Rack inlet temperatures varied between 57°F and 81°F, which was a much higher range than was expected. Several rack inlet temperatures were only slightly improved and ironically, in one rack within the test region the inlet temperature had actually increased.

Eaton, expecting to see greater improvements, visited the physical data center to take a closer look at conditions there. Eaton, in conjunction with Future Facilities performed flow and temperature measurements in the facility with and without the cold aisle containment systems installed. These measurements included:

- Inlet temperatures of all devices
- Volumetric airflow of all perforated tiles
- Volumetric airflow of cable cutouts within the containment region
- Volumetric airflow of CRACs
- Supply temperatures of CRACs
- Return temperatures of CRACs
- Static pressure measurements
- Thermal imagery of the device inlets and rack faces

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Installation of Cold Aisle Containment (cont.)

When inspecting the facility, Eaton noticed that four of the racks used side-to-side airflow equipment and were fully open from the front to provide an air path for side-breathing equipment. All of the other racks made full use of blanking panels and were front-to-back breathing.

Even in the locations where full blanking panels were used, Eaton observed gaps at both the top and bottom of the racks. Many of these gaps were more than two inches wide attributed to using recessed front mount rails. Several racks used integrated fan systems to assist in removing heat exhaust from the cabinet. Some of the racks had fan tops and several had rear fan doors. All four racks with side-to-side airflow devices used rear fan doors.

Performing Simulation and Measurement

Eaton used 6SigmaDC to model the containment region because the CFD software could provide a highly accurate representation of the internal server-rack configuration. This type of modeling is essential in determining actual inlet temperatures of IT equipment.

Three different versions of the Eaton Paramount enclosure were used in the space and each was mapped appropriately into the model. BayCare provided Eaton with documentation that mapped the rack unit location for every device in each rack. This device list was imported into 6SigmaDC where each device model was matched to a corresponding library representation and placed in the correct location in 3D space. The library objects are a device specific description (manufacturer and model) that accurately reflects the thermal and physical characteristics of the device and its impact on the data center environment.

Airflow demand was determined by values for fan behavior with respect to the inlet temperature contained in the 6SigmaDC library. Approximately 90% of the data was found in the 6SigmaDC Libraries, however if the information was not in the library, it was obtained from the equipment manufacturer.

Total volumetric airflow demand from the devices in the containment region was determined to be 10,500 cubic feet per minute (CFM). The CRAC units were Liebert DS105s. Each had a specified volumetric airflow rate of 14,600 CFM.

Figure 2. The top image shows CFD simulation predictions for equipment inlet temperatures and the bottom image shows actual measurements of the same devices as a function of time.

Measurements performed with a balometer showed that actual air supply was slightly less than the rating. Volumetric airflow did not change when the cold aisle containment solution was deployed, which indicated the containment field was not maintaining internal pressure.

The total volumetric airflow supply though the floor tiles was 7,770 CFM. This was much less than the airflow demand from the devices. Total power consumption from the IT devices in Region A was measured at 144 kilowatts. This measurement was well under the 243 kilowatt rated "sensible cooling capacity" of the CRAC units.

The section of Region A with the containment system installed was simulated as a virtual room. This was performed without modeling the entire data center, as measured data was used to create new boundary conditions.

For example, airflow and air temperature were measured at the floor tiles and this data was applied as a direct input for one of the boundary conditions. The measured data for the equipment inlet temperature was then used to test assumptions for other boundary conditions. The CFD results, as shown in the top half of Figure 2 are consistent, with the physical measurements shown in the bottom half. Each color line represents a different server inlet temperature.

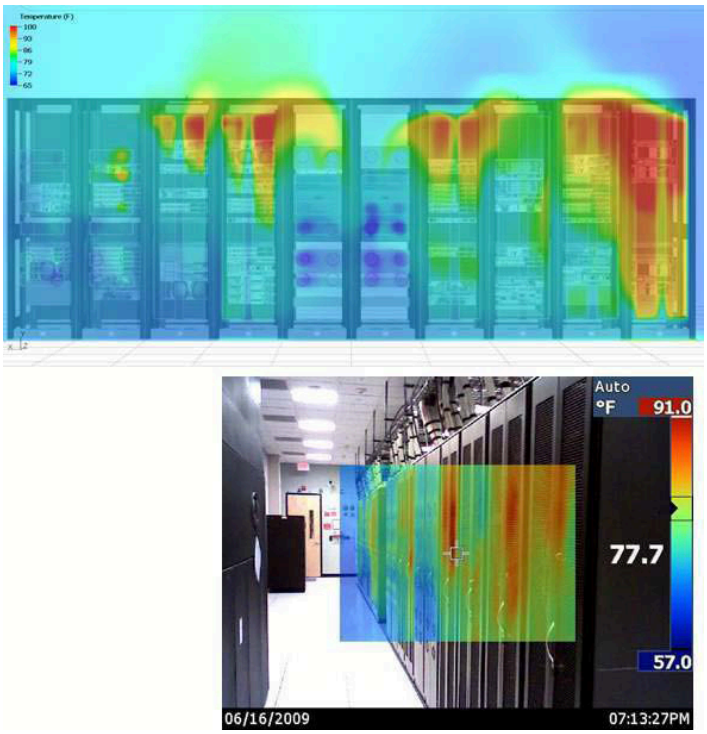

Figure 3. The top image shows a CFD simulation of temperatures at the rear exhaust and the bottom image shows thermal imagery of the same cabinets rear exhaust.

As shown in Figure 3, the CFD simulation representation matches the actual thermal imagery of the cabinet's rear exhaust temperatures. Eaton used the detailed CFD results to develop a better understanding of conditions within the containment area.

Diagnosing the Data Center

Figure 4 shows the simulation view of airflow from the tiles without cold aisle containment . The CFD simulation illustrates that the device inlets at the top of racks and on the end of rows receive a very limited amount of cold air delivered directly from the air conditioning unit. There is not enough air delivered through the floor tiles to meet the airflow demands from the rack-mounted equipment.

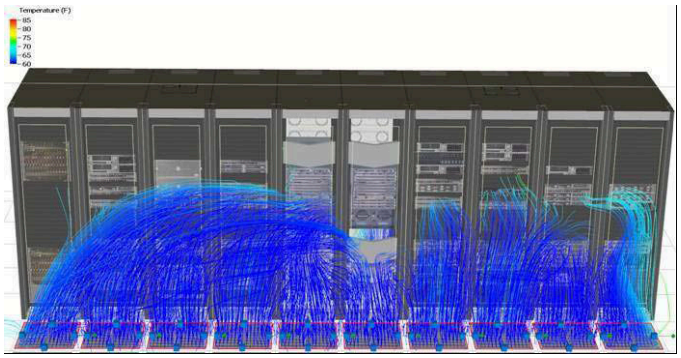

Figure 4. Plot from floor grills without cold aisle containment

Figure 5 shows how the air flows into the equipment inlets without cold aisle containment. The CFD model illustrates that the make-up air (air not delivered through the tiles) is composed of ambient air (light blue), warm remixed air recirculated overhead from behind the cabinets (yellow and green) and direct hot air exhaust through leakage areas within the cabinet (red).

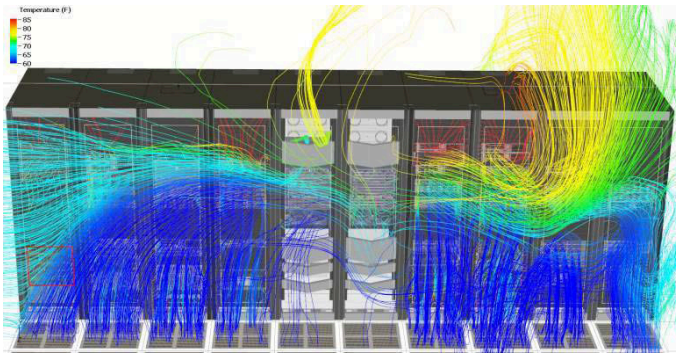

Figure 5. Plot from device inlets without cold aisle containment

Figure 6 shows the simulation view of airflow from the tiles with cold aisle containment. It also illustrates that cold aisle containment prevents end of row air recirculation. Thus the cold air from the tiles reaches more equipment located at the end of the rows.

With and without cold aisle containment the CFD models show that a large proportion of the cold air rushes to the rear fan doors in the central racks; and thus, the incoming cold air is unavailable for equipment cooling.

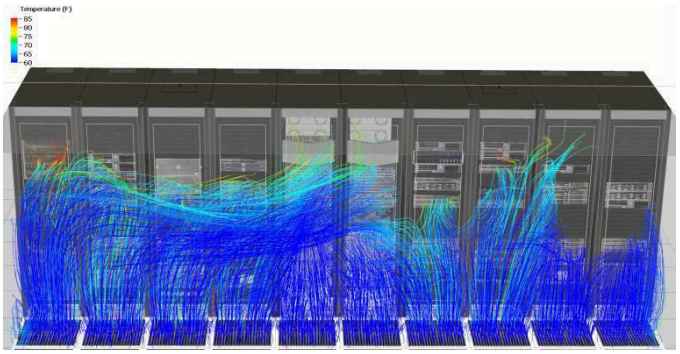

Figure 6. Plot from floor grills with cold aisle containment

Figure 7 shows how the air flows into the equipment inlets with cold aisle containment deployed. The CFD models show how effective the solution is at preventing overhead recirculation and ambient air from entering the containment field. However, when the demand air exceeds the supply, with cold aisle containment deployed, the make–up air can only come from leakage areas within the cabinet. This explains why some inlet temperatures increased.

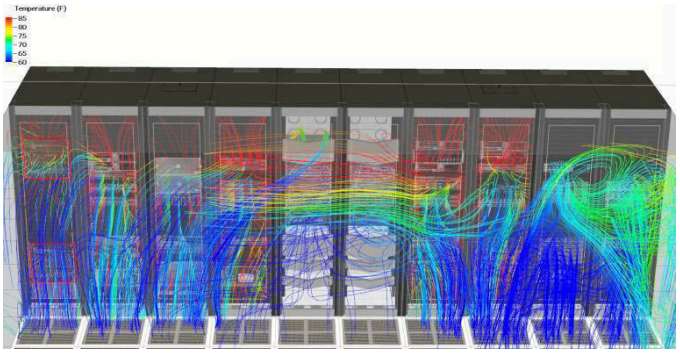

Figure 7. Plot from device inlets with cold aisle containment

After analyzing data center conditions, Eaton recommended sealing racks at the bottom and top, as well as filling in all side mounting rail gaps. Eaton also advised sealing the gaps between the floor and bottom of the cabinets.

In addition, Eaton counseled BayCare's data center team to:

- Turn off rear fan doors or replace them with perforated, vented doors.
- Increase the airflow supply from each floor tile to match the demand of the devices.
- Deploy cold aisle containment throughout Region A of the data center.

BayCare complied by replacing several perforated tiles with grate tiles and changing several components within the CRAC units to increase airflow supply. Seal kits were used to confine the leaks within the cabinets; and several fans, within the rear fan doors, were turned off. Results of these changes are shown in Figure 8.

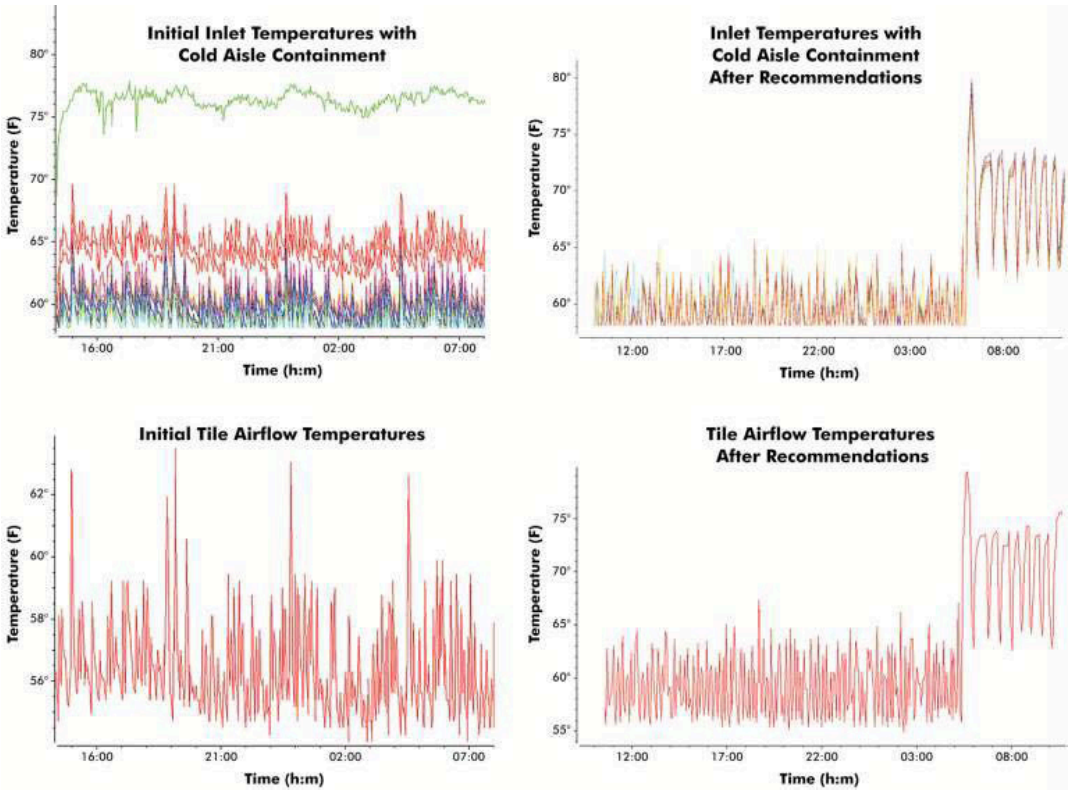

Figure 8. Comparing inlet and tile airflow temperatures before and after recommendations were deployed.

Prior to the recommended changes, the device inlet temperatures varied significantly from the supplied air temperature to the nearest floor tile. This variance was as much as 24°F. After the CFD proven recommended changes were implemented, the inlet air temperatures for all front-to-back flow equipment were within 1°F of the supply temperature. Providing lower, consistent inlet temperatures allowed BayCare to significantly increase the CRAC return temperatures without placing any rack mounted computer equipment at risk of overheating.

Conclusion

With the help of CFD simulation modeling, Eaton's cold aisle containment recommendations have provided BayCare Health Systems with more consistent inlet temperatures and increased energy savings in its data center.

About the Author

Brent Goren is a Data Center Consultant with Eaton where he provides technical expertise to assist clients in designing scalable, reliable and efficient data centers. He has in-depth knowledge in power and cooling in the data center and has taken a lead role in building a practice surrounding CFD modeling and airflow management. Prior to joining Eaton, Mr. Goren spent more than 15 years working within IT environments in various roles and capacities; the last three years dedicated to data center consolidation and relocation projects. Mr. Goren received Bachelors degrees in Electrical Engineering and General Sciences, from the University of Manitoba and has been a registered Professional Engineer since 1997.

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