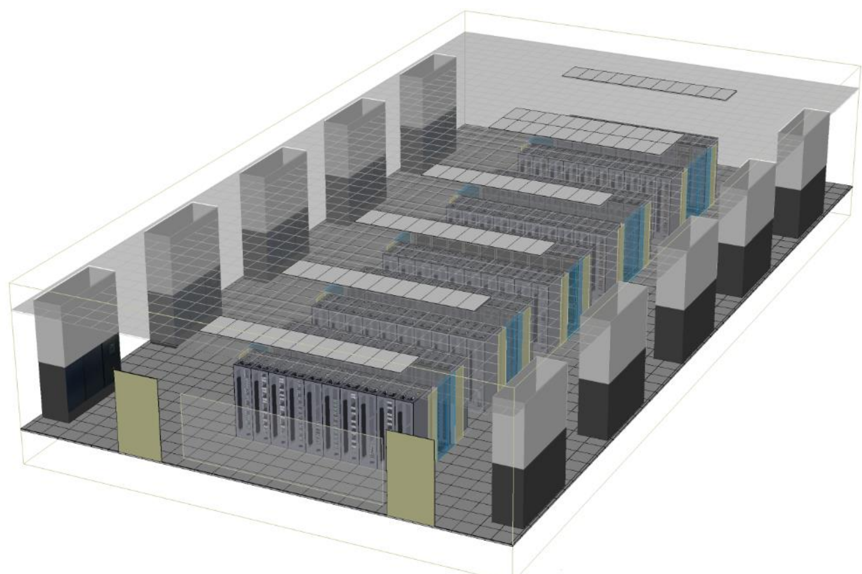
Enclosure and Airflow Management Solution

CFD Analysis Report



Des Plaines, Illinois

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Mission Critical Systems

Affiliated Engineers, Inc.

Contents

Executive Summary

Purpose of Study

IMS Engineered Products, AMCO enclosures engaged Affiliated Engineers, Inc. (AEI) to perform a computational fluid dynamic (CFD) analysis to study their IT enclosures and airflow management products. Future Facilities 6Sigma DC Room CFD software was used to evaluate the performance of their products.

The objective of the study is to leverage CFD modeling to predict performance of the AMCO Titan enclosures and airflow management solutions to identify energy savings. The evaluation simulated a 100 cabinet data center environment of 10 cabinet rows with 10 cabinets per row arranged in cabinet power densities that varied from 3.8kW to 34.5kW. The facility is modeled with an IT equipment load of 1,500 kW.

Multiple forms of AMCO's airflow management solutions were analyzed to evaluate the energy savings. The solutions were examined in an incremental method to differentiate each case. The models developed include

- Baseline with supply air temperature at 55 ^{o}F
- Baseline with supply air temperature at 75 ^{o}F
- Baseline with rail sealing kits and supply air temperature at 75 ^{o}F
- Hot Aisle End of Row Doors
- Cold Aisle End of Row Doors
- Cold Aisle Containment (CAC)
- Hot Aisle Containment (HAC)
- Hot and Cold Aisle Containment
- Cabinet Chimney Containment
- Cabinet Chimney Containment with Cold Aisle Containment

Summary of Results

The results of this study are intended to represent a facility with varying cabinet densities to provide a perspective on energy savings and operational outcomes. The results in this model will likely vary from site to site and will depend largely upon the IT equipment and control systems deployed. A successful model of the airflow management solution is represented as keeping the inlet temperature of the IT equipment at or below 80.6^{o}F (ASHRAE recommended Class A1 requirement) and minimizing the amount of additional supply airflow above the IT equipment airflow needs, noted as oversupply.

The modeling study of AMCO Titan enclosures and AMCO airflow management solutions concluded the following:

- The baseline model using a 75°F supply air temperature exhibited a maximum IT equipment inlet temperature of 132°F with an airflow oversupply of 238%.
- The models deploying end of row doors improved the IT equipment inlet temperatures by 30°F over the baseline with 75°F supply air. The solution falls short keeping only 20-30% of the cabinet intake temperatures within the ASHRAE recommended class A1 temperature range.
- Cold Aisle Containment (CAC) allowed over 90% of the cabinets to be within the ASHRAE recommended class A1 temperature range with an oversupply of 19%. The maximum recorded temperature was 80.9°F
- The Hot Aisle Containment (HAC) model allowed 84% of the cabinets to be within the ASHRAE recommended class A1 temperature range with an oversupply of 43%. The maximum recorded inlet temperature was 81.7°F
- Combining Cold and Hot Aisle Containment allowed all the cabinets to meet the ASHRAE recommended class A1 temperature range with a 19% oversupply.
- Cabinet Chimney Containment model allowed 48% of the cabinets to be within the ASHRAE recommended class A1 temperature range with a 19% oversupply. For cabinets with IT equipment airflow below 1380 CFM (17.kW @ 80 CFM/kW), a cabinet with a passive chimney would be a viable containment solution.

- When the AMCO Cabinet Chimney Containment is combined with AMCO's cold aisle containment, 72% of the cabinets are within the ASHRAE recommended class A1 temperature range with a 19% oversupply. The cabinets with higher density IT equipment loads above 22kW produced local cabinet leakage as a result of positive pressure in the rear of the cabinet. Leakage rates and temperatures were minimized through the use of cold aisle containment compared to the cabinet chimney containment model.

Computational Model

System Overview:

The data center white space has an area of 5,700 sq. ft. and air handlers located on two perimeter walls perpendicular to the cabinet rows. The room is occupied with 100 AMCO Titan cabinets arranged in 10 cabinet rows with 10 cabinets in each row. For this modeling study all lighting and other electrical loads are not included as part of this study.

The cooling strategy is based on vertical style down-flow air handling units located on the perimeter walls perpendicular to the IT equipment cabinets. The raised access floor plenum is pressurized from the air handlers allowing the air to enter the cold aisles through raised access floor grate tiles. These tiles have a 56% free area and do not contain a damper for shutoff or airflow control. After the air is processed by the IT equipment, the air will be returned to the air handlers through the use of a lay-in ceiling plenum. Each air handling unit provides 18,000 CFM of air to the raised floor plenum. The air handlers are connected to the ceiling plenum with an air handler plenum extension. The control method used in this analysis is a constant volume fan with a supply air temperature control algorithm.

Room Parameters:

Room Height: 14.0 ft. from top of raised floor to bottom of the lay in ceiling.

Raised floor plenum height: 4.0 ft.

Raised floor Grid Size: 2 ft. X 2 ft. 56% free area

Raised Floor Thickness: 2.0 in.

Raised Floor leakage: Gap size 0.02 in.

Lay-in Ceiling Plenum Height: 3.0 ft.

Lay-in Ceiling Grid Size: 2 ft. X 2 ft.

Lay-in Ceiling Grate Size: 2 ft. X 4 ft.

Lay-in Ceiling Thickness: 1.5 in.

Lay-in Ceiling Leakage: Gap Size 0.02 in.

Cabinet Construction

The AMCO TitanDT cabinet construction details are 51RU, 24 in. wide X 48 in. deep, open bottom, (10) brushed cable openings on the cabinet top with a 75% sealing efficiency. An 8" X 6" brush grommet is placed in the rear center of the cabinet with a sealing efficiency of 80%. Un-used rack U-space is blanked with a 5% leakage factor. In the models where the mounting rail air blocks are installed, a 3% leakage factor is applied.
Containment.
Frame for doors, chimney and ceiling AMCO extrusions 6061 Aluminum
Plastic for doors and aisle chimney Markolon GP .118" thick or Boltaron 4325
Ceiling Vintec .060" thick

Data Center Equipment Loads:

As part of the modeling initiative, the cabinet power densities were closely aligned with typical power strip capacities that would represent a cabinet loading scenario. As modeled, the data center has an electrical load of 1497.9kW with an additional 175kW of electrical load from the air handling equipment for a total room load of 1672.9kW. The IT equipment details, cabinet elevations, and operating conditions of the IT equipment used in the model can be found in Appendix A. The following table defines the row power capacity details.

Row #	Input Power Strip Plug	Volts	Amps	Phase	Power strip Capacity (kW)	Actual Row Power (kW)
1	L6-30P	208	30	1	5.0	43.3
2	L21-20P	208	20	3	5.8	38.2
3	L21-30P	208	30	3	8.6	72.1
4	IEC	208	60	1	10.0	91.0
5	L22-20P	400	20	3	11.1	108.2
6	CS6365C	208	50	3	14.4	143.4
7	IEC	208	60	3	17.7	172.8
8	IEC	208	80	3	23.0	225.7
9	IEC	208	100	3	28.8	258.0
10	HARDWAIRED	208	120	3	34.5	345.2
					Total Room IT Electrical Load	1497.9

Table 1. IT Equipment Cabinet Row Power Detail.

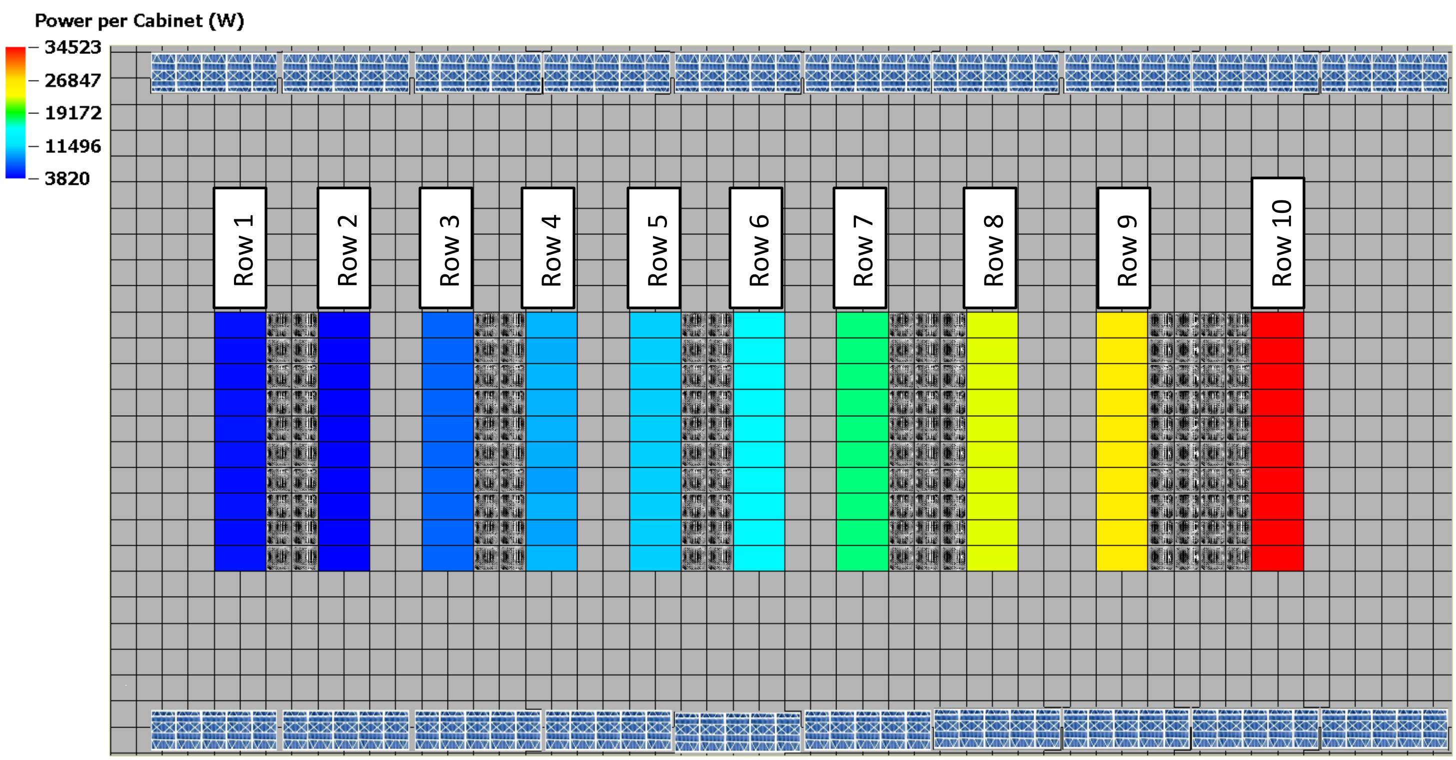


Figure 1. Data Center Floor Plan Describing Cabinet Power Densities.

Data Center Environmental Conditions:

In many traditional data center facilities the white spaces is maintained at very cold temperatures and typically supplied with 2-3 times the amount of air required by IT equipment. This operating scenario is due to poor airflow management and a perception about IT equipment operation.

For facilities that operate with newer IT equipment, the environmental parameters of the operating equipment has greatly increased. The increased IT equipment inlet temperature conditions allow for inlet temperatures of IT equipment to be 15-20°F higher than former industry standards. The increased operating temperatures allows more hours of economization and typically a reduction in cooling plant energy use.

The following table and psychometric chart demonstrate the most recent operating conditions for data center IT equipment. The operating conditions represent the temperature at the inlet to the IT equipment.

Classes (a)	Equipment Environmental Specifications							
	Product Operations (b)(c)					Product Power Off (c) (d)		
	Dry-Bulb Temperature (˚C) (e) (g)	Humidity Range, non-Condensing (h) (i)	Maximum Dew Point (˚C)	Maximum Elevation (m)	Maximum Rate of Change(˚C/hr) (f)	Dry-Bulb Temperature (˚C)	Relative Humidity (%)	Maximum Dew Point (˚C)
Recommended (Applies to all A classes; individual data centers can choose to expand this range based upon the analysis described in this document)								
A1 to A4	18 to 27	5.5ºC DP to 60% RH and 15ºC DP						
Allowable								
A1	15 to 32	20% to 80% RH	17	3050	5/20	5 to 45	8 to 80	27
A2	10 to 35	20% to 80% RH	21	3050	5/20	5 to 45	8 to 80	27
A3	5 to 40	-12˚C DP & 8% RH to 85% RH	24	3050	5/20	5 to 45	8 to 85	27
A4	5 to 45	-12˚C DP & 8% RH to 90% RH	24	3050	5/20	5 to 45	8 to 90	27
B	5 to 35	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29
C	5 to 40	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29

Table 2. ©ASHRAE 2011 Thermal Guidelines.[1]

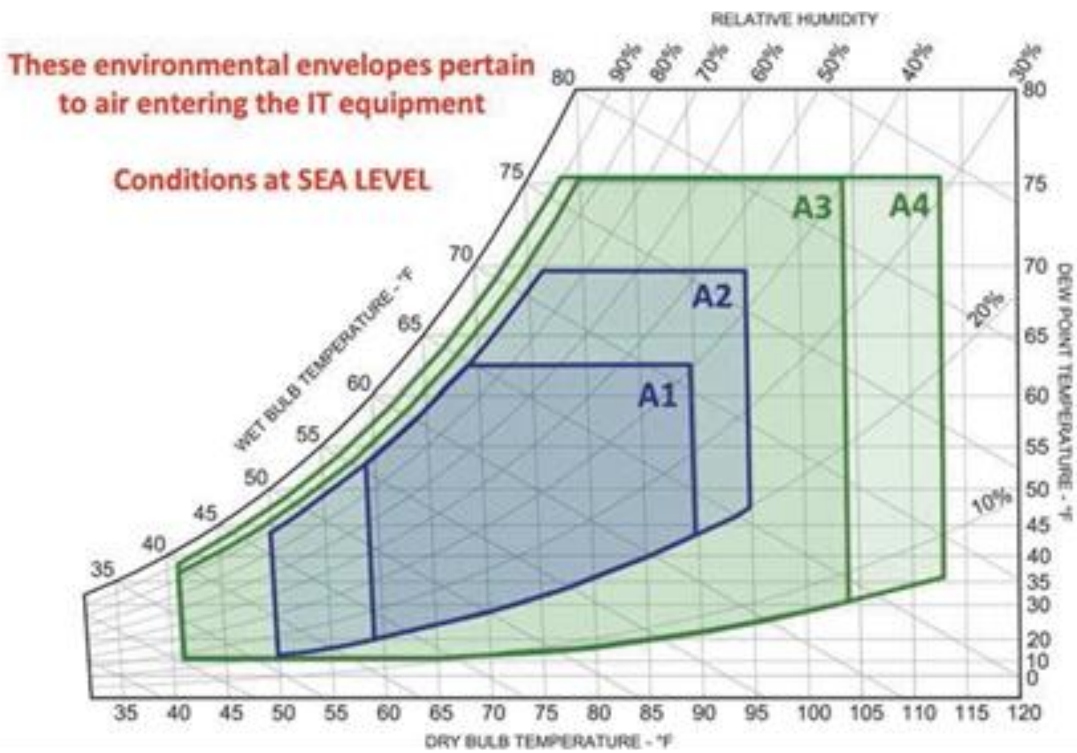


Figure 2. Psychometric chart ©ASHRAE 2011 Thermal Guidelines.[1]

The approved conditions noted above refer primarily to new IT equipment and hardware. Some legacy IT equipment and tape storage systems need careful review of acceptable conditions especially when examining the use of an allowable temperature range conditions.

CFD Modeling Discussion:

Baseline with Supply Air Temperature at 55°F

Baseline with Supply Air Temperature at 55°F Conditions Summary					
IT Equipment Airflow (CFM)	**Air Handler Supplied Airflow (CFM)**	**Airflow Oversupply**	**Supply Air Temperature (°F)**	**Maximum Inlet Temperature (°F)**	**Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition**
151273.2	360000	238%	55.0	115.0	32%

The baseline model developed for this study includes (20) 18,000 CFM air handlers distributed on two perimeter walls of the data center white space. Figures 3 & 4 below represent the data center floor plan for the baseline scenario.

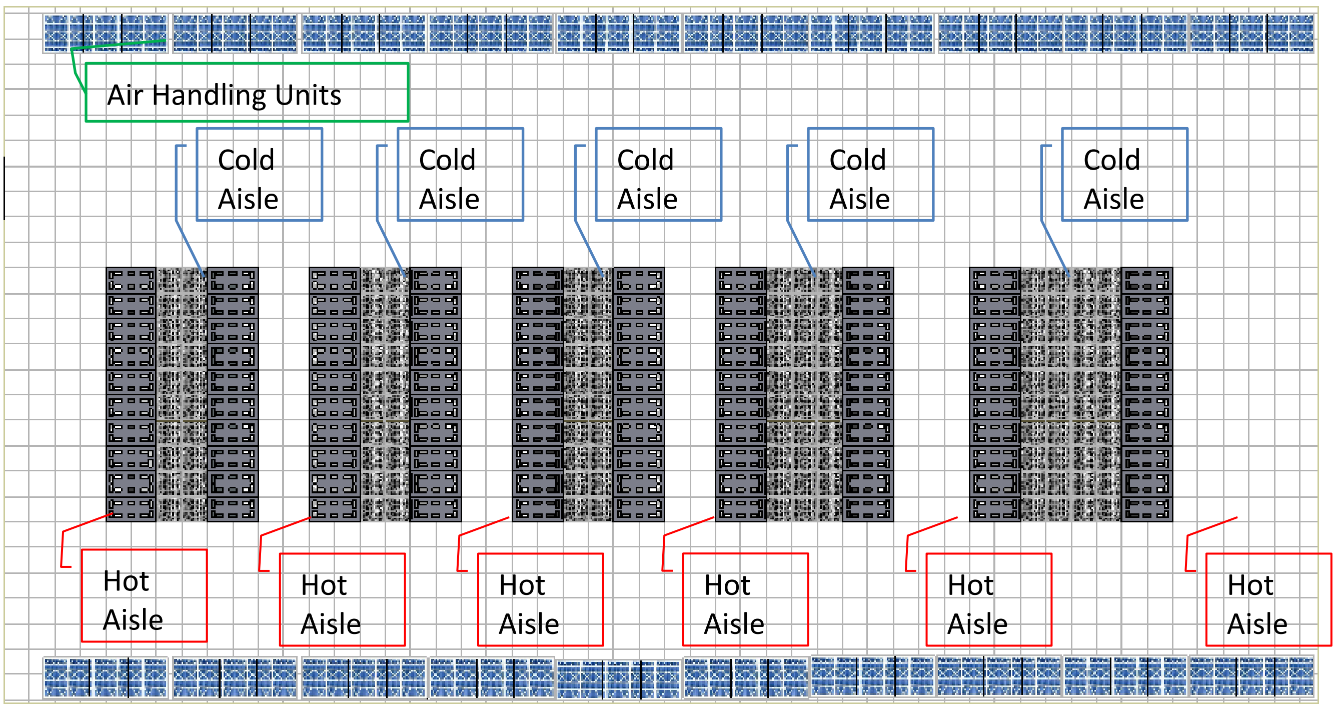


Figure 3. Plan View of Baseline Data Center Floor Layout.

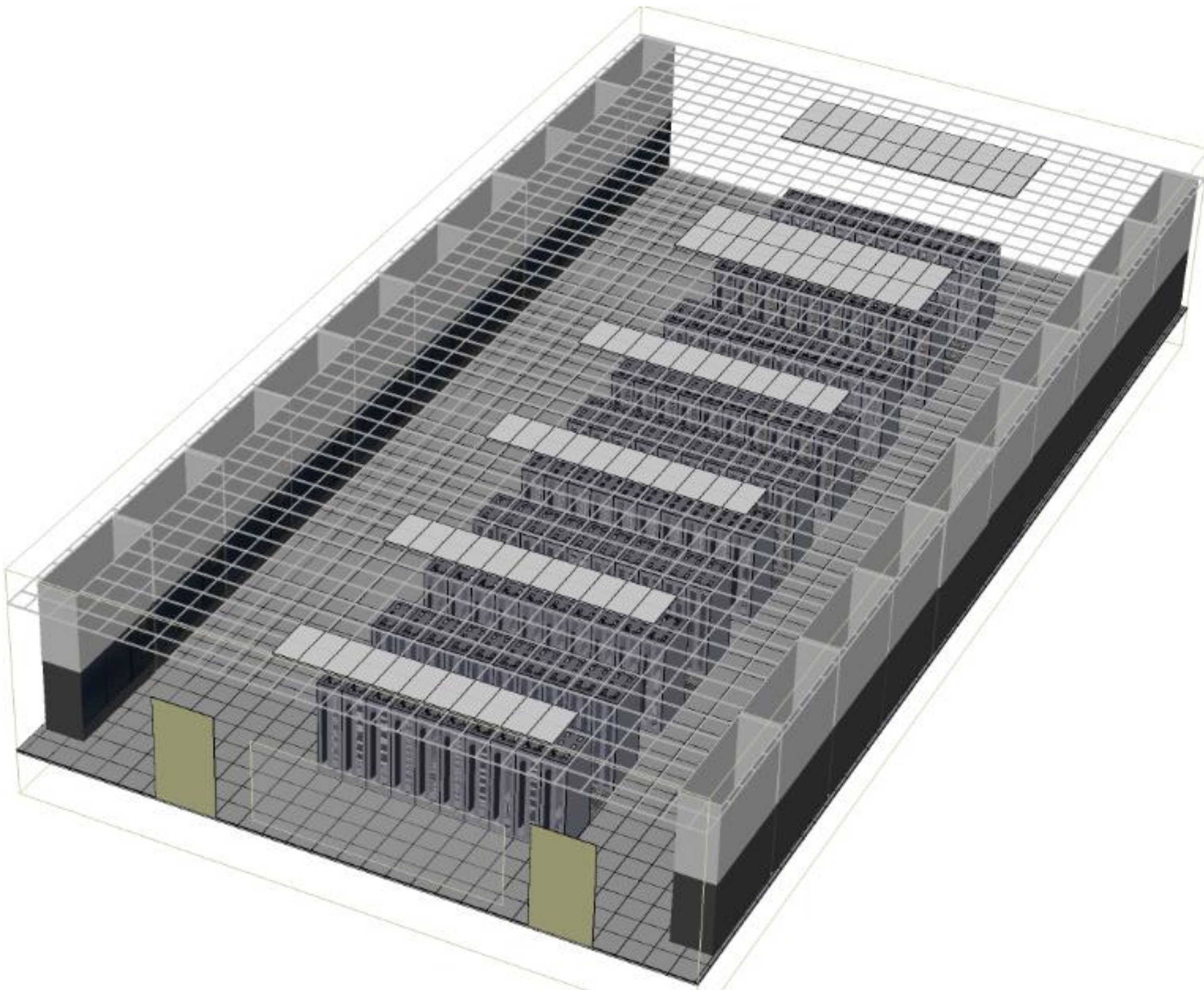


Figure 4. Isometric View of Data Center Floor Plan.

The ceiling above the hot aisles uses ceiling grates to allow the hot IT equipment exhaust air to enter the ceiling plenum. This method of air return minimizes the short cycling of supply air.

This baseline model uses a traditional cooling supply air temperature of 55°F delivered from the air handlers. The cabinets are raised above the floor 1.9” to simulate castors and leveling legs. The IT equipment mounting rails do not have sealing kits around the perimeter.

In figure 5, the facility is uncontained and lacks any airflow management at the cabinet level. There's significant air mixing and inlet temperatures that exceed the ASHRAE 2011 class A1 recommended temperature range.

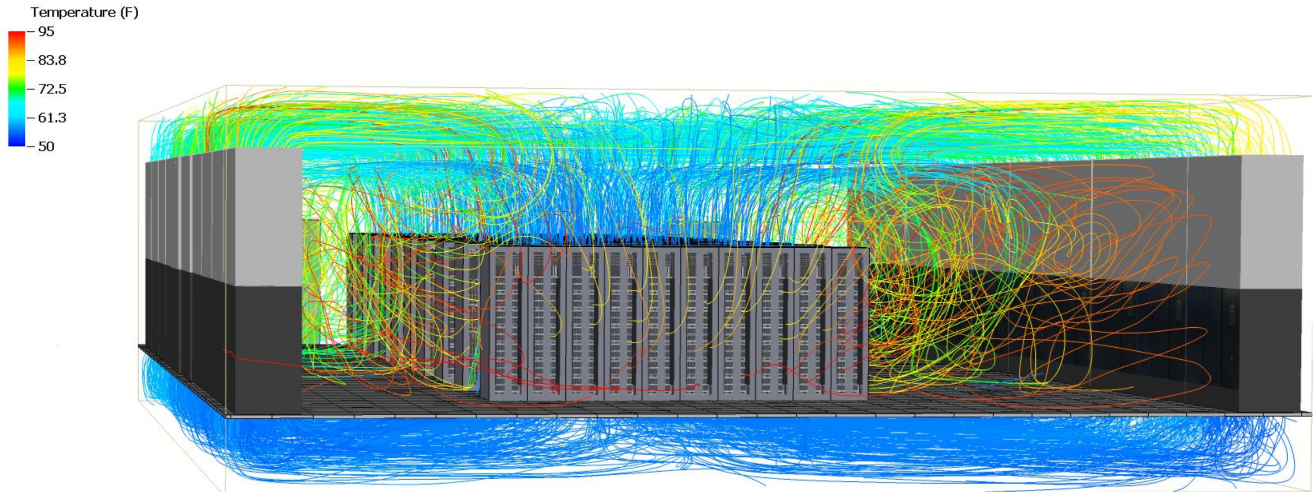


Figure 5. Streamline Plot of the Uncontained Data Center with Air Mixing at a 55°F Supply Air Temperature.

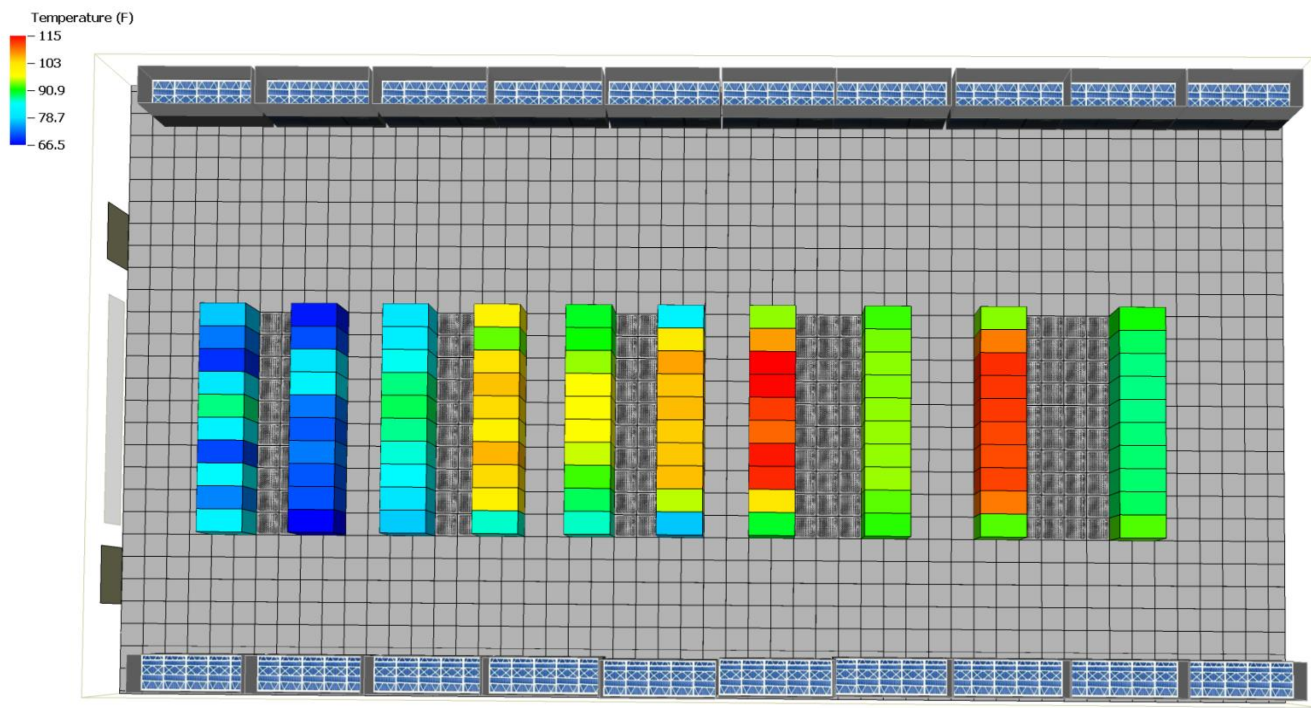


Figure 6. Maximum IT Equipment Inlet Temperature Plot.

This model demonstrates with a low supply air temperature of 55°F and an oversupply of 2.4 times the required IT airflow the IT inlet temperatures are above 80.6°F. To accommodate the goal of keeping all IT equipment inlet temperatures at or below 80.6°F a lower supply air temperature and more air will be required using additional energy.

Baseline with Supply Air Temperature at 75°F

Baseline with Supply Air Temperature at 75°F Conditions Summary					
IT Equipment Airflow (CFM)	Air Handler Supplied Airflow (CFM)	Airflow Oversupply	Supply Air Temperature (°F)	Maximum Inlet Temperature (°F)	Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition
151273.2	360000	238%	75.0	132.0	0%

In this baseline model, the same parameters from the previous baseline were used but the supply air temperature in this model has been adjusted to 75°F.

In this model the AMCO Titan cabinets are raised above the floor 1.9" to simulate castors and leveling legs. The IT equipment mounting rails do not have sealing kits around the perimeter. In Figure 8 below, the facility is uncontained and lacks airflow management at the cabinet level. There's significant air mixing and inlet temperatures that exceed the ASHRAE 2011 class A1 recommended temperature range. Temperatures are nominally 20°F higher than the model using a 55°F supply air temperature.

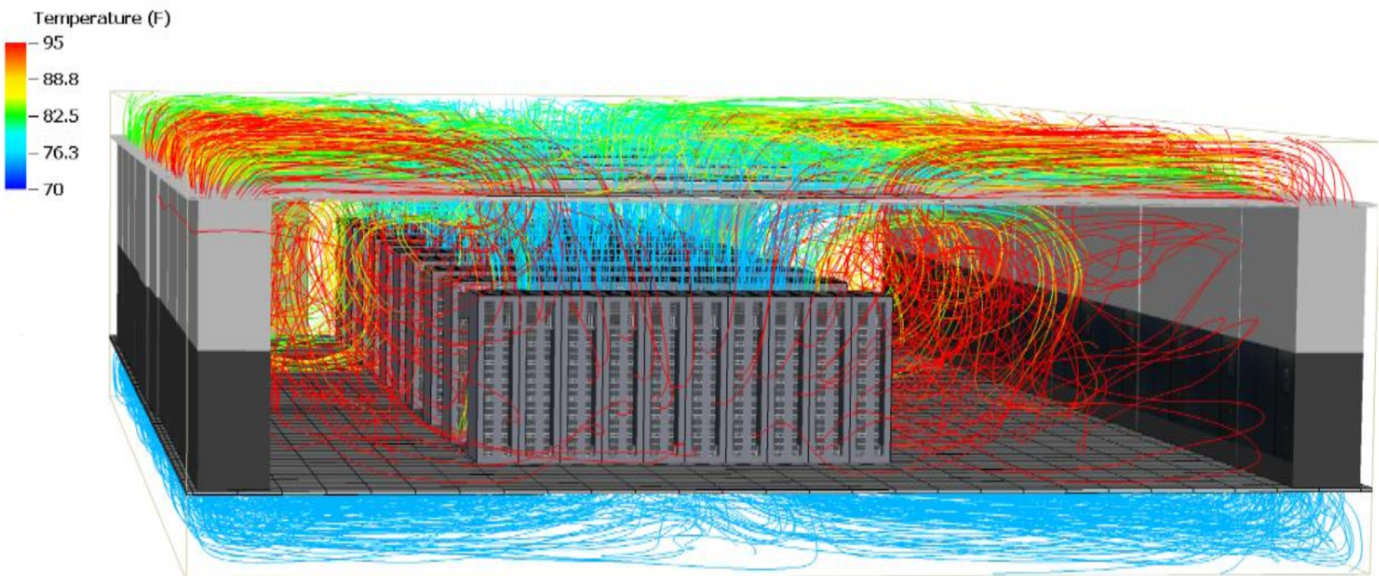


Figure 7. Streamline Plot of the Uncontained Data Center with Air Mixing at a 75°F Supply Air Temperature.

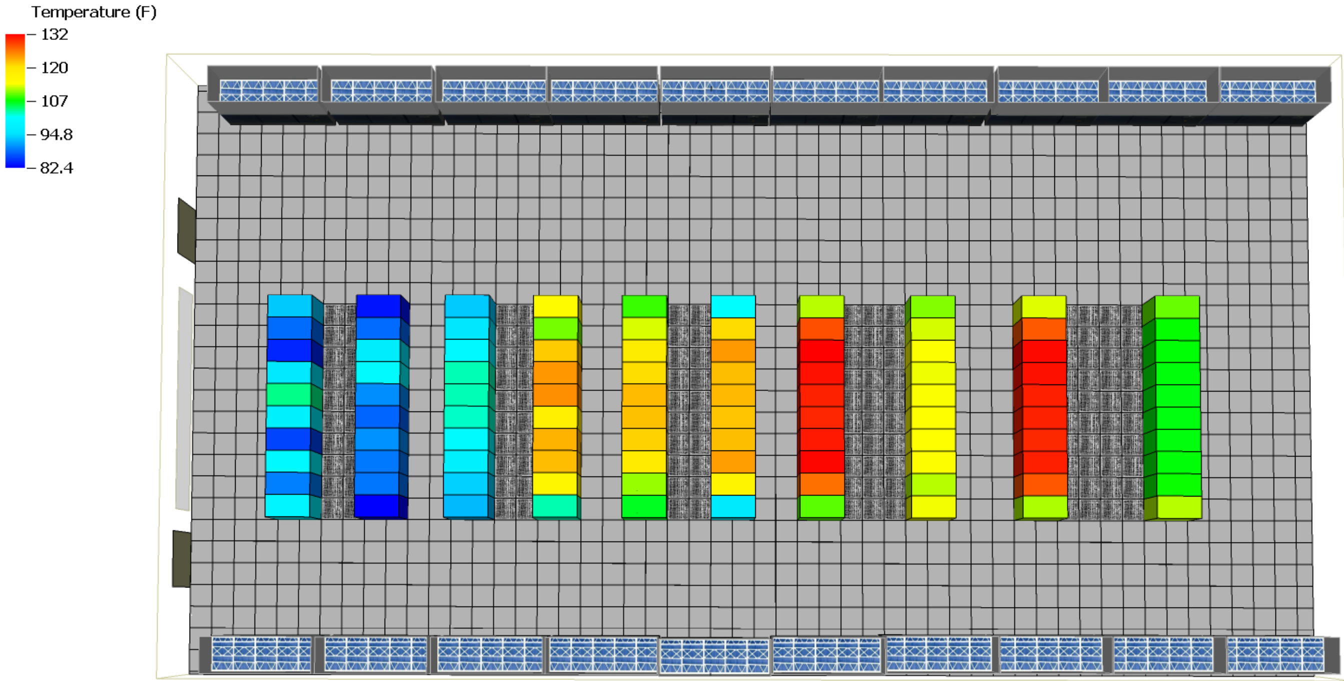


Figure 8. Maximum IT Equipment Inlet Temperature Plot.

The inlet temperatures to the IT equipment are above 80.6°F with a supply air temperature of 75°F and an oversupply of 2.4 times the required IT airflow. To accommodate the goal of keeping all IT equipment inlet temperatures at or below 80.6°F, a lower supply air temperature and more air will be required using additional energy.

Baseline with Rail Sealing Kits and Supply Air Temperature at 75°F

Baseline with Rail Sealing Kits and Supply Air Temperature at 75°F Conditions Summary					
IT Equipment Airflow (CFM)	**Air Handler Supplied Airflow (CFM)**	**Airflow Oversupply**	**Supply Air Temperature (°F)**	**Maximum Inlet Temperature (°F)**	**Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition**
151273.2	360000	238%	75.0	106.0	25%

In this baseline model adjustments are made to block air migrating from the hot aisle to the cold aisle under the AMCO Titan cabinet and around the side rails. By placing the AMCO cabinet directly on the raised floor with no leveling legs or castors, the model simulates an air block at the base of the cabinet to prevent hot air migrating from the hot aisle to the cold aisle. In addition air blocks were installed around the IT equipment mounting rails with a simulated leakage rate of 3%. The supply air temperature of 75°F and volume of air remain unchanged in this model.

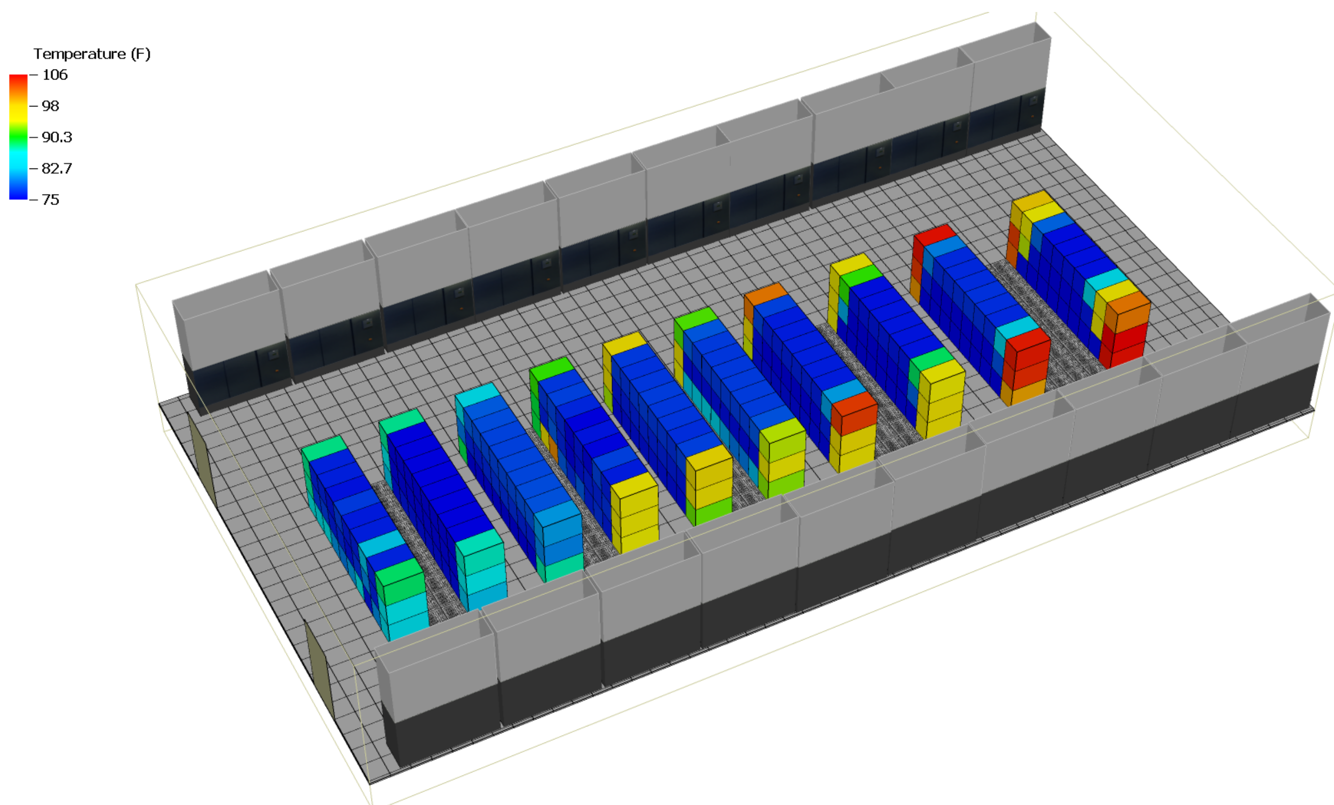


Figure 9. Maximum Cabinet Vent Inlet Temperature Plot.

In this model compared with the previous two models the temperature stability at the bottom of the AMCO cabinet is improved and the inlet temperatures to the IT equipment is reduced. This model also exhibits greater temperature stability for the cabinets residing in the center of the cabinet row. However many of the cabinet's still exhibit higher inlet temperatures and above the ASHRAE 2011 class A1 recommended temperature range of 80.6°F.

Figures 10 & 11 demonstrate hot air influencing the cold aisles and IT equipment intake temperature at the end of the row. The next models will demonstrate multiple forms of airflow management to reduce and eliminate air mixing.

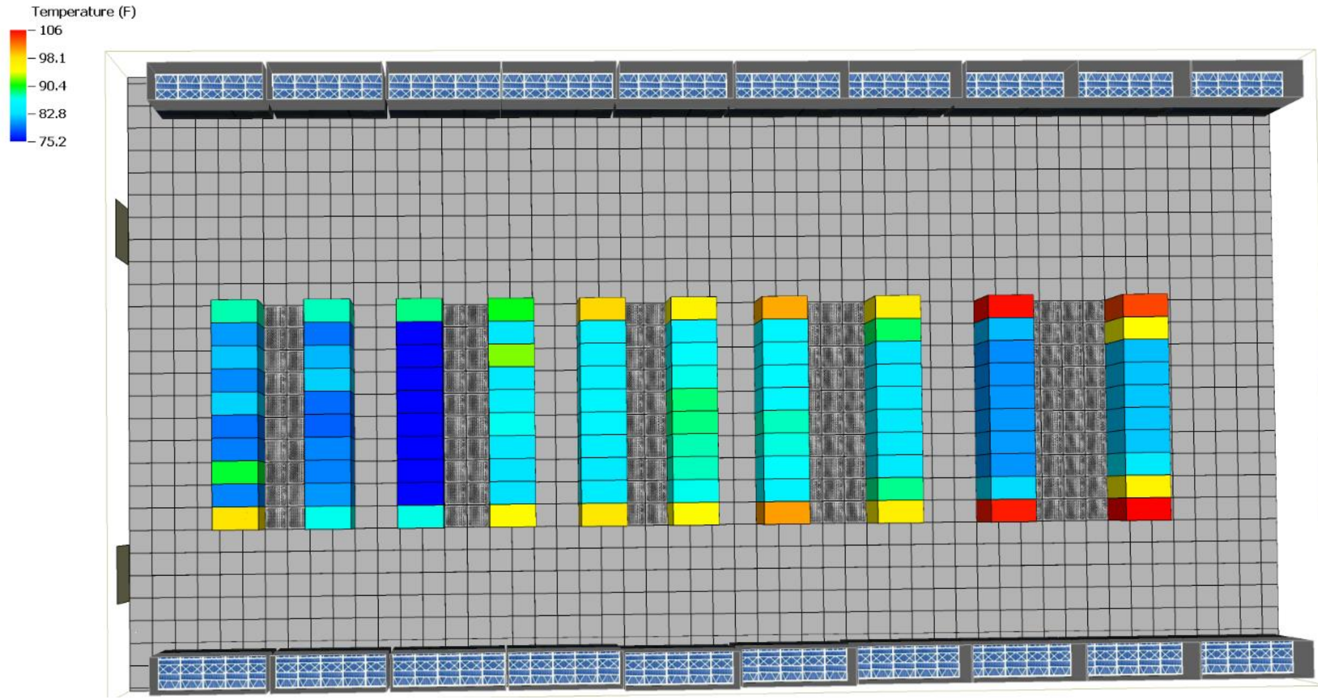


Figure 10. Maximum Cabinet IT Equipment Intake Temperature Plot.

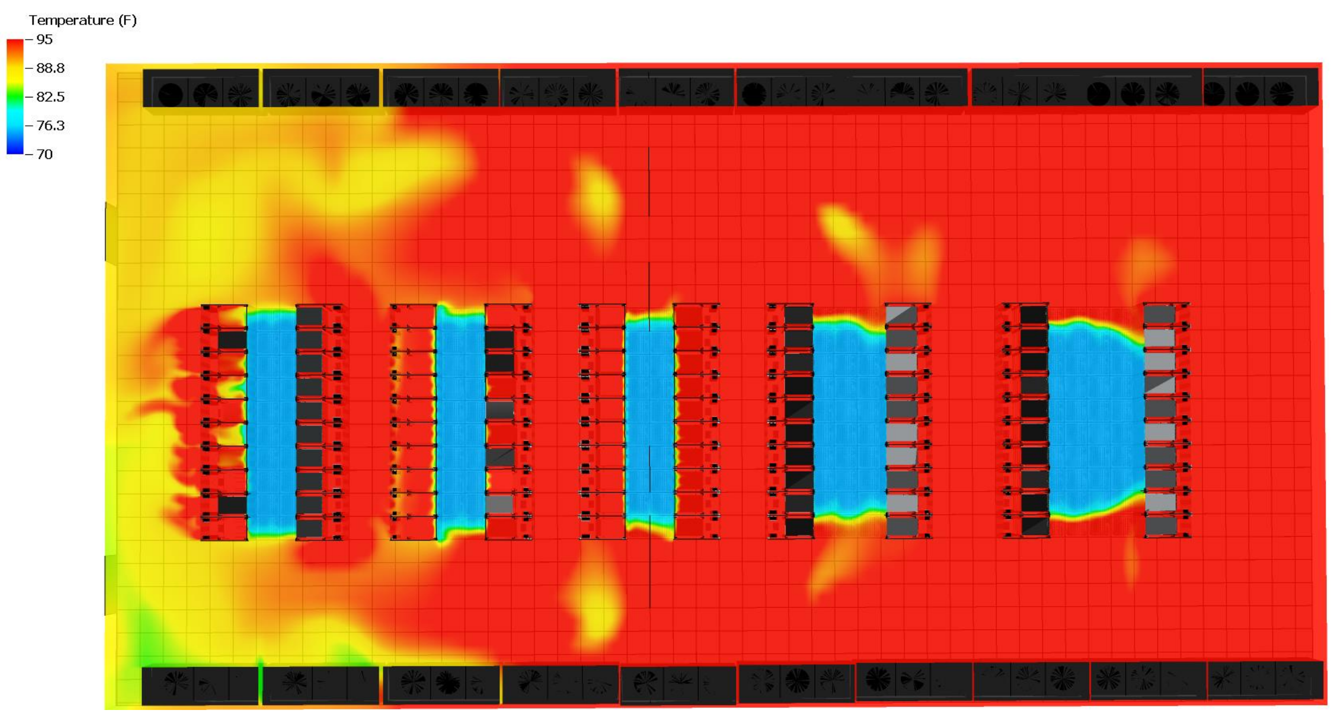


Figure 11. Plan View Temperature Plot at 6' Above Raised Floor.

Hot Aisle End of Row Doors

Hot Aisle End of Row Doors Condition Summary					
IT Equipment Airflow (CFM)	Air Handler Supplied Airflow (CFM)	Airflow Oversupply	Supply Air Temperature (°F)	Maximum Inlet Temperature (°F)	Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition
151273.2	360000	238%	75.0	95.2	31%

A common first step in approaching airflow management and containment is to prevent hot air from influencing the cold aisles. One approach to this is blocking doors at the end of the row to prevent hot air or cold air from spilling into the room.

The figure below demonstrates the use of IMS AMCO end of row doors placed at the end of the hot aisles. The hot aisles that weren't defined between two cabinet rows assumed a wall was installed where the other cabinet row would be located.

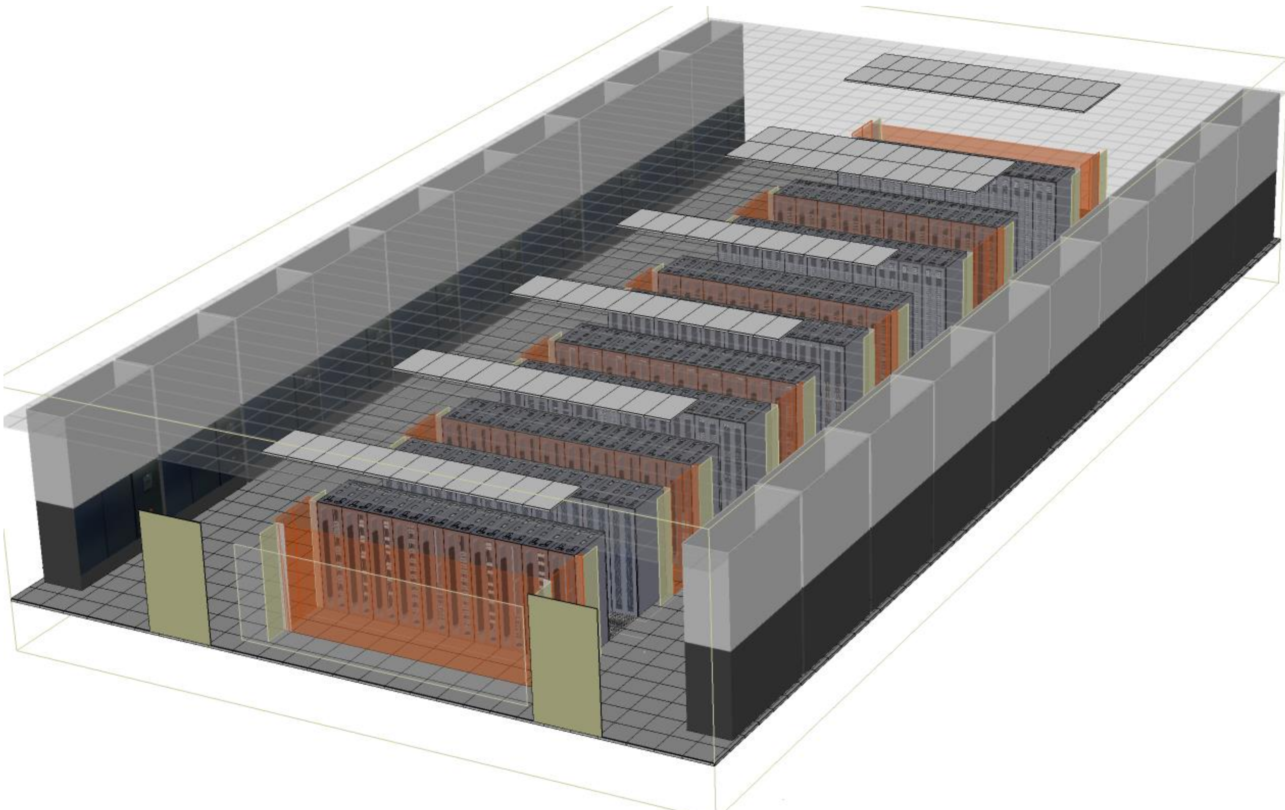


Figure 12. Isometric View of Data Center with Hot Aisle End of Row Doors.

Figure 13 demonstrates the temperature stability while using IMS AMCO end of row doors installed at the end of the hot aisles. A considerable decrease in temperature at the end of the aisle is noticed compared to the previous models without end of row doors. A decrease in temperature of at least 10°F is noticed in multiple locations at the end of the row compared to the previous models.

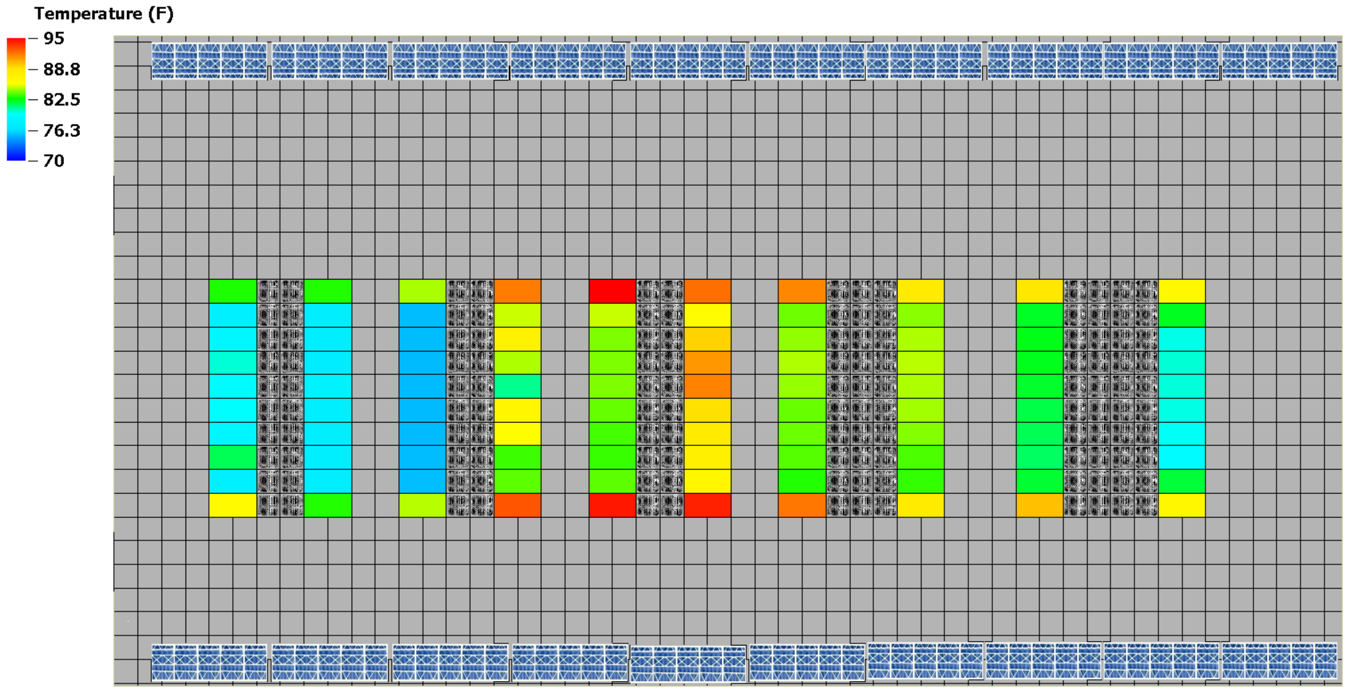


Figure 13. Maximum Cabinet IT Equipment Intake Temperature Plot.

Figure 14 highlights the pooling of hot air in the hot aisles. Since the hot air is not fully contained and given a direct path back to the air handlers, the hot air has the opportunity to migrate and mix with the cold air. As noticed in the figure below the cold aisles are still influenced by the hot air at the end of the aisles.

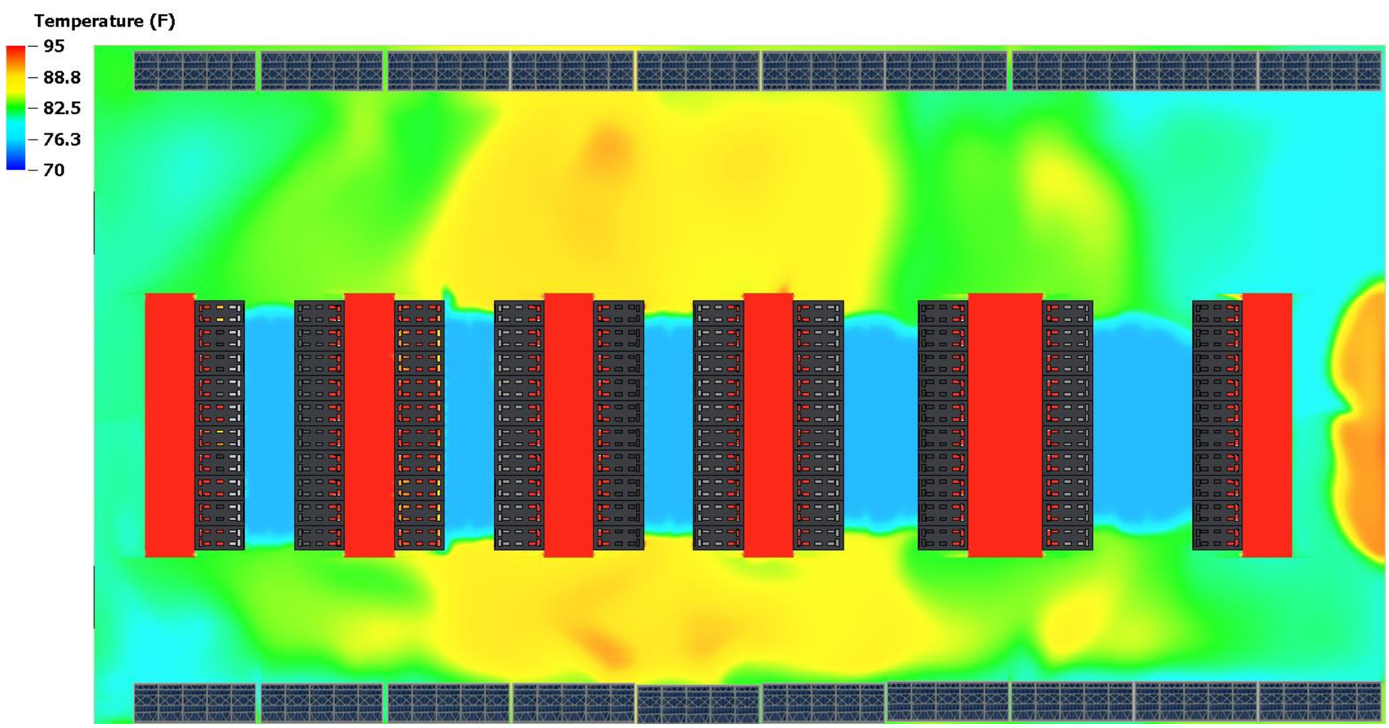


Figure 14. Plan View Temperature Plot at 6' Above Raised Floor.

Cold Aisle End of Row Doors

Cold Aisle End of Row Doors Condition Summary					
IT Equipment Airflow (CFM)	**Air Handler Supplied Airflow (CFM)**	**Airflow Oversupply**	**Supply Air Temperature (°F)**	**Maximum Inlet Temperature (°F)**	**Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition**
151273.2	360000	238%	75.0	102.0	20%

Another option for airflow management at the aisle level is to install doors at the end of the cold aisle. Figure 16 demonstrates the further improved intake temperatures at the cabinet level and at the end of the cabinet row. Many cabinet intake temperatures are further decrease beyond the gains with the hot aisle end of row doors.

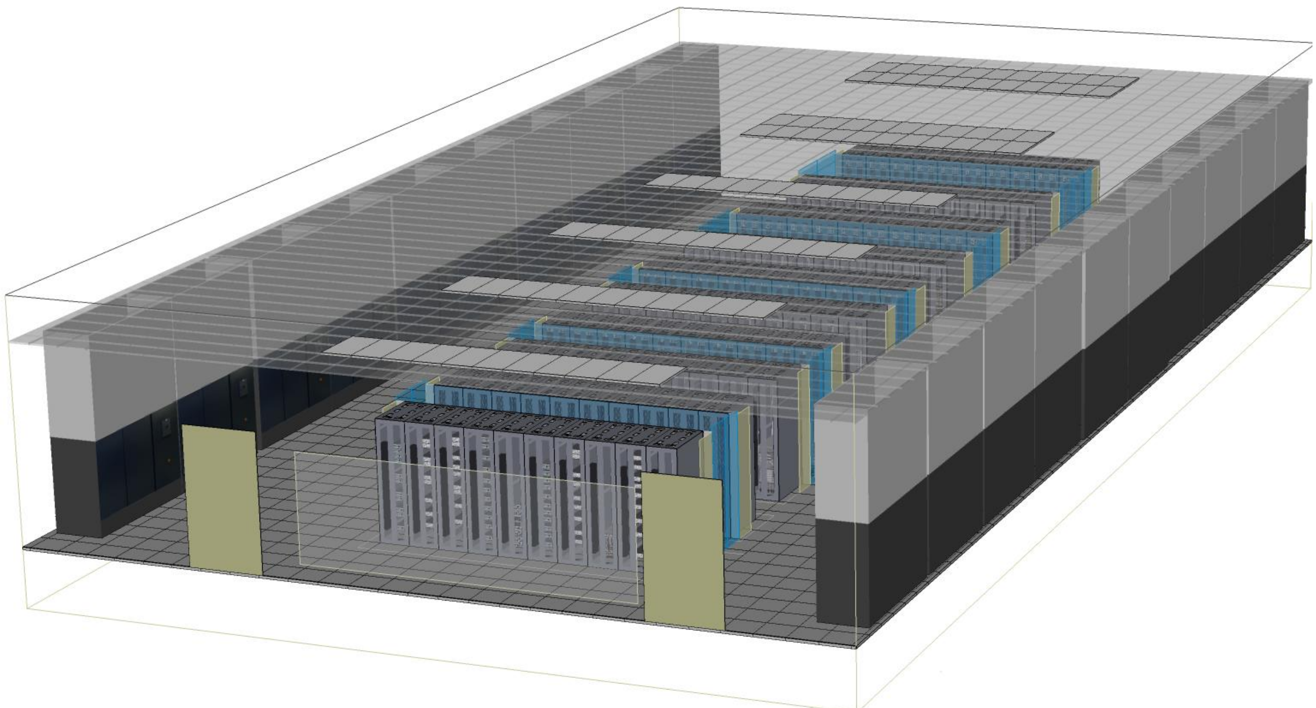


Figure 15. Isometric View of Cold Aisle End of Row Doors.

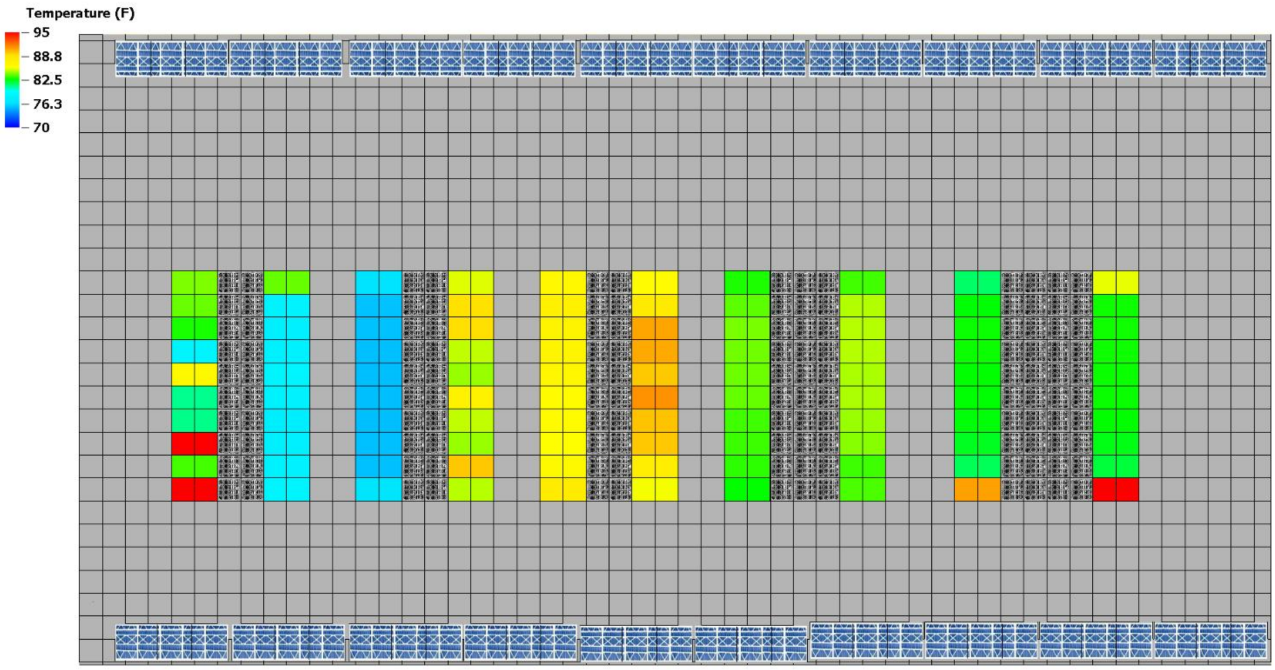


Figure 16. Maximum Cabinet IT Equipment Intake Temperature Plot.

Similar to the hot aisle end of row door model with pooled hot air, the cold air is pooled with the use of the cold aisle end of row doors. However in some areas the hot air still navigates into the cold aisle mixing with the cold air and affecting the IT equipment inlet temperatures. Hot air influencing the end of the rows is highlighted in the figure 17.

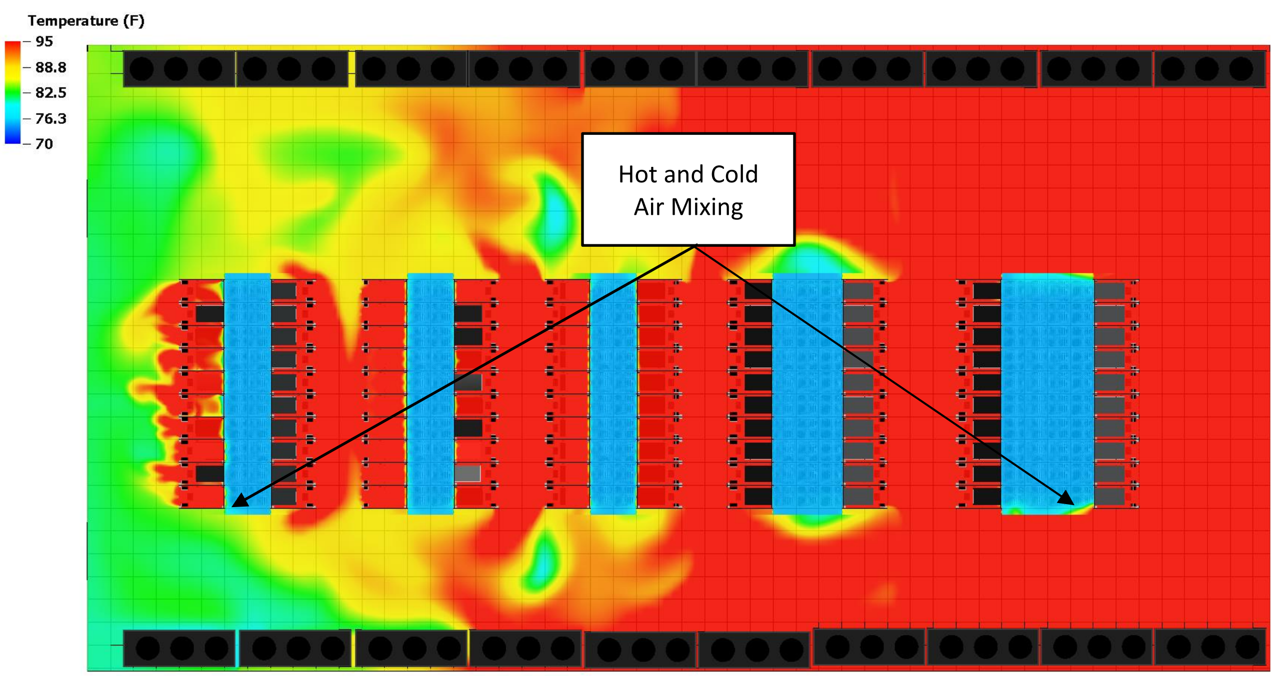


Figure 17. Plan View Temperature Plot at 6' Above Raised Floor.

Cold Aisle Containment (CAC)

Cold Aisle Containment Conditions Summary					
IT Equipment Airflow (CFM)	Air Handler Supplied Airflow (CFM)	Airflow Oversupply	Supply Air Temperature (°F)	Maximum Inlet Temperature (°F)	Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition
151273.2	180000	19%	75.0	80.9	93%

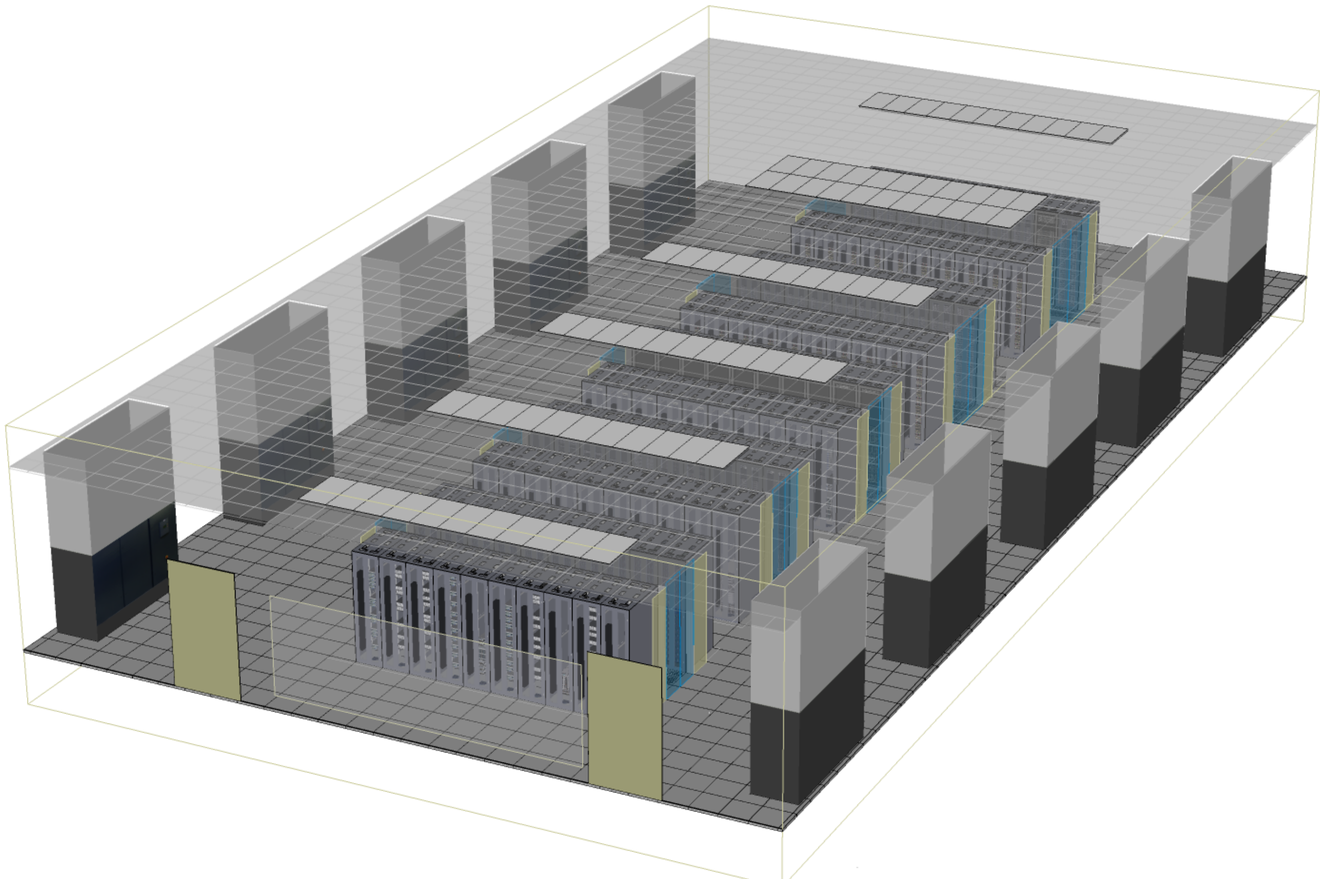


Figure 18. Isometric View of Cold Aisle Containment Layout

The previous models and figures with AMCO end of row doors demonstrated an improved and more stable IT equipment inlet temperature. However there are still additional methods for further separating the hot and cold air to improve temperatures at the inlet to the IT equipment. In addition to improved temperature stability, less air from the air handlers is required.

One method for fully containing the cold air is by using AMCO Cold Aisle Containment (CAC). CAC uses end of row doors at the end of the cold aisle and adds a "roof" over the cold aisle. By adding an AMCO roof over the cold aisle the cold air is fully processed by the IT equipment. Additionally, by fully enclosing the cold aisle, hot air cannot be entrained into the cold aisle to affect the IT equipment intake temperatures. The figures 19 & 20 demonstrate the difference between end of row doors and fully enclosing the cold aisle. The temperature stability is representative of an outcome using IMS AMCO's cold aisle containment products.

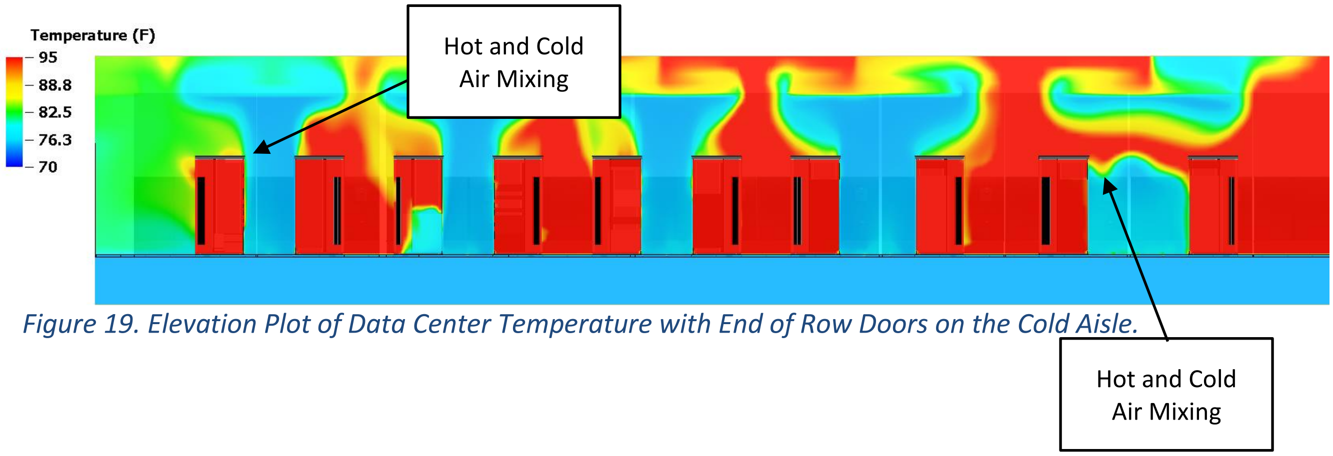


Figure 19. Elevation Plot of Data Center Temperature with End of Row Doors on the Cold Aisle.

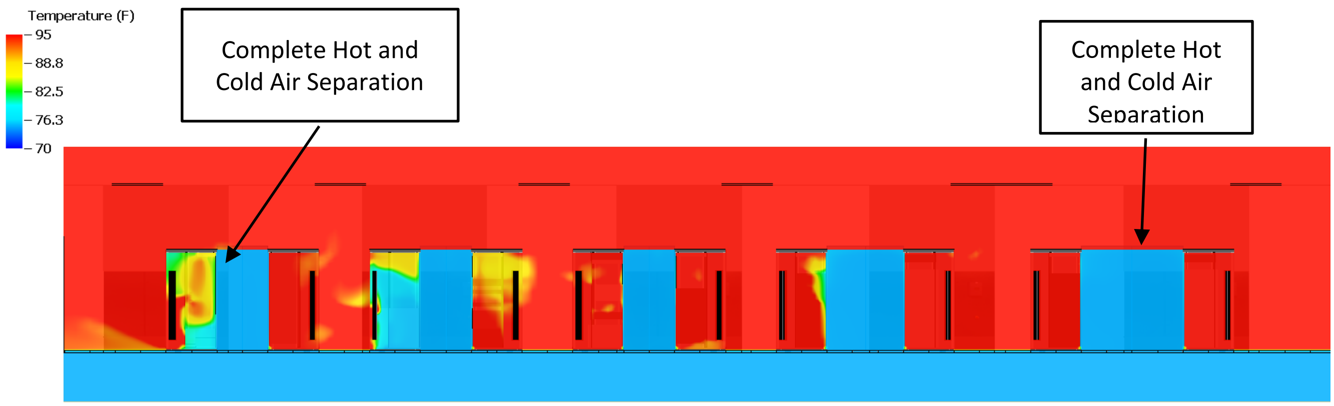


Figure 20. Elevation Plot of Data Center Temperature with Cold Aisle Containment.

After initial modeling iterations the number of air handlers when using IMS AMCO's cold aisle containment was decreased from 20 to 10 units; a decrease of 180,000 CFM. The 10 air handlers provide a volume of air similar to the required volume of air by the IT equipment.

Figures 21 & 22 represent the maximum inlet temperature to the IT equipment. The highest inlet temperature recorded was 80.9°F which only occurred at the bottom of 7 cabinets with power densities greater than 20kW. This temperature is slightly higher than the ASHRAE 2011 Class A1 recommended temperature of 80.6°F. With higher temperature occurring consistently toward the bottom of the cabinet additional sealing at the bottom of the cabinet or moving the IT equipment to a higher u-space in the cabinet would be recommended to mitigate the issue.

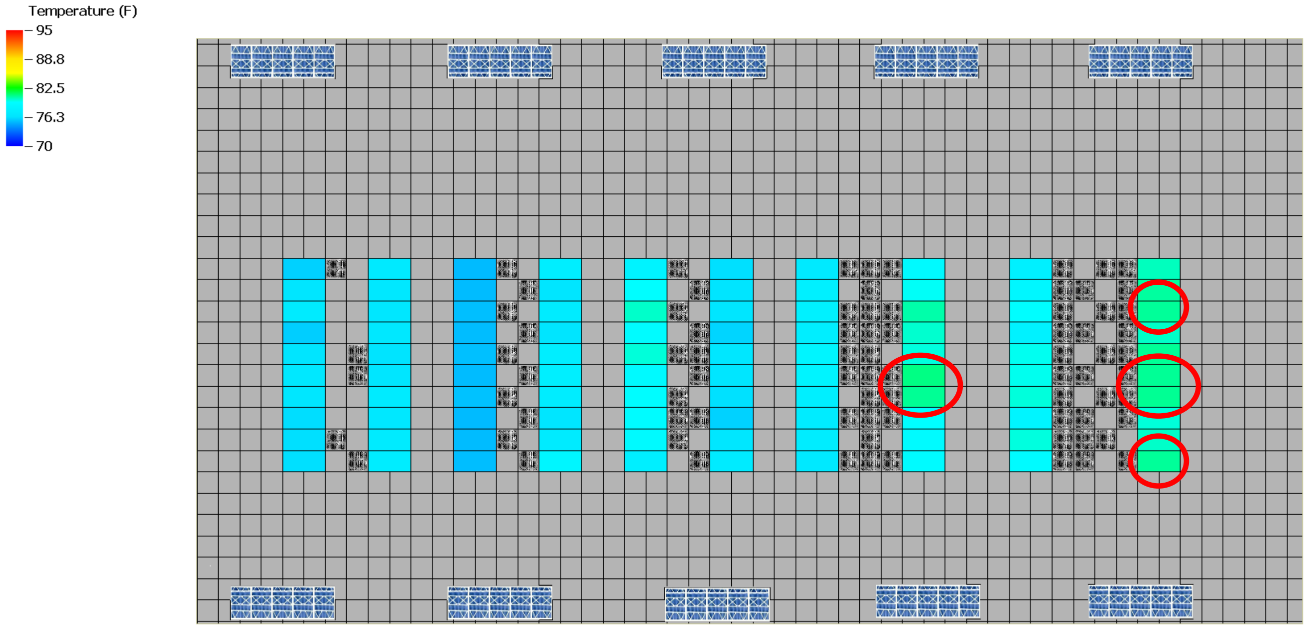


Figure 21. Plan View Plot of the Maximum Cabinet Intake Temperature.

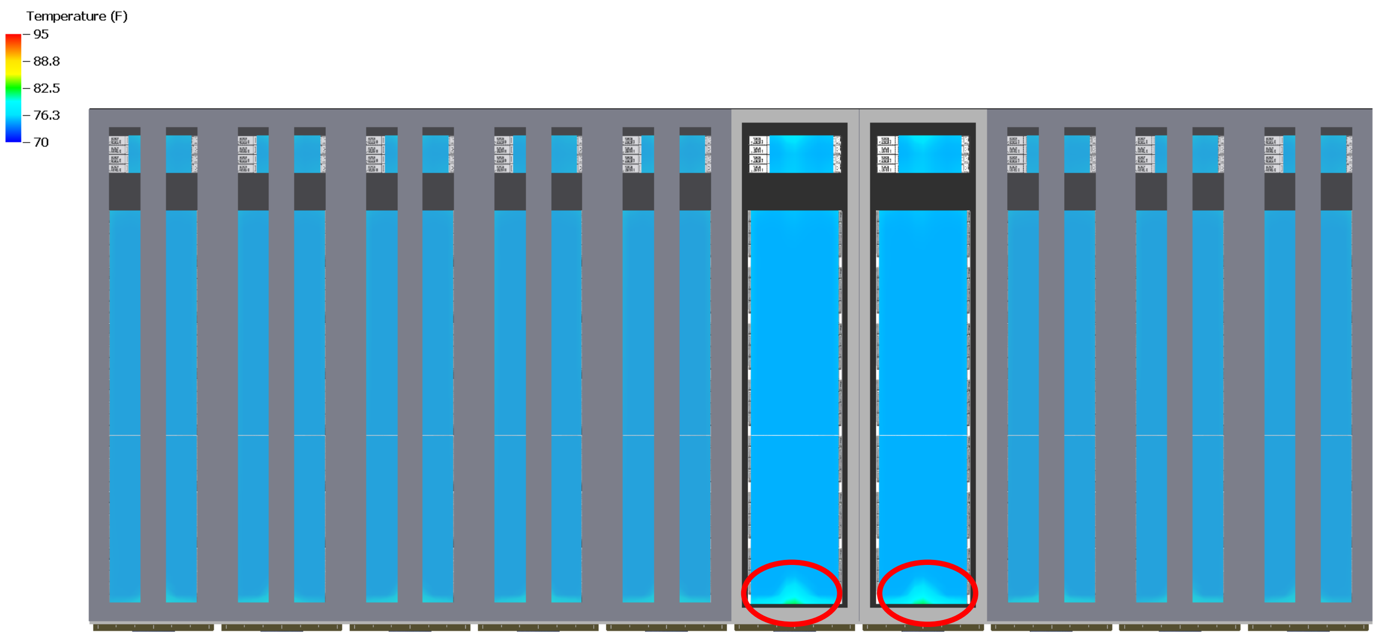


Figure 22. IT Equipment Intake Temperature Plot in an Elevation View of Row 8 Cabinets.

Figure 23. IT Equipment Intake Temperature Plot in an Elevation View of Row 10 Cabinets.

The cabinet elevations shown in figures 22 & 23 demonstrate increased temperatures in regions located directly behind the intersection of the two cabinet front doors. This can be attributed to a low pressure region directly behind the blocked area from the cabinet front doors with higher velocity air coming through the vents.

Below is an example of a cabinet elevation with the front door perforations expanded to the edges of the cabinet to show implications of a full perforated door. The increased inlet temperatures are at the edges of the cabinet closest to the airflow restriction.

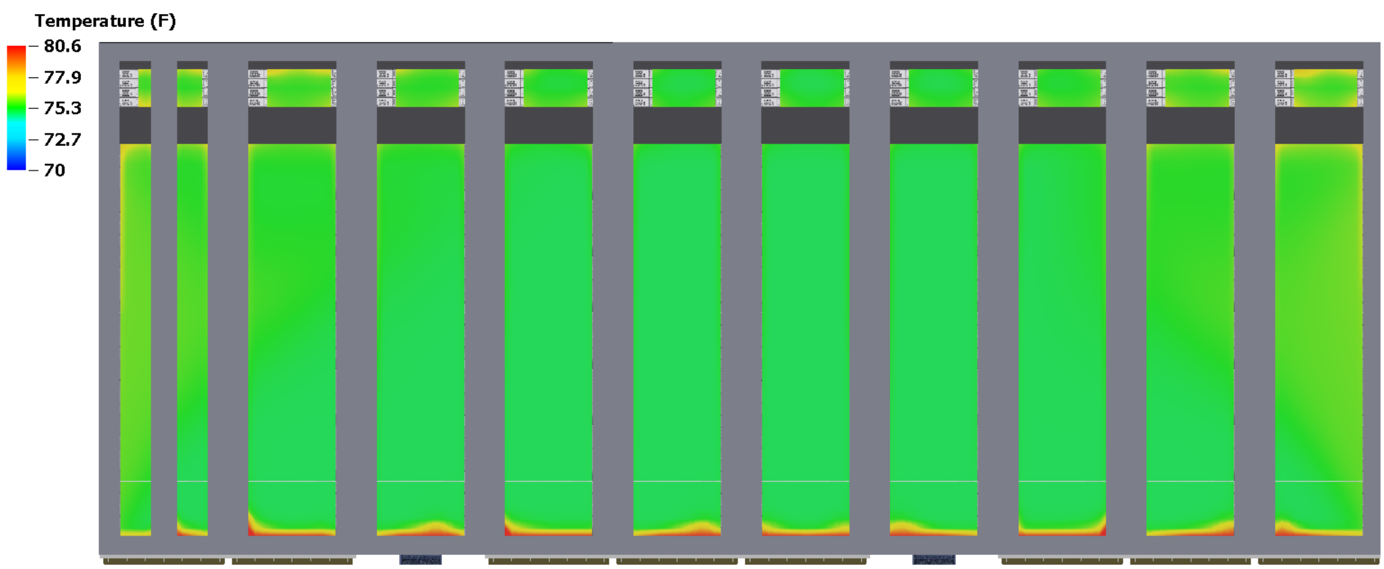


Figure 24. Representative Cabinet Elevation with Full Perforated Door.

Hot Aisle Containment (HAC)

Hot Aisle Containment Conditions Summary					
IT Equipment Airflow (CFM)	Air Handler Supplied Airflow (CFM)	Airflow Oversupply	Supply Air Temperature (°F)	Maximum Inlet Temperature (°F)	Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition
151273.2	216000	43%	75.0	81.7	84%

Another method of containment is AMCO Hot Aisle Containment (HAC). HAC similarily to CAC fully encloses the hot aisle with end of row doors and an aisle chimney that connects the hot air captured in the enclosed aisle to the ceiling plenum. By connecting the hot aisle to the ceiling plenum, the hot air is contained and given a path directly back to the air handling system. This method of containment allows the room to be flooded with cool air. By containing the hot air the number of air handling units was reduced by 40%. The number of floor tiles were reduced in addition to the number of air handling units.

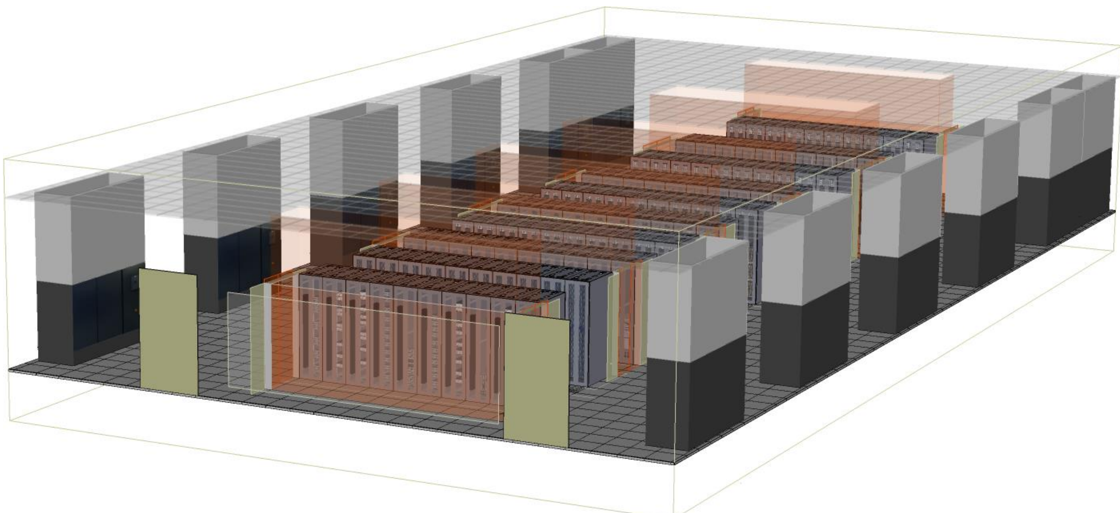


Figure 25. Isometric View of Hot Aisle Containment Layout.

As shown in figure 26, the room remains cool while the hot air is contained inside the AMCO aisle containment.

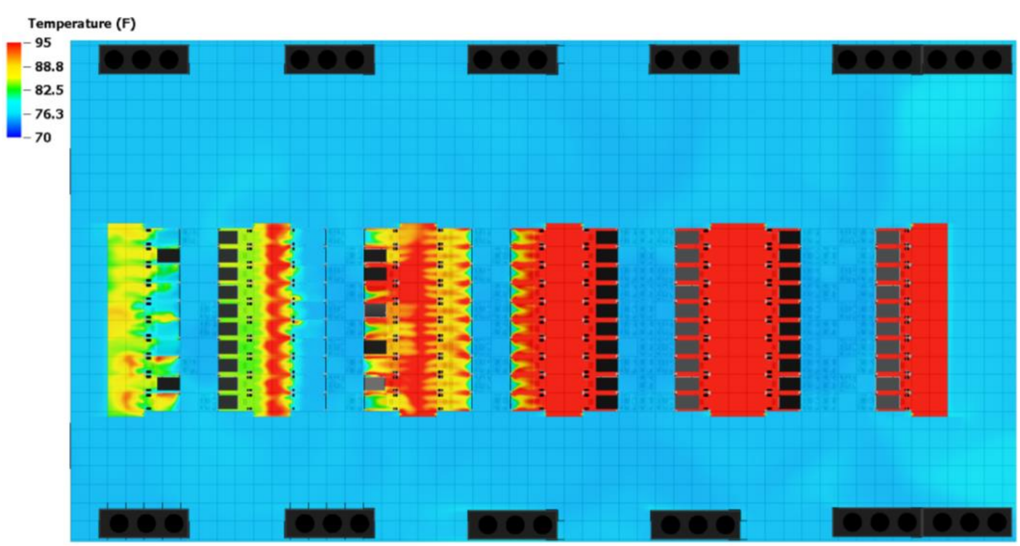


Figure 26. Plan View Temperature Plot at 6' Above Raised Floor.

Even though the hot aisle is contained and the room remains a consistent temperature, there are still some elevated local temperatures at the cabinet level. Local cabinet leakage caused some cabinets to have higher inlet temperatures above ASHRAE 2011 class A1 recommended temperatures as shown in figure 27.

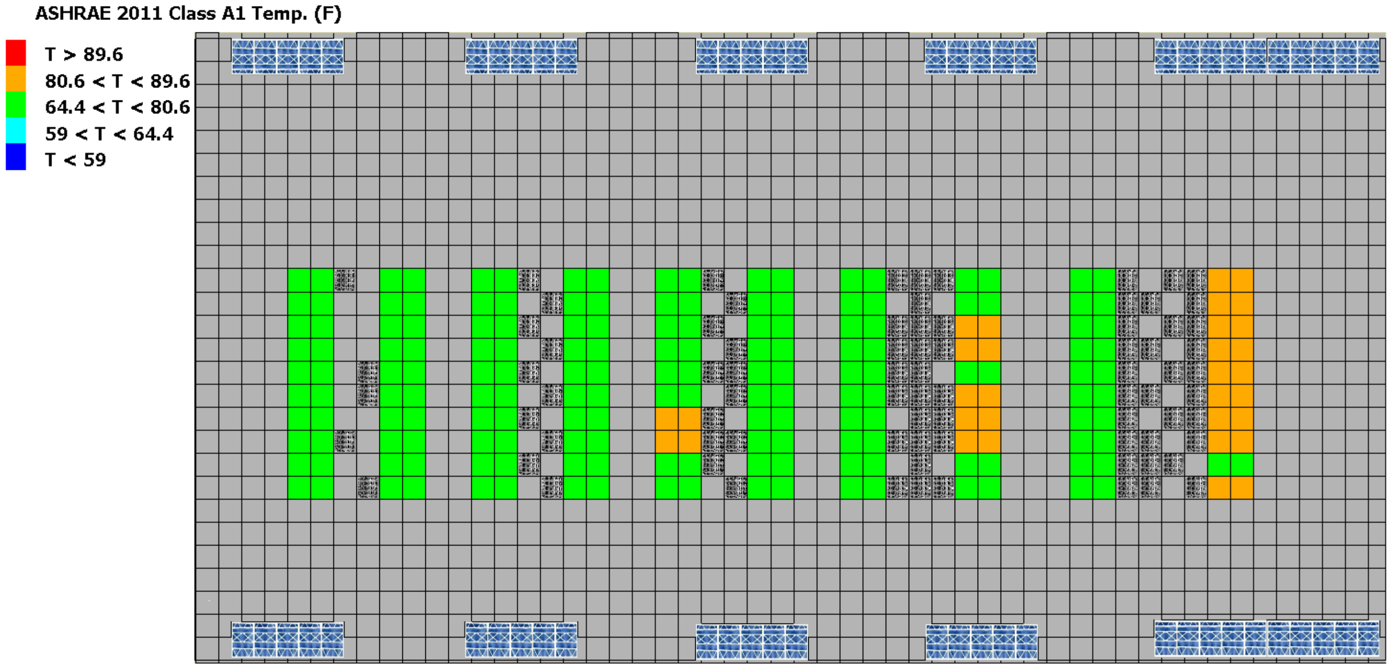


Figure 27. Plan View Plot of ASHRAE 2011 Class A1 Recommended Inlet Temperature Conditions.

Figure 28 below shows a plan view noting the maximum inlet temperatures. The maximum inlet temperatures correspond to the figure above with increased inlet temperatures.

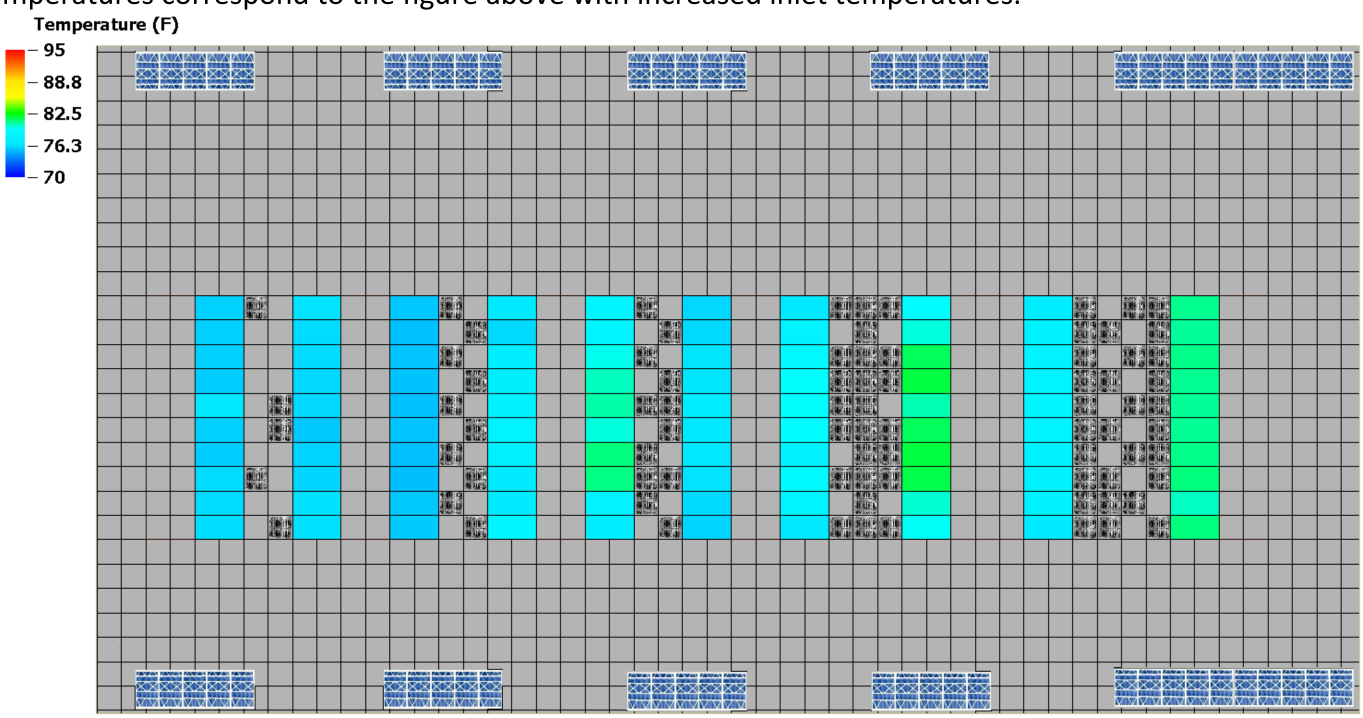


Figure 28. Maximum Cabinet IT Equipment Intake Temperature Plot.

Similar to the cold aisle containment scenario, the inlet temperatures at the equipment level are elevated at the bottom of the cabinets in the hot aisle containment scenario. However the perforated door temperatures shown in figure 30 remain at an acceptable level while the inlet temperatures remain elevated as shown in figure 29. This is indicative of the low pressure that is created behind the cabinet doors with high flow rates through the perforated areas.

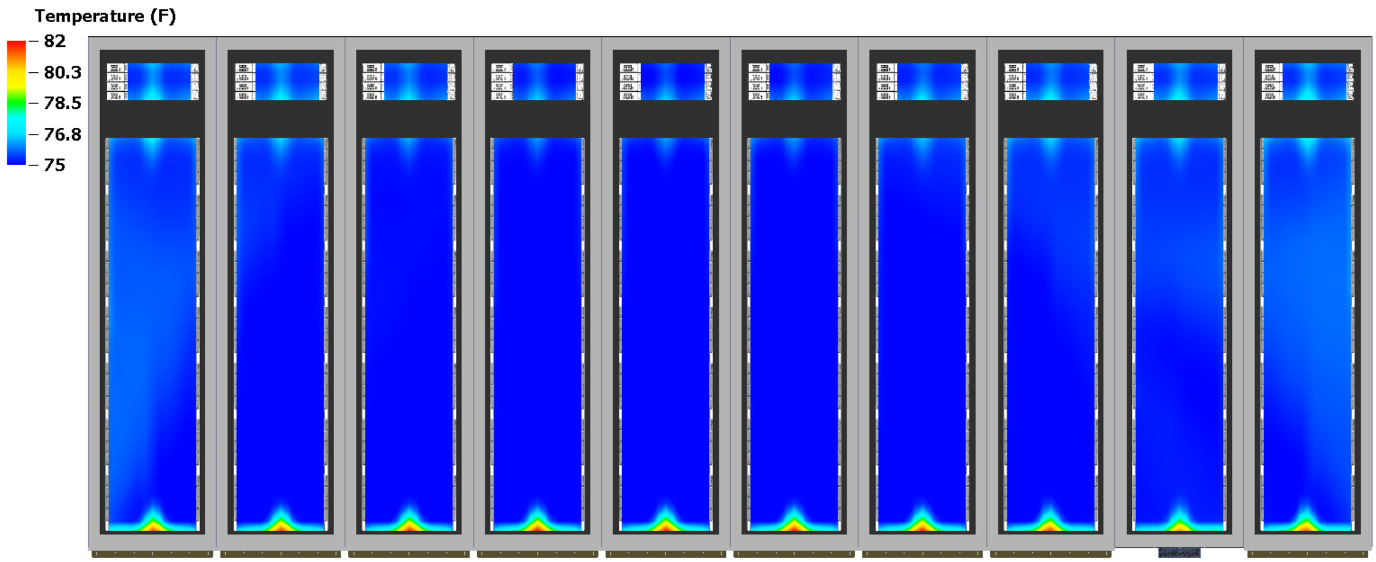


Figure 29. Row 10 IT Equipment Intake Temperature Elevation Plot in HAC Model.

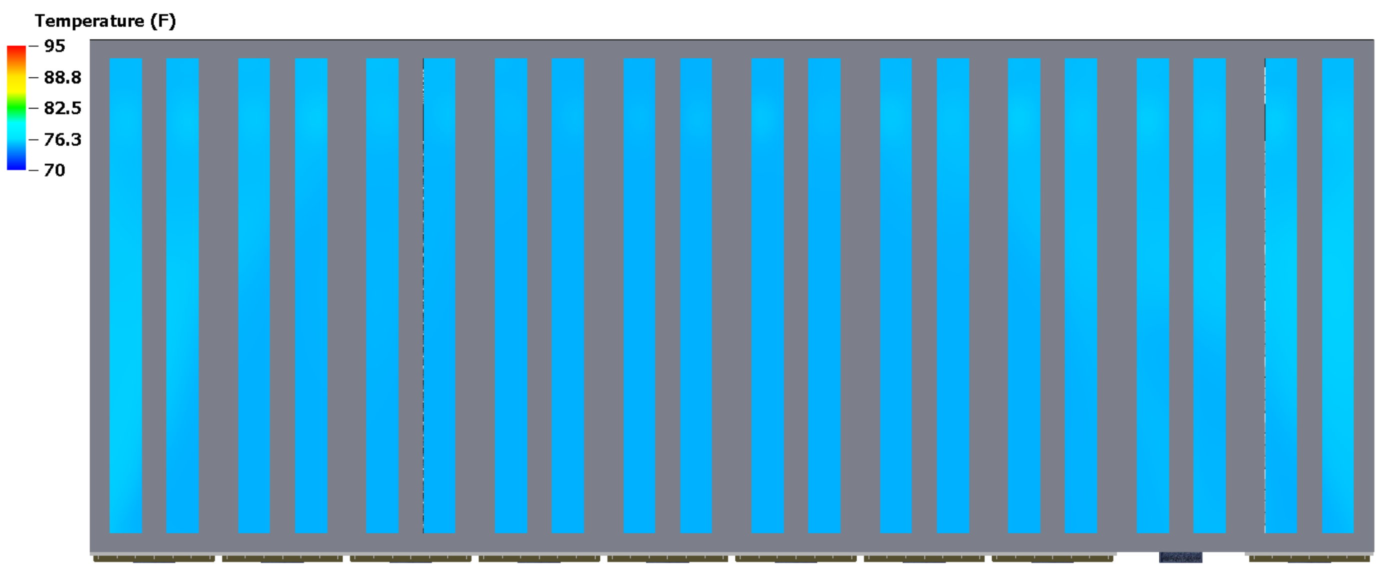


Figure 30. Row 10 Cabinet Perforation Temperature Plot in HAC Model.

While some cabinets exhibit higher inlet temperatures, the pressure in the hot aisles remains negative to ensure hot air is removed from the aisles. In figure 31 the pressure in the hot aisle is kept at a negative pressure compared to the room. The ceiling plenum pressure remains relatively constant across the room.

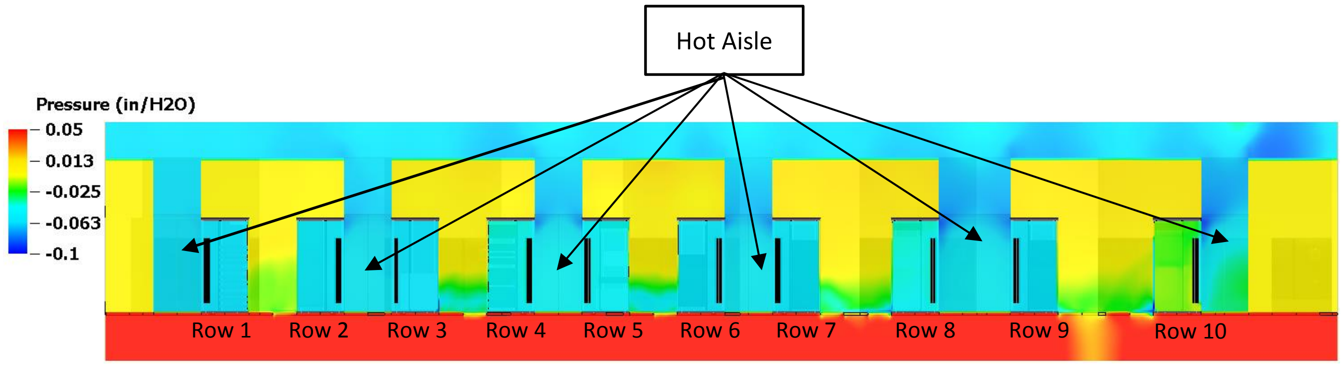


Figure 31. Elevation of Cabinet Plot through Midpoint of Cabinet Rows.

As a reference for the figure 31, the figure 32 demonstrates the multiple cabinet power densities on a per row basis. The highest density cabinet occurs in Row 10 at 34.5kW.

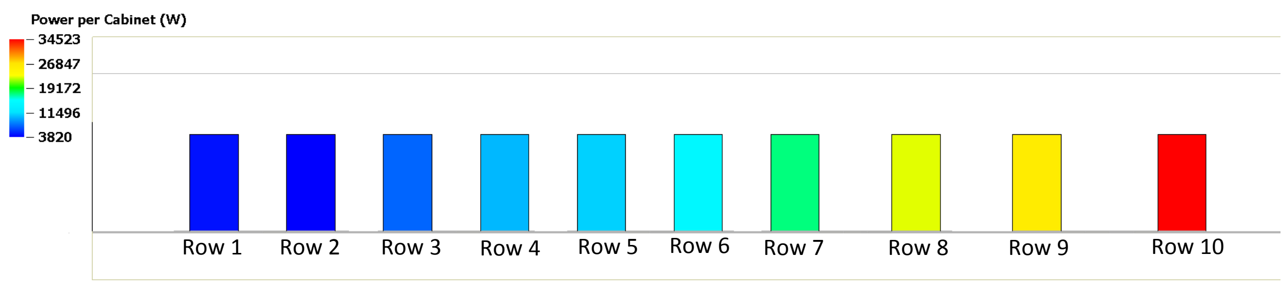


Figure 32. Cabinet Elevation View of Cabinet Power Densities.

Hot and Cold Aisle Containment

Cold and Hot Aisle Containment Conditions Summary					
IT Equipment Airflow (CFM)	**Air Handler Supplied Airflow (CFM)**	**Airflow Oversupply**	**Supply Air Temperature (°F)**	**Maximum Inlet Temperature (°F)**	**Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition**
151273.2	180000	19%	75.0	80.1	100%

The best performance when evaluating the different IMS AMCO aisle containment solutions occurred when both the hot and cold aisles were contained. With both aisles contained all the cold air from the cold aisle is processed by the IT equipment and then the processed hot air is then exahusted into the contained aisle. This method results in a tight closed loop system. The following image depicts the room layout when both AMCO HAC and CAC are deployed. In addition the number of air handling units was reduced by 10 and the number of floor tiles was reduced by 39%.

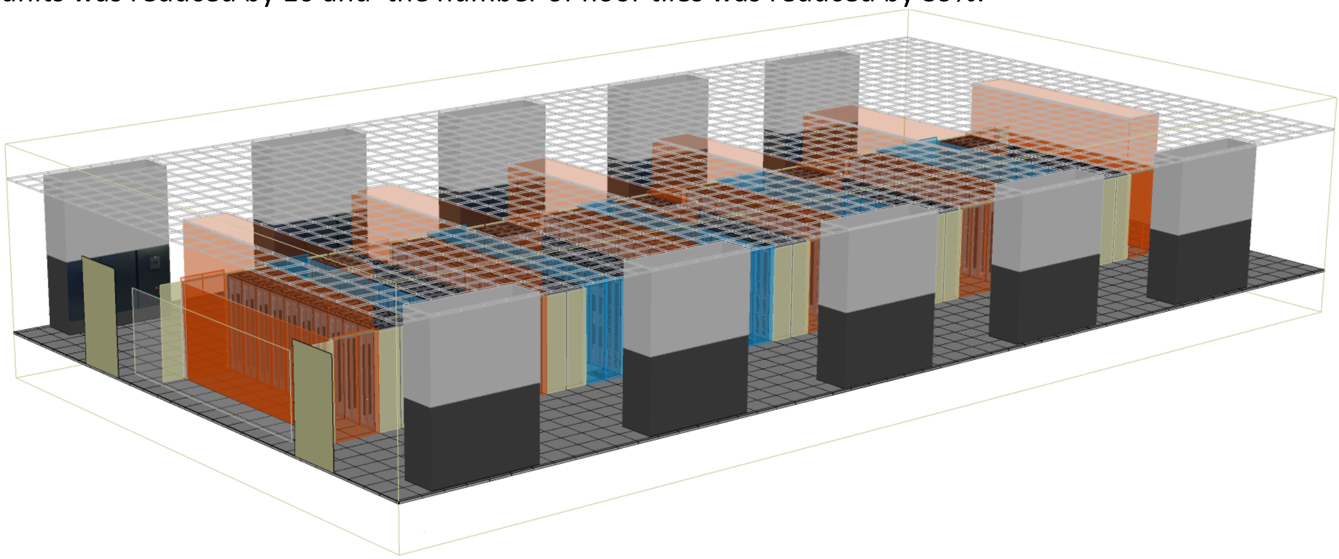


Figure 33. Isometric View of Combined HAC and CAC

In addition to the number of floor tiles and air handlers being reduced, all cabinets with IT equipment remianed within the ASHRAE 2011 class A1 recommended temperature range as shown in the figure 34.

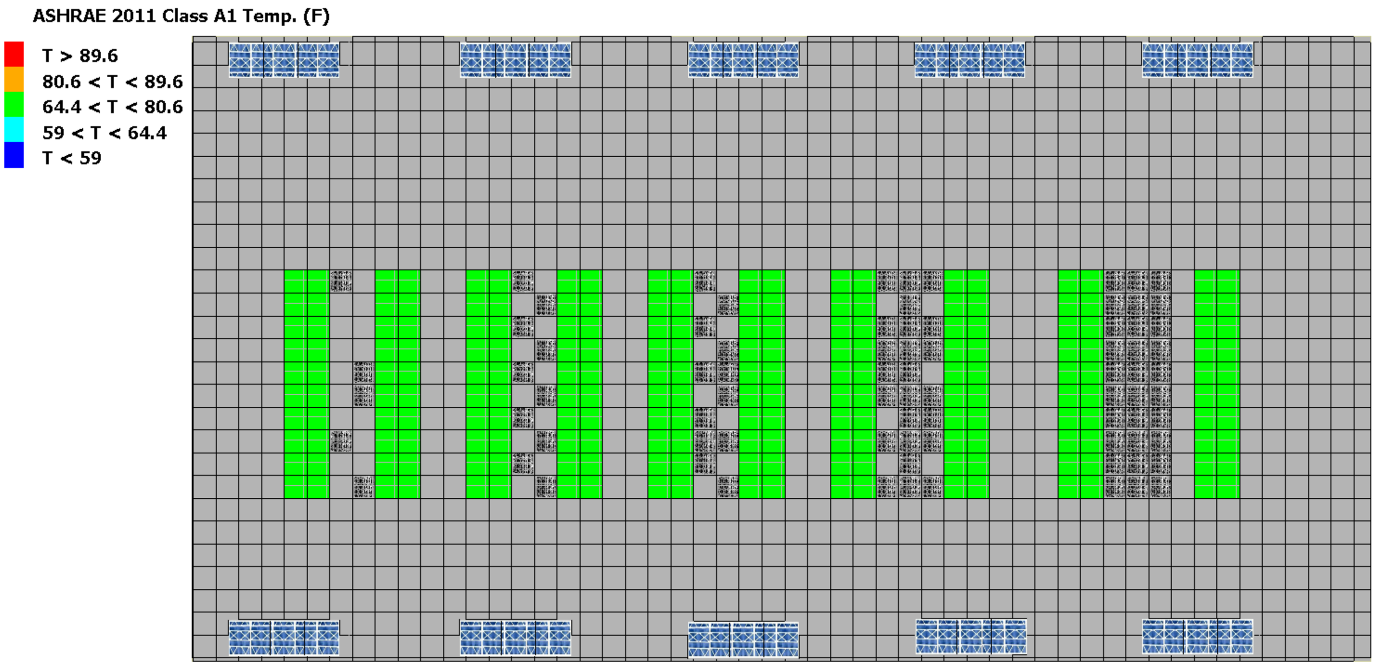


Figure 34. Plan View Plot of ASHRAE 2011 Class A1 Recommended Inlet Temperature Conditions.

Figure 35 desribes the overall room conditions and exemplifies the hot and cold aisle containment in this model.

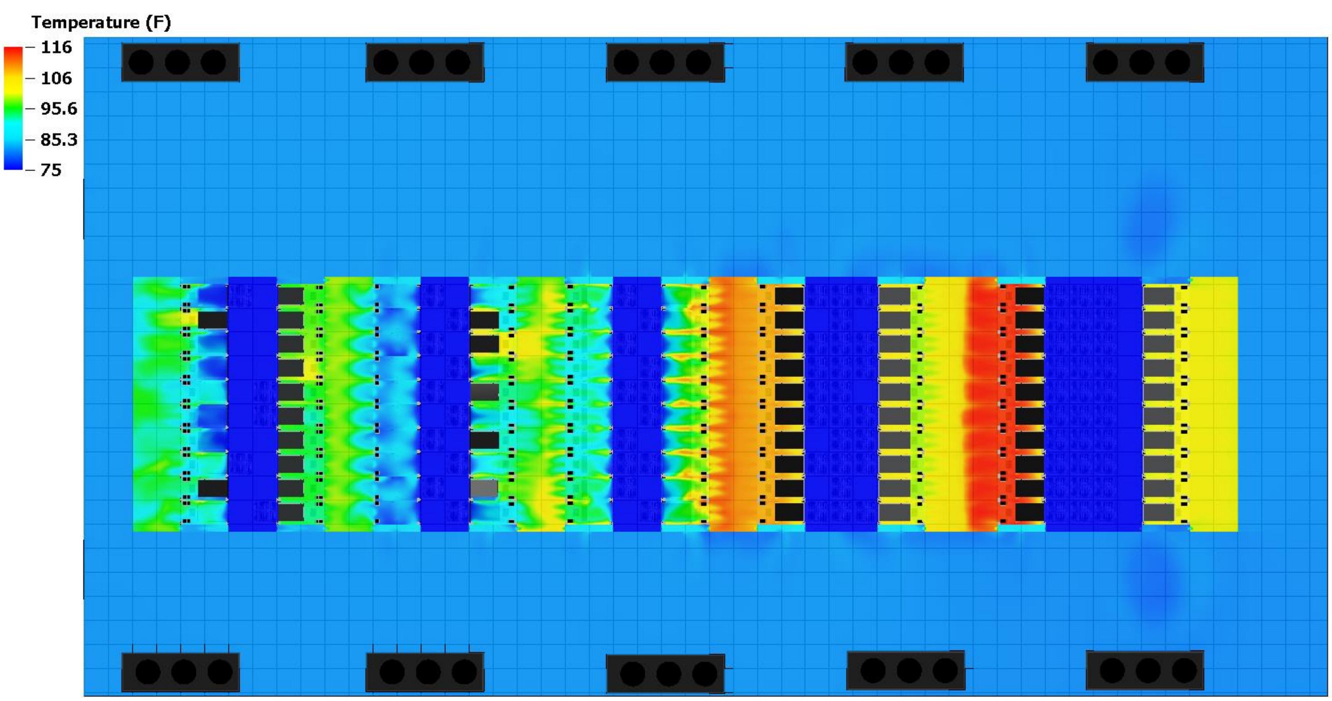


Figure 35. Plan View Temperature Plot at 6' Above Raised Floor.

Cabinet Chimney Containment

Cabinet Chimney Containment Conditions Summary					
IT Equipment Airflow (CFM)	Air Handler Supplied Airflow (CFM)	Airflow Oversupply	Supply Air Temperature (°F)	Maximum Inlet Temperature (°F)	Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition
151273.2	180000	19%	75.0	104.0	48%

Another method of containment is IMS AMCO's cabinet chimney containment. This method of containment is similar to hot aisle containment but keeps the hot IT exhaust air inside the IT cabinet. The common cabinet perforated rear doors are replaced with solid rear doors keeping all the hot air inside the cabinet. Also similar to the hot aisle containment system, a duct is attached to an opening on the cabinet top and extended to the bottom of the lay-in ceiling plenum. The duct acts as a conduit for the hot air allowing a direct path to the ceiling plenum. The IMS AMCO chimney is 16.7" X 15.8" (W X L) and is centered in the rear of the cabinet. The following figure depicts this model's floor plan.

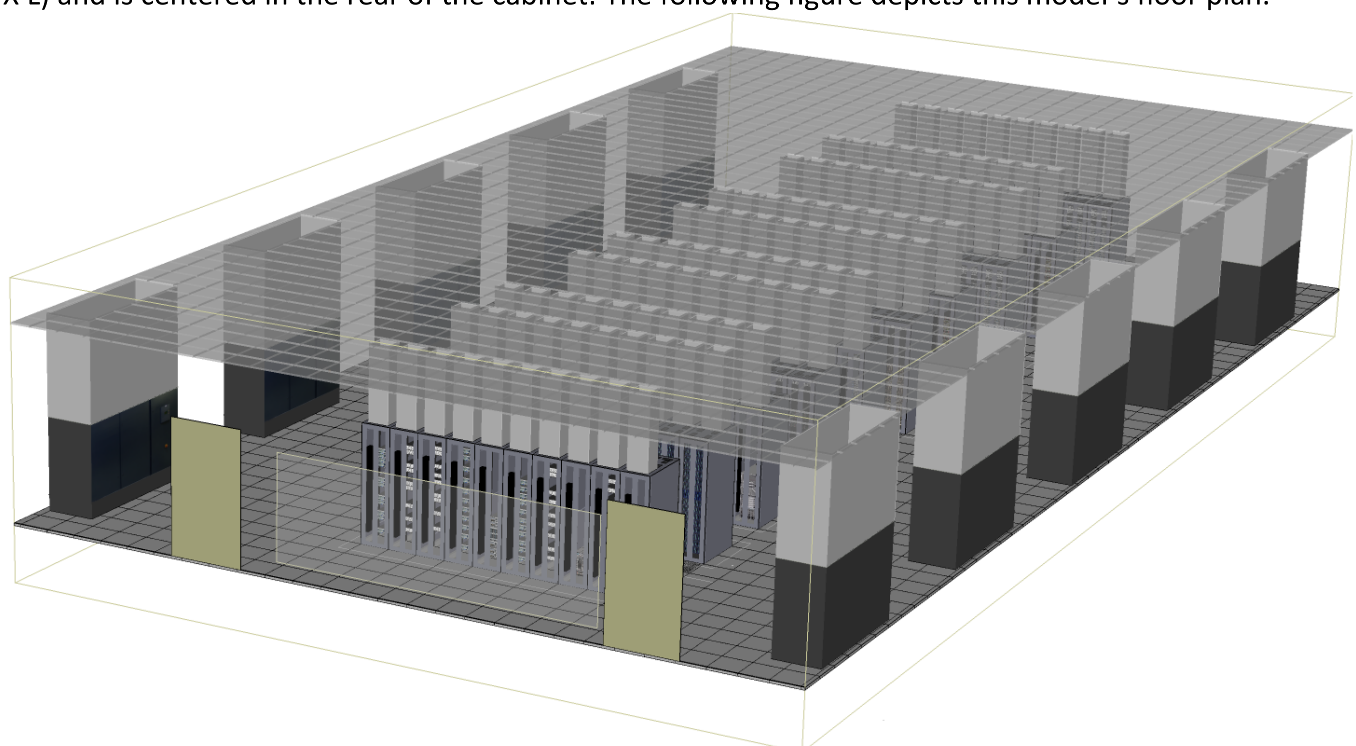


Figure 36. Isometric View of Cabinet Chimney Containment.

This method of containment allows the room to be flooded with cool air from the air handlers. In addition the number of air handlers can generally be reduced. The following figure depicts that in some instances the IT equipment inlet temperatures are above the ASHRAE 2011 class A1 recommended inlet temperature condition. In this situation 48% of the cabinets met the ASHRAE 2011 class A1 recommended inlet temperature condition.

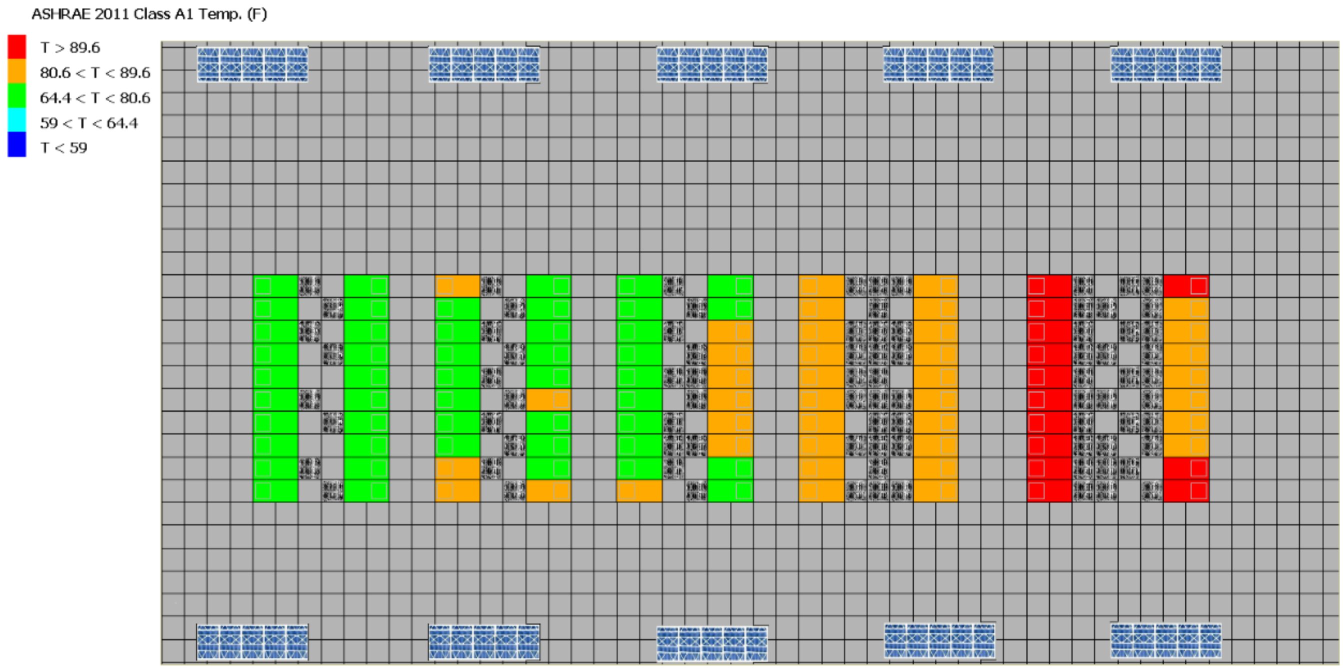


Figure 37. Plan View Plot of ASHRAE 2011 Class A1 Recommended Inlet Temperature Conditions.

Figures 38 & 39 depict the relationship between the IT equipment power and the associated airflow. The cabinet elevations depict that as the power density increases the airflow per cabinet also increase. The relationship between the airflow and cabinet chimney play an important role in the quantity of IT equipment that can be deployed. As the IT equipment airflow increase the velocity through the duct also increases.

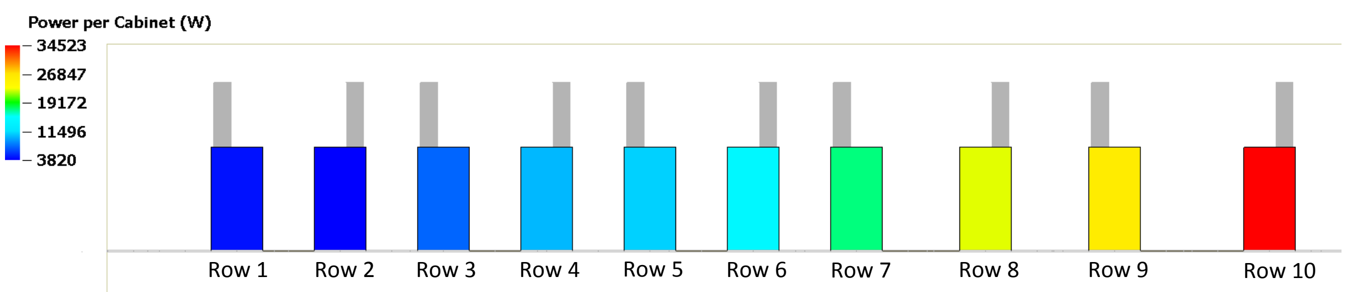


Figure 38. Elevation Plot of Cabinet Power Densities.

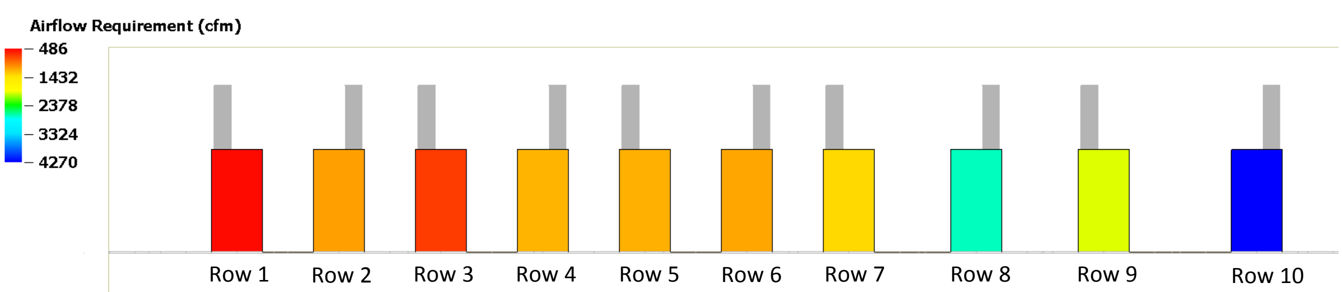


Figure 39. Elevation Plot of Cabinet Airflow.

As the IT equipment airflow increases and the velocity of the air through the cabinet chimney increases the pressure in the rear of the cabinet increases. Even though the ceiling plenum and the chimney may appear to be negative, the cabinet can remain positive due to the volume of air being moved by the servers.

Figures 40 & 41 exhibit a velocity plot and a pressure plot of cabinets in the same position. This plot is taken through the cabinet center of the 5th cabinet in each row. In this case the IMS AMCO cabinet chimney solution beings to fail at 1380 CFM (17.28kW @ 80 CFM/kW) per cabinet.

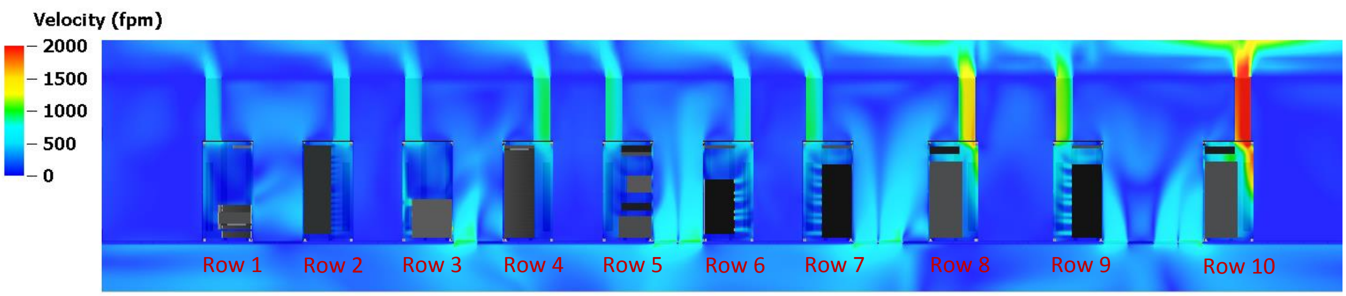


Figure 40. Elevation Velocity Plot through the Middle of the 5th Cabinet.

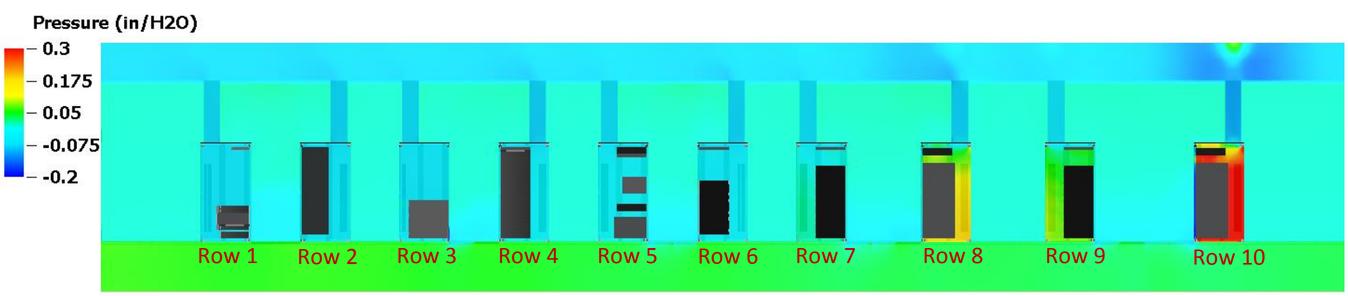


Figure 41. Elevation Pressure Plot through the Middle of the 5th Cabinet.

With the increase in cabinet pressure, local cabinet leakage is present creating local hot spots. The local hotspots are created in the cabinets with the highest pressures where the air is leaking through blanking panels or around the side rails of the cabinet. This issue is depicted in figure 42 and highlighted with red circles.

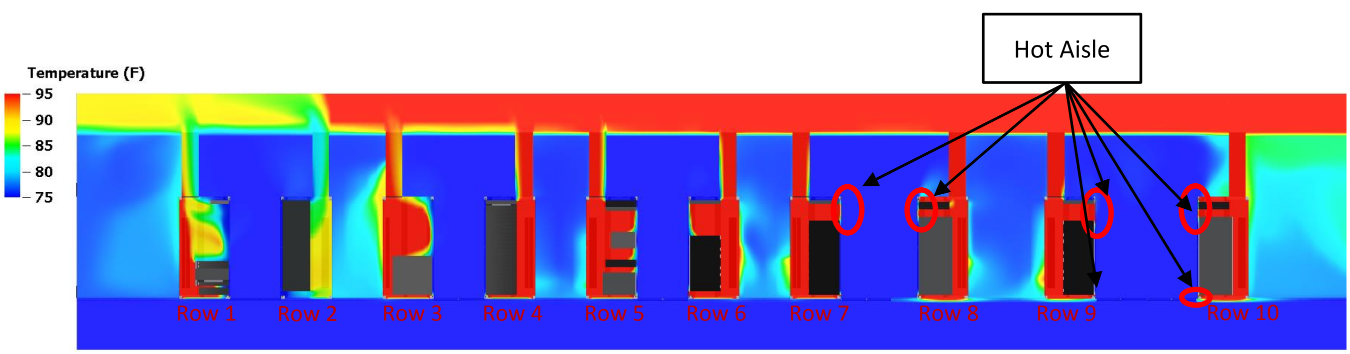


Figure 42. Elevation Temperature Plot through the Middle of the 5th Cabinet.

Cabinet Chimney Containment with Cold Aisle Containment

Cabinet Chimney Containment with Cold Aisle Containment Conditions Summary					
IT Equipment Airflow (CFM)	**Air Handler Supplied Airflow (CFM)**	**Airflow Oversupply**	**Supply Air Temperature (°F)**	**Maximum Inlet Temperature (°F)**	**Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition**
151273.2	180000	19%	75.0	87.1	72%

The final method of containment evaluated is using a combination of the IMS AMCO cabinet chimney and cold aisle containment. Similar to the combination of using HAC and CAC, this containment scenario couples the cold air in the contained aisle with the cabinet. The cold air is processed by the IT equipment and the hot air is exhausted from the cabinet using the cabinet chimney. Figure 43 represents the model used for this simulation.

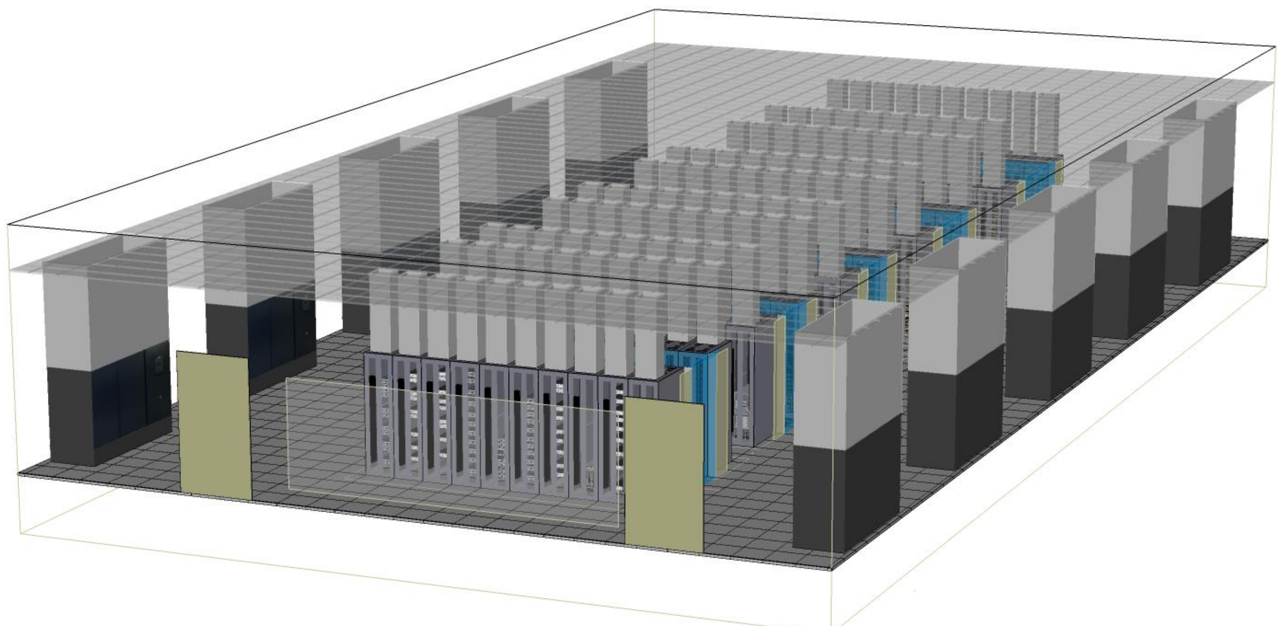


Figure 43. Isometric View of Cabinet Chimney and Cold Aisle Containment.

Similar to the previous cabinet chimney containment model there are some IT equipment inlet temperatures outside the ASHRAE 2011 class A1 recommended temperature range. This occurs again due to the high pressure that resides in the rear of the cabinet causing localized leakage and hot spots. 72% of the cabinets were within the ASHRAE 2011 class A1 recommended temperature range. Figure 44 describes the cabinets having localized leakage and outside the ASHRAE 2011 class A1 recommended temperature range.

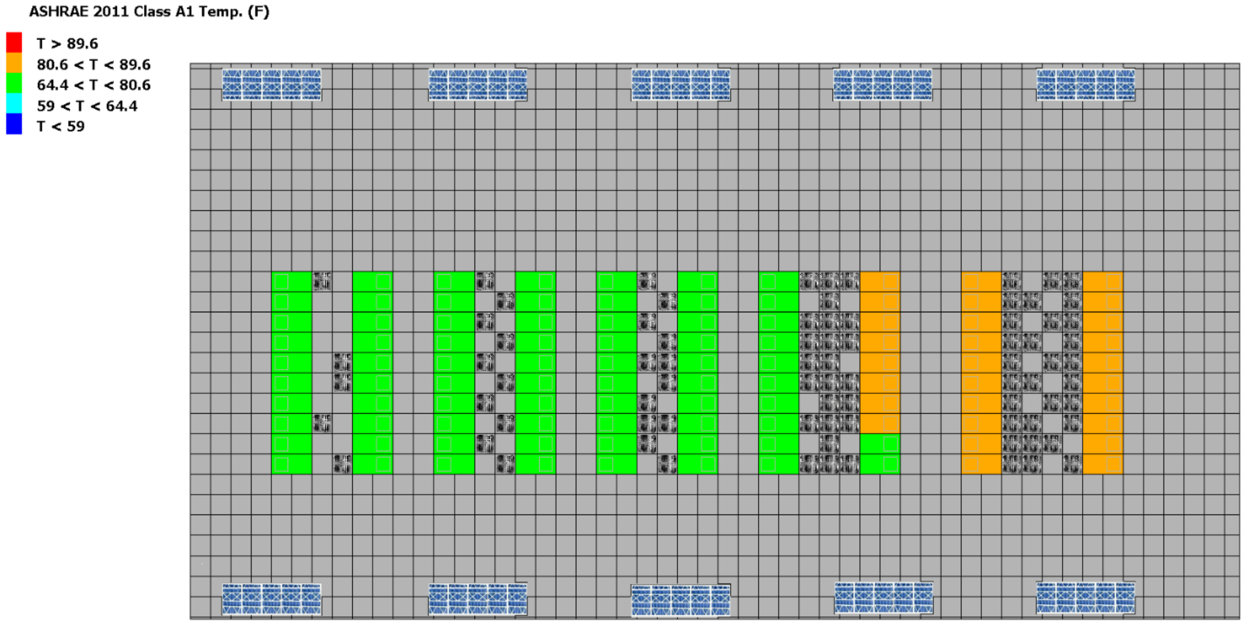


Figure 44. Plan View Plot of ASHRAE 2011 Class A1 Recommended Inlet Temperature Conditions.

When combining the cold aisle containment with the cabinet chimney containment, the cabinet inlet temperatures are more stable than the model with only cabinet chimney containment. The inlet temperatures remain more stable due to the direct pressurization of the cold aisles. F demonstrates the stability of the aisles and the overall effects this method of containment has on the room.

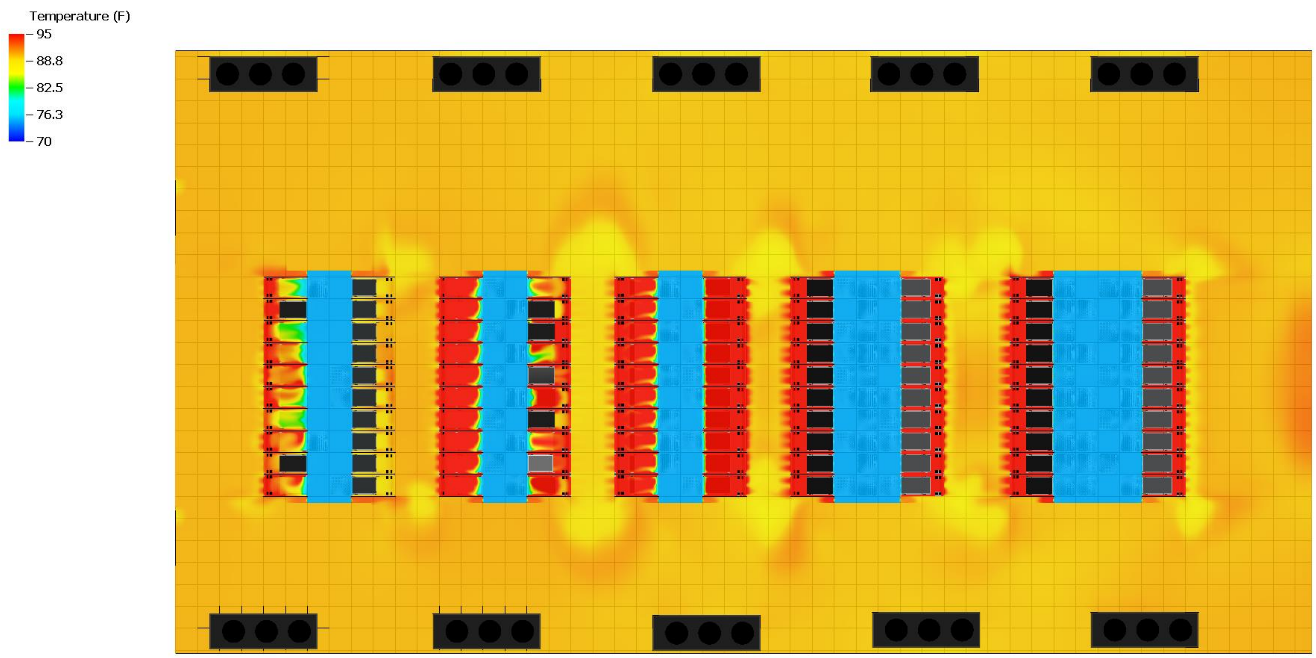


Figure 45. Plan View Temperature Plot at 6' Above Raised Floor.

Conclusion

The results of this study are intended to represent a facility with varying cabinet densities to provide a perspective on energy savings and operational outcomes. A successful model of the airflow management solution is represented as keeping the inlet temperature of the IT equipment at or below 80.6°F (ASHRAE recommended Class A1 requirement) and minimizing the amount of additional supply airflow above the IT equipment airflow needs, noted as oversupply.

The modeling study of AMCO Titan enclosures and AMCO airflow management solutions concluded the following:

- The baseline model using a 75°F supply air temperature exhibited a maximum IT equipment inlet temperature of 132°F with an airflow oversupply of 238%.
- The models deploying end of row doors improved the IT equipment inlet temperatures by 30°F over the baseline with 75°F supply air. The solution falls short keeping only 20-30% of the cabinet intake temperatures within the ASHRAE recommended class A1 temperature range.
- Cold Aisle Containment (CAC) allowed over 90% of the cabinets to be within the ASHRAE recommended class A1 temperature range with an oversupply of 19%. The maximum recorded temperature was 80.9°F
- The Hot Aisle Containment (HAC) model allowed 84% of the cabinets to be within the ASHRAE recommended class A1 temperature range with an oversupply of 43%. The maximum recorded inlet temperature was 81.7°F
- Combining Cold and Hot Aisle Containment allowed all the cabinets to meet the ASHRAE recommended class A1 temperature range with a 19% oversupply.
- Cabinet Chimney Containment model allowed 48% of the cabinets to be within the ASHRAE recommended class A1 temperature range with a 19% oversupply. For cabinets with IT equipment airflow below 1380 CFM (17.kW @ 80 CFM/kW), a cabinet with a passive chimney would be a viable containment solution.
- When Cabinet Chimney Containment is combined with cold aisle containment, 72% of the cabinets are within the ASHRAE recommended class A1 temperature range with a 19% oversupply. The cabinets with higher density IT equipment loads above 22kW produced local cabinet leakage as a result of positive pressure in the rear of the cabinet. Leakage rates and temperatures were minimized through the use of cold aisle containment compared to the cabinet chimney containment model.

When using the IMS AMCO containment solutions the air temperature in many cases remains very stable at an elevated supply air temperature. The air temperature stability at the inlet of the IT equipment remains within 6°F of the supply air temperature in multiple scenarios. This allows the volume of air supplied to the space to more closely match the volume of air required by the IT equipment. By matching the supply air volume from the air handlers to the IT equipment a fan power savings of 50% over the baseline was achieved.

These airflow management strategies allow using an elevated supply air temperature enabling additional cooling plant savings. It is reasonably estimated that an additional cooling plant savings of at least 15-20% is possible based on a 1% savings for every degree temperature increase in chilled water temperature. In addition to the cooling plant savings, the hours available for use of a waterside or airside economizer would be significantly improved.

It is important to note that the cabinet construction and cabinet airflow management strategy is an integral part to achieving the stable intake air temperatures demonstrated in this model. Sealed cabinet equipment rails and bottom panels, and rigid brush strips for all cable entry and egress are all very important items to the cabinet construction and performance.

The performance of these systems demonstrates at a conceptual level the advantages to using the IMS AMCO IT cabinets with their containment products. The results are based upon the configurations delivered in this report and the associated layout of the cooling and IT equipment. Results could vary depending on room configuration, IT equipment, and cooling strategy. The airflow control strategy will also have an important influence on the success of the space and the efficiency achievements.

Results Summary Table

	Baseline 55F	Baseline 75F	Baseline 75F with Side Air Blocks	Cold Aisle End of Row Doors	Hot aisle End of Row Doors	Cold Aisle Containment	Hot Aisle Containment	Cold and Hot Aisle Containment	Cabinet Chimeny Containment	Cabinet Chimney Containment with Cold Aisle Containment
IT Equipment Airflow	151273.2	151273.2	151273.2	151273.2	151273.2	151273.2	151273.2	151273.2	151273.2	151273.2
Air Handler supplied airflow (CFM)	360000	360000	360000	360000	360000	180000	216000	180000	180000	180000
Oversupply based on equipment specs	238%	238%	238%	238%	238%	19%	43%	19%	19%	19%
Supply Air Temperature (F)	55	75	75	75	75	75	75	75	75	75
Maximum Inlet Temperature	115.0	132.0	106.0	102.0	95.2	80.9	81.7	80.1	104.0	87.1
Percentage of Cabinets Meeting ASHRAE 2011 Class A1 Recommended Inlet Temperature Condition	32%	0%	25%	20%	31%	93%	84%	100%	48%	72%
Motor HP Calculation: HP=CFM *.0015										
Total Air Handler Motor Horsepower (HP)	540	540	540	540	540	270	324	270	270	270
Total Air Handler Motor Electrical Load (kW)	402.7	402.7	402.7	402.7	402.7	201.3	241.6	201.3	201.3	201.3
Annual Air Handler Motor Energy (kWh)	3529472.7	3529472.7	3529472.7	3529472.7	3529472.7	1764736.3	2117683.6	1764736.3	1764736.3	1764736.3
Cost/ kWh	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10
Total Annual Fan Energy Cost	$352,947	$352,947	$352,947	$352,947	$352,947	$176,474	$211,768	$176,474	$176,474	$176,474

Table 3. Results Summary Table Detailing Study Findings

In the table above the fan horsepower is calculated using ASHRAE 90.1 Table 6.5.3.1.1A Fan Power Limitation table under the Variable Volume Option 1: Fan System Motor Nameplate hp. The motor horsepower is calculated using the following equation

$HP = CFM_s \times 0.0015$

Where

CFM_s = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute.

HP = the maximum combined motor nameplate horsepower.

References

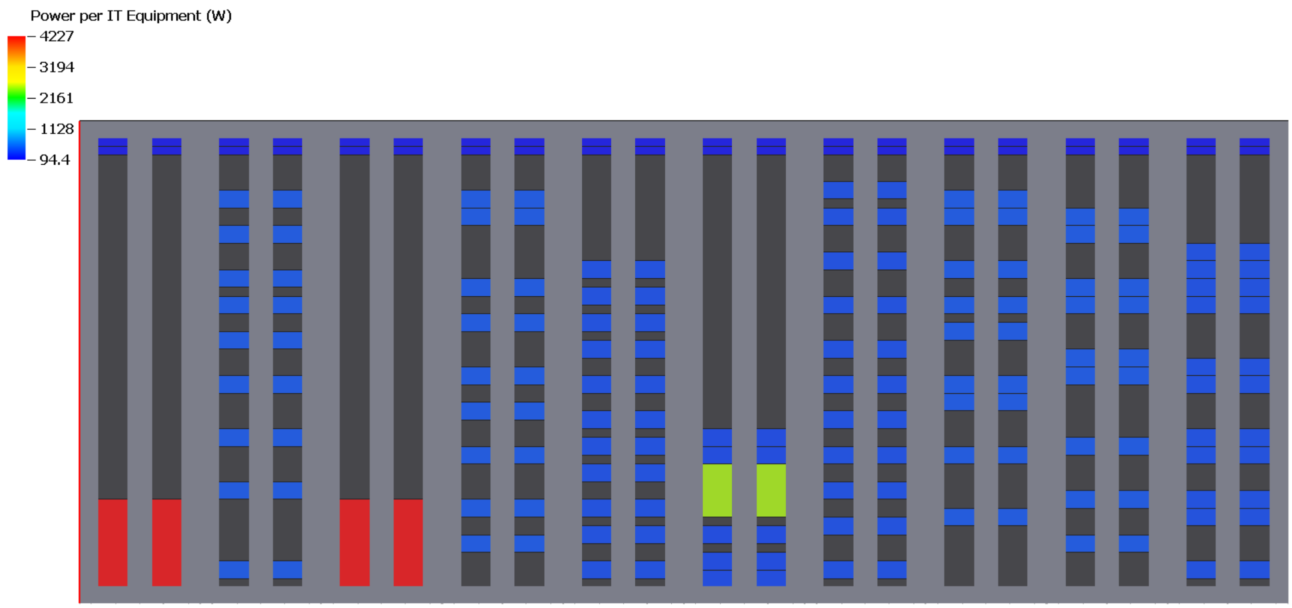
1. *Thermal Guidelines for Data Processing Environments*. 3rd ed. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2012
2. ASHRAE Standard 90.1 (IP Edition) Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI Approved; IESNA Co-sponsored), 2010

Appendix A: IT Cabinet Elevations

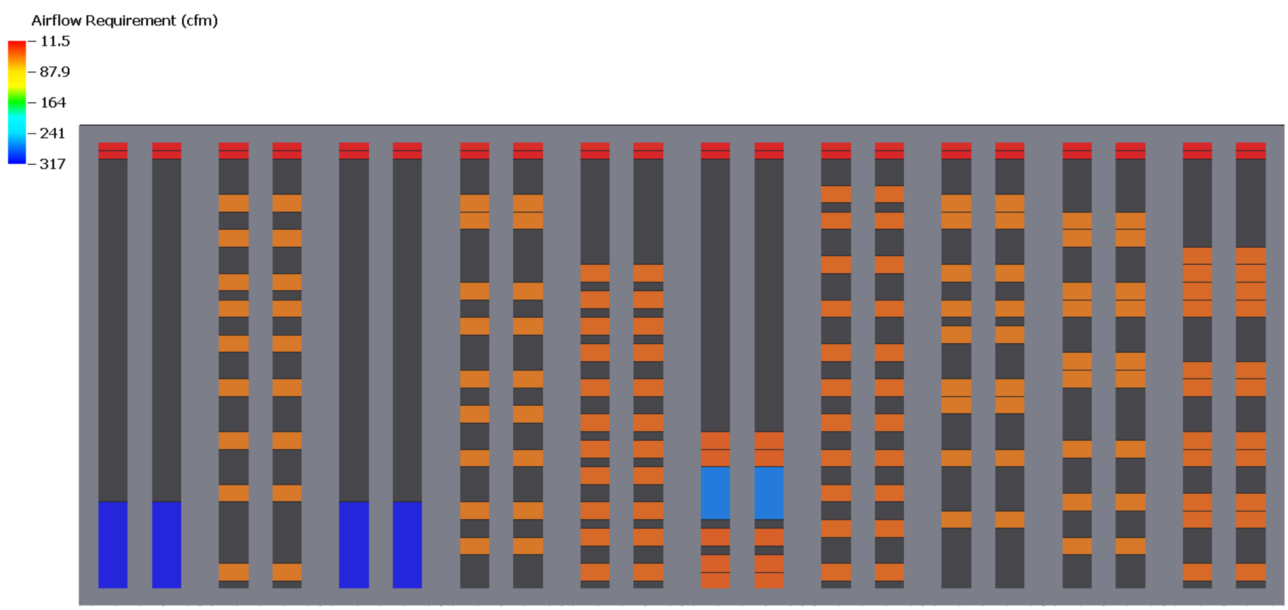
Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
1	1	Dell	M1000E	1	4227	319	41.68	4415.8
		Cisco	2248TP GE	2	94.4	11.5	25.82	
1	2	HP	DL380 G8	9	447	50.9	27.6	4211.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	3	Dell	M1000E	1	4227	319	41.7	4415.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	4	HP	DL380 G8	9	447	50.9	27.6	4211.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	5	Dell	2950	11	381	43.5	27.7	4379.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	6	Cisco	C210M2	5	351	43.5	28.6	4457.8
		Cisco	UCS5108	1	2514	277	28.5	
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	7	Dell	2950	11	381	43.5	27.7	4379.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	8	HP	DL380 G8	9	447	50.9	27.6	4211.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	9	HP	DL380 G8	9	447	50.9	27.6	4211.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
1	10	Dell	2950	11	381	43.5	27.7	4379.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
						Row Total Power		**43276**

Row 1 IT Equipment, Power, and Airflow Details.

Row 1 IT Equipment Cabinet Elevations.



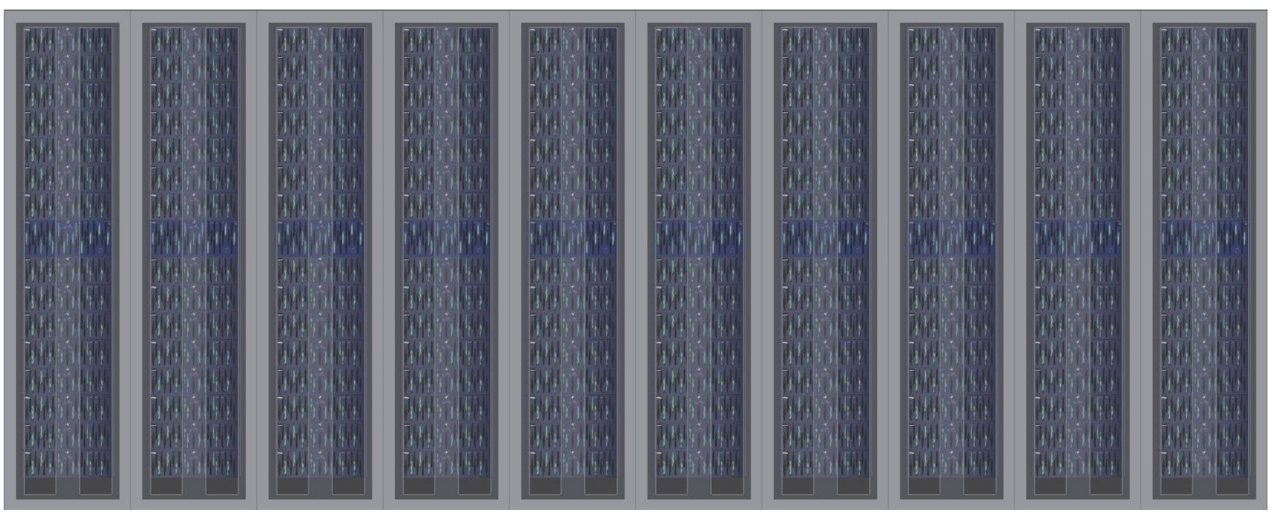
Row 1 IT Equipment Cabinet Elevation: Power Requirements.



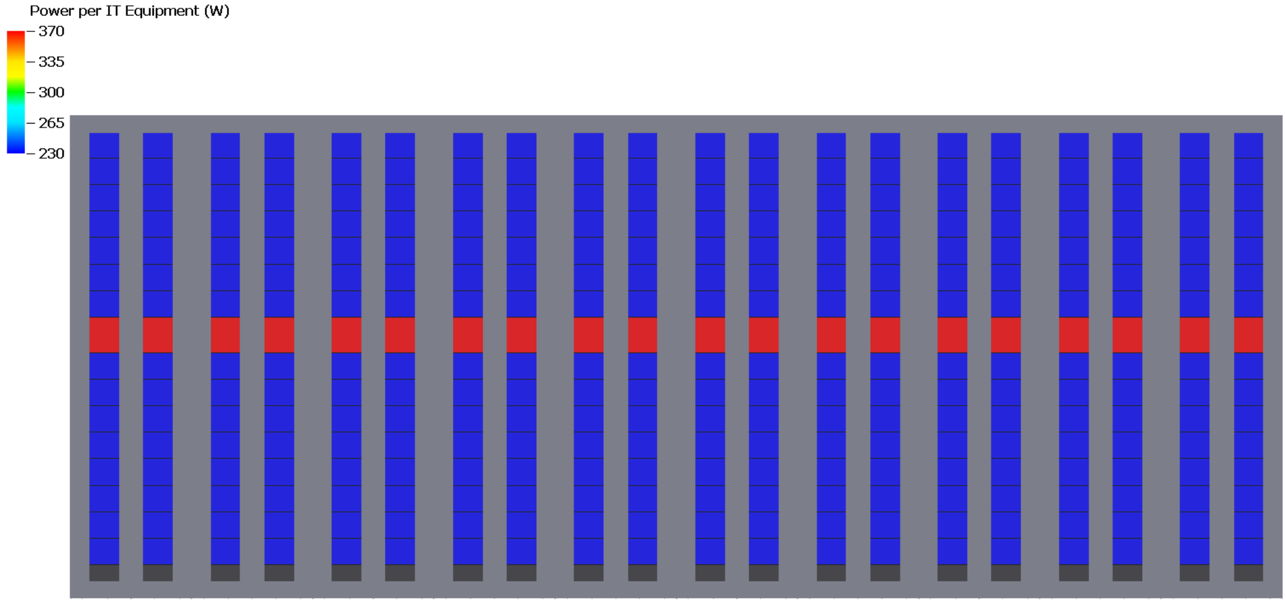
Row 1 IT Equipment Cabinet Elevation: Airflow Requirements

Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
2	1	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	2	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	3	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	4	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	5	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	6	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	7	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	8	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	9	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
2	10	Hitachi	DF-F800-RKAK	15	230	27.7	26.1	3820
		Hitachi	DF800-RK2	1	370	44.5	26.2	
						Row Total Power		**38200**

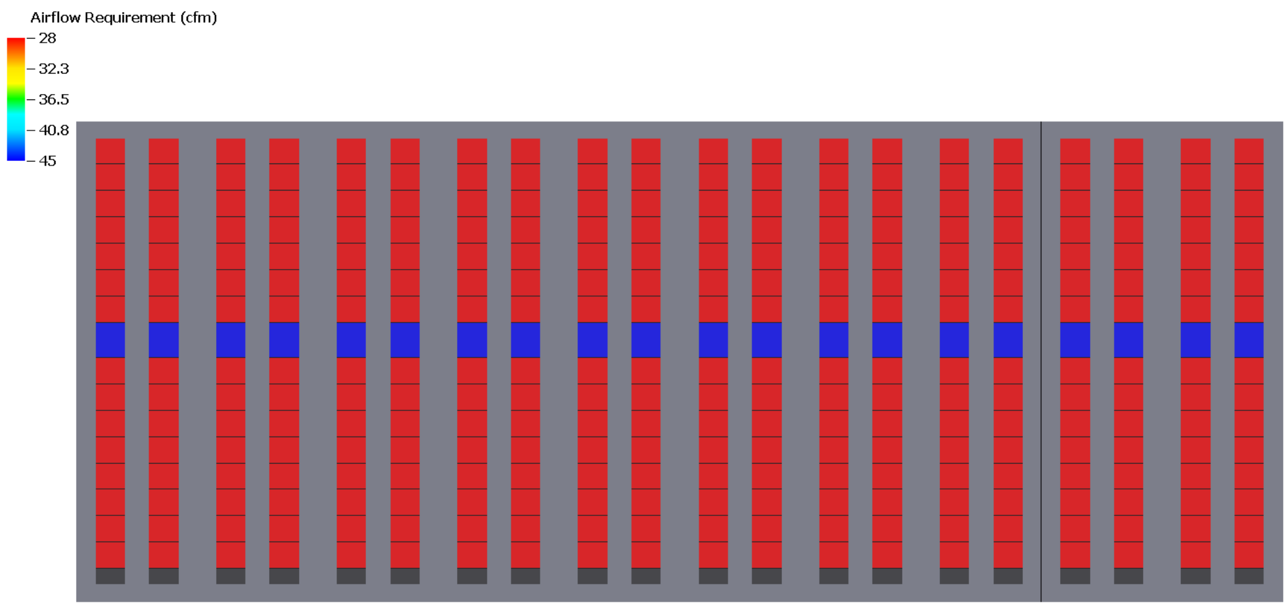
Row 2 IT Equipment, Power, and Airflow Details.



Row 2 IT Equipment Cabinet Elevations.



Row 2 IT Equipment Cabinet Elevation: Power Requirements.

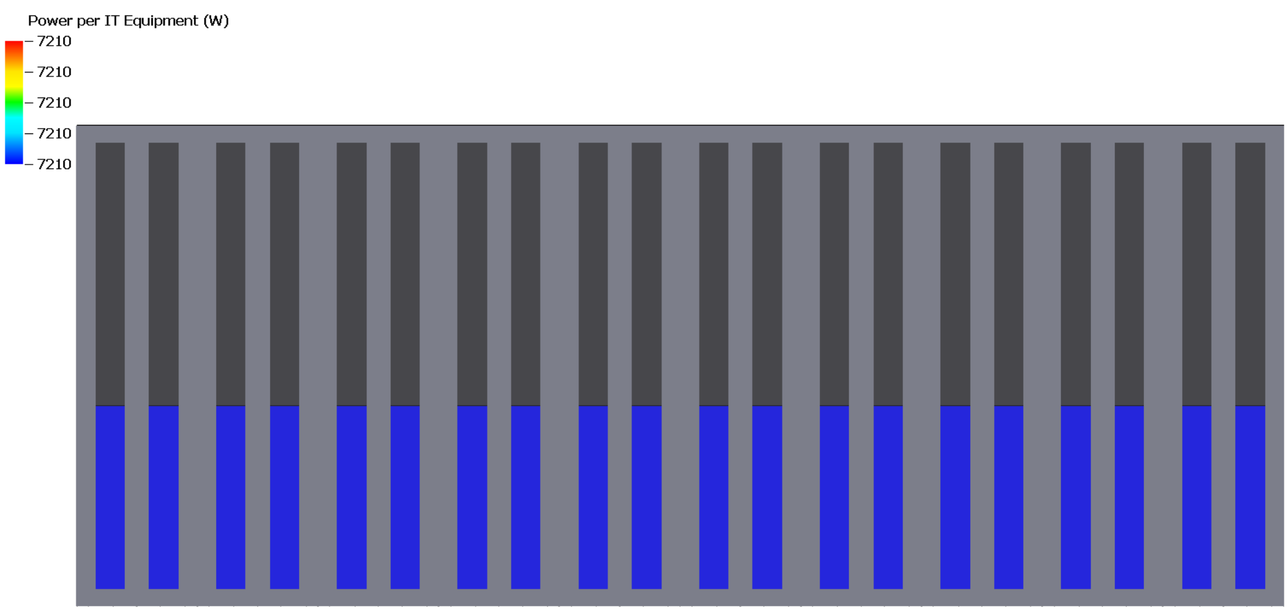


Row 2 IT Equipment Cabinet Elevation: Airflow Requirements.

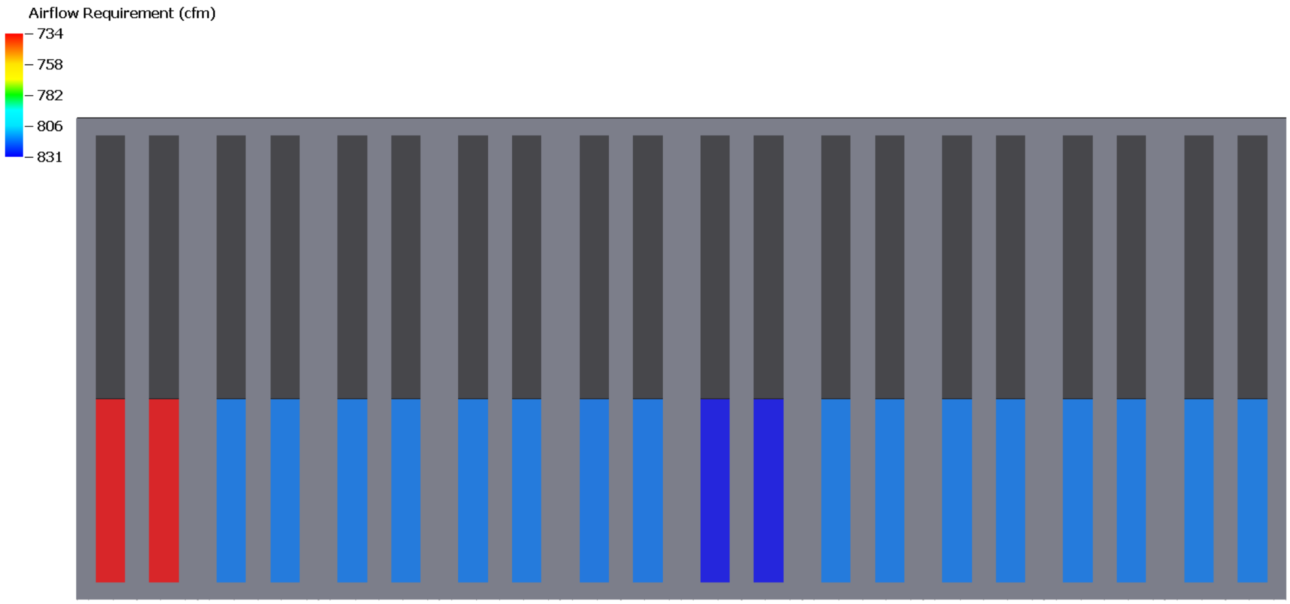
Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
3	1	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	2	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	3	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	4	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	5	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	6	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	7	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	8	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	9	Cisco	Nexus 7010	1	7210	734	30.9	7210
3	10	Cisco	Nexus 7010	1	7210	734	30.9	7210
						Row Total Power		**72100**

Row 3 IT Equipment, Power, and Airflow Details.

Row 3 IT Equipment Cabinet Elevations.



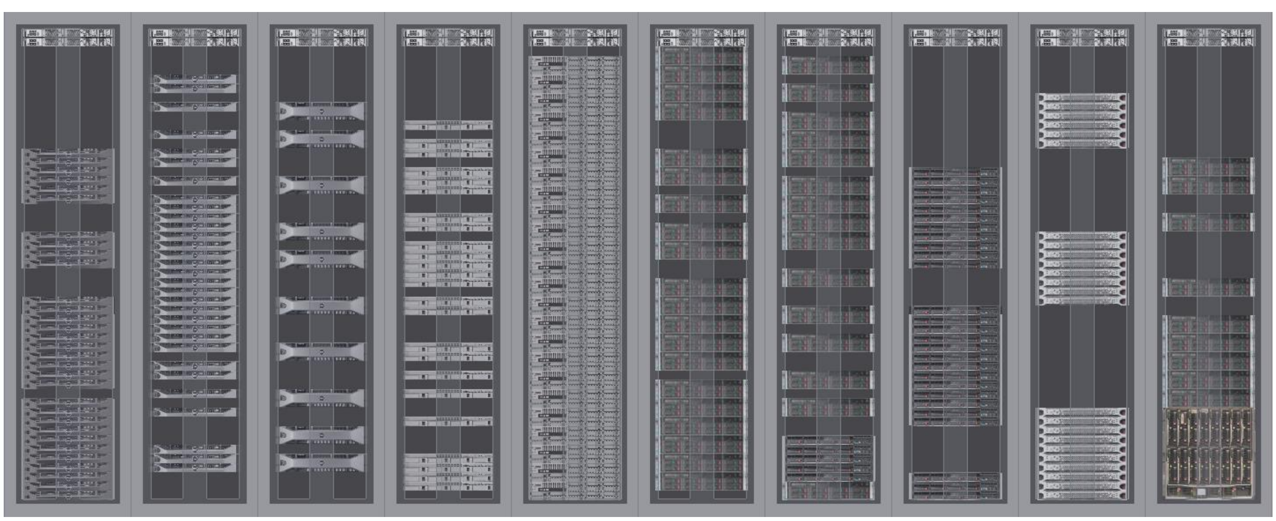
Row 3 IT Equipment Cabinet Elevation: Power Requirements.



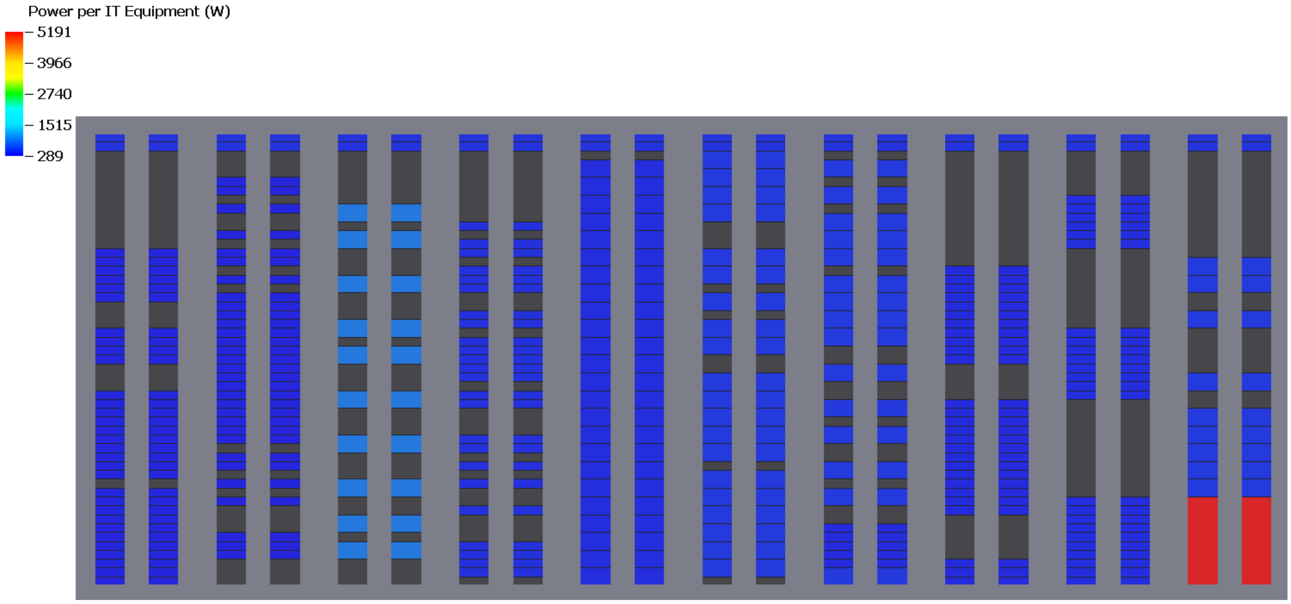
Row 3 IT Equipment Cabinet Elevation: Airflow Requirements.

Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
4	1	Dell	R420	31	293	28.1	32.8	9271.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	2	Dell	R620	31	289	21.1	43.1	9147.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	3	Dell	R720	10	913	54.7	52.5	9318.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	4	Cisco	C220SFF M3	24	375	41.8	28.2	9188.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	5	Cisco	UCS C210 M2	24	374	45.5	25.9	9164.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	6	HP	DL380 G8	20	447	50.9	27.6	9128.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	7	HP	DL380 G8	15	447	50.9	27.6	8558.8
		HP	DL360 G7	5	333	32.2	32.5	
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	8	HP	DL360 G7	27	333	32.2	32.5	9179.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	9	HP	DL160 G8	24	353	34.1	32.6	8660.8
		Cisco	2248TP GE	2	94.4	11.5	25.8	
4	10	HP	DL380 G8	9	447	50.9	27.6	9402.8
		HP	C7000	1	5191	404	40.4	
		Cisco	2248TP GE	2	94.4	11.5	25.8	
						Row Total Power		**91023**

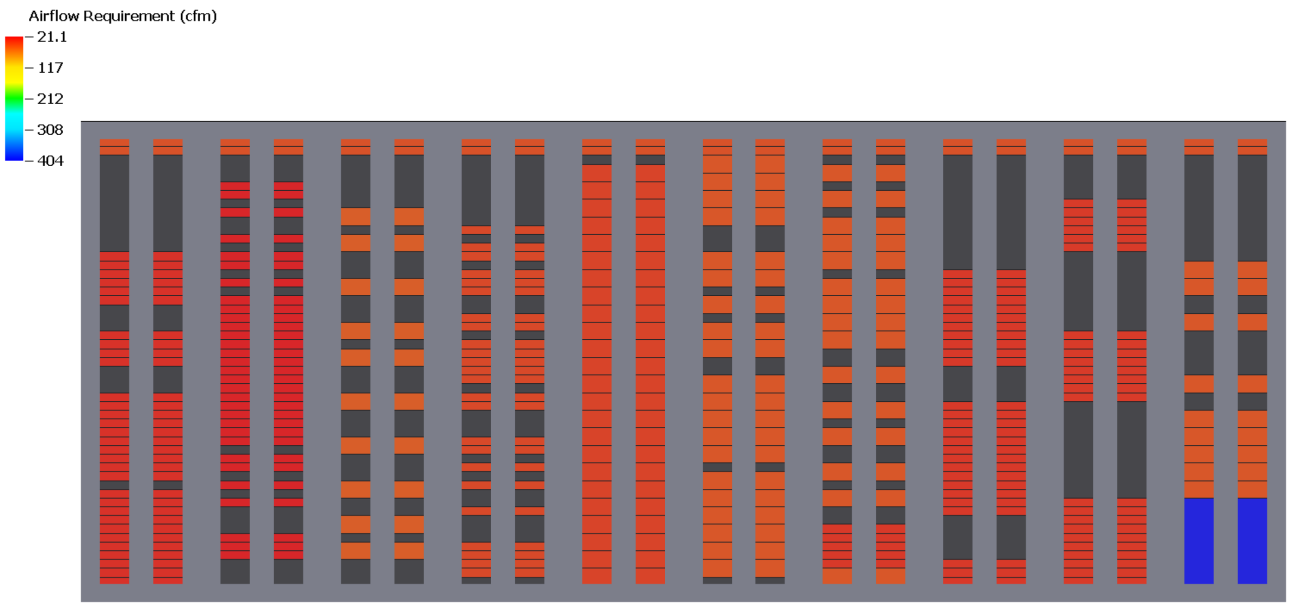
Row 4 IT Equipment, Power, and Airflow Details



Row 4 IT Equipment Cabinet Elevations.



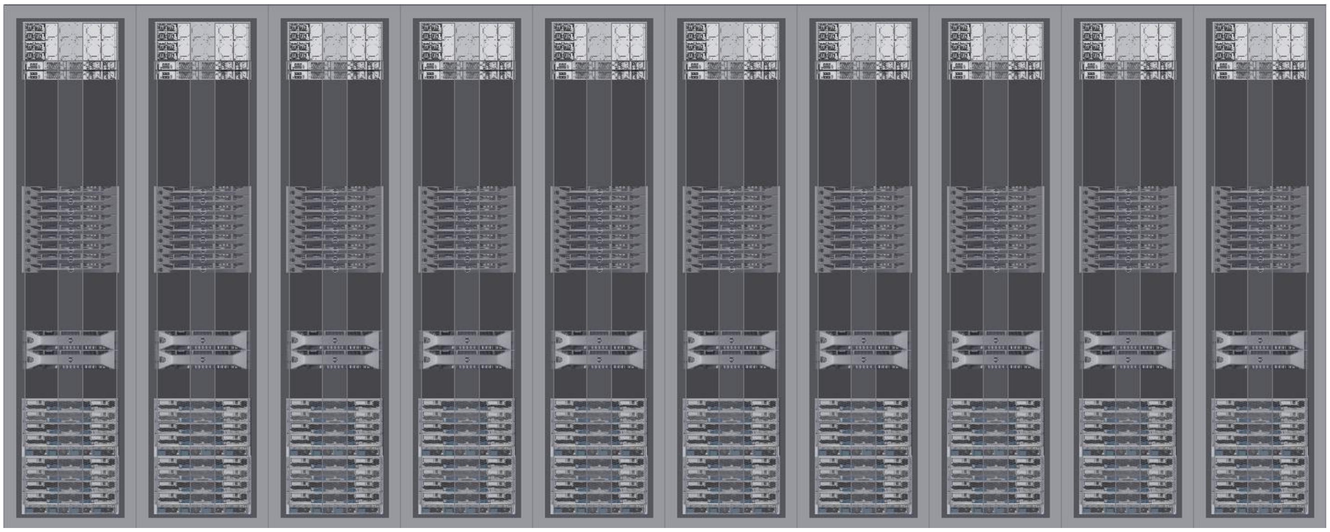
Row 4 IT Equipment Cabinet Elevation: Power Requirements.



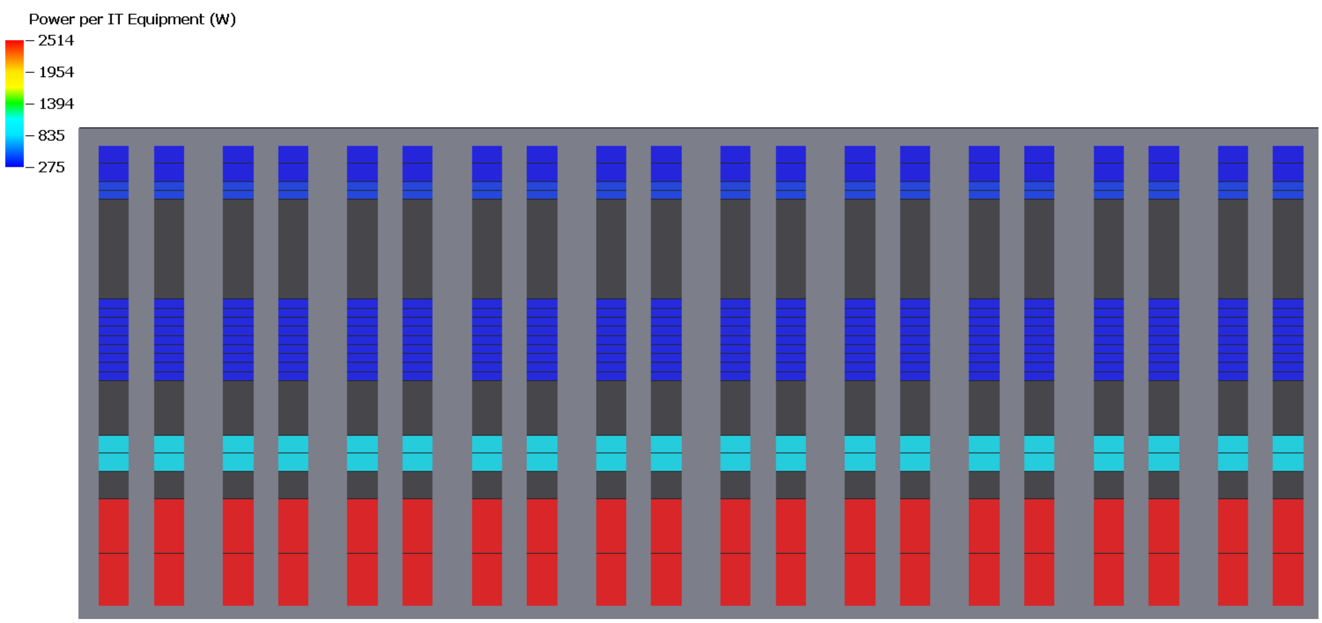
Row 4 IT Equipment Cabinet Elevation: Airflow Requirements.

Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
5	1	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	2	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	3	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	4	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	5	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	6	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	7	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	8	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	9	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
5	10	Dell	R420	9	293	28.1	32.8	10821
		Dell	R720	2	913	54.7	52.5	
		Cisco	UCS5108	2	2514	277	28.5	
		Cisco	UCS 6140XP	2	275	33.5	25.8	
		Cisco	UCS 5548P	2	390	47.5	25.8	
						Row Total Power		**108210**

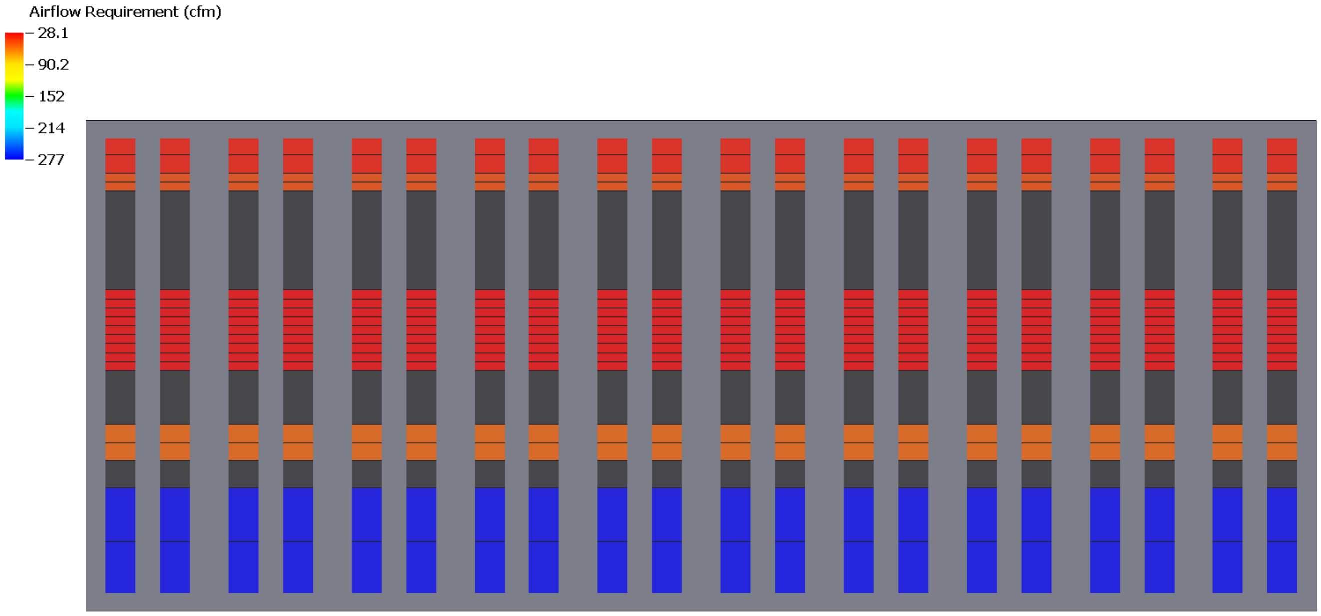
Row 5 IT Equipment, Power, and Airflow Details



Row 5 IT Equipment Cabinet Elevations.



Row 5 IT Equipment Cabinet Elevation: Power Requirements.

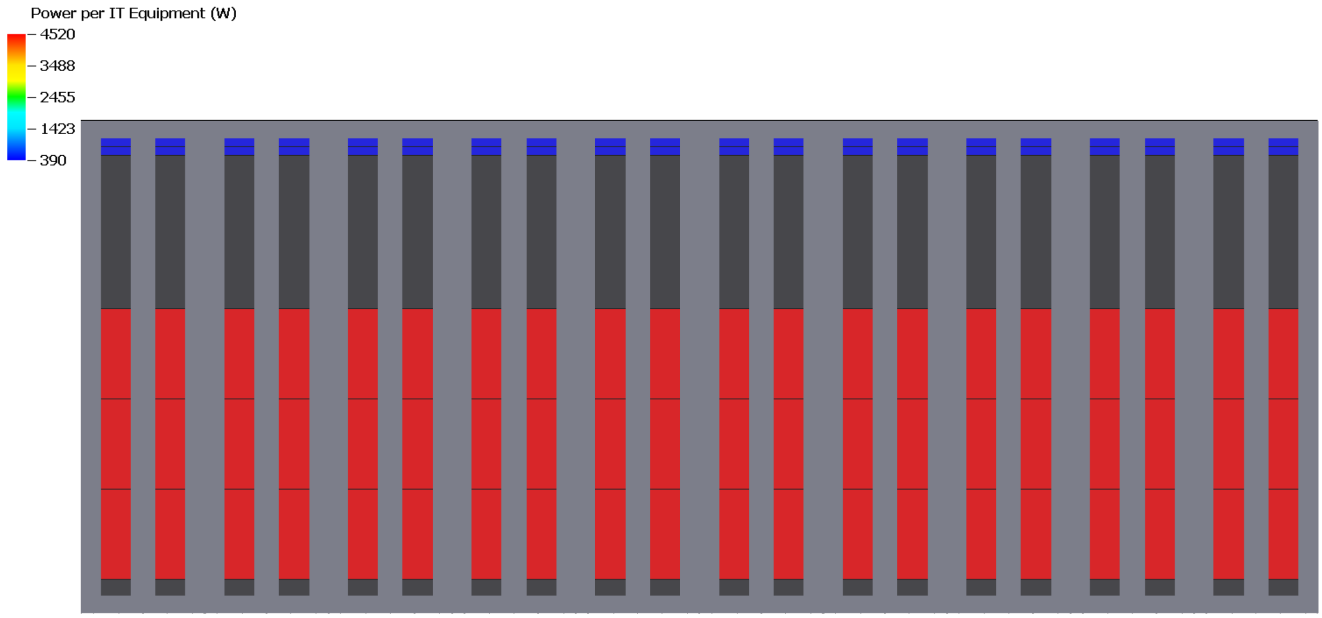


Row 5 IT Equipment Cabinet Elevation: Airflow Requirements.

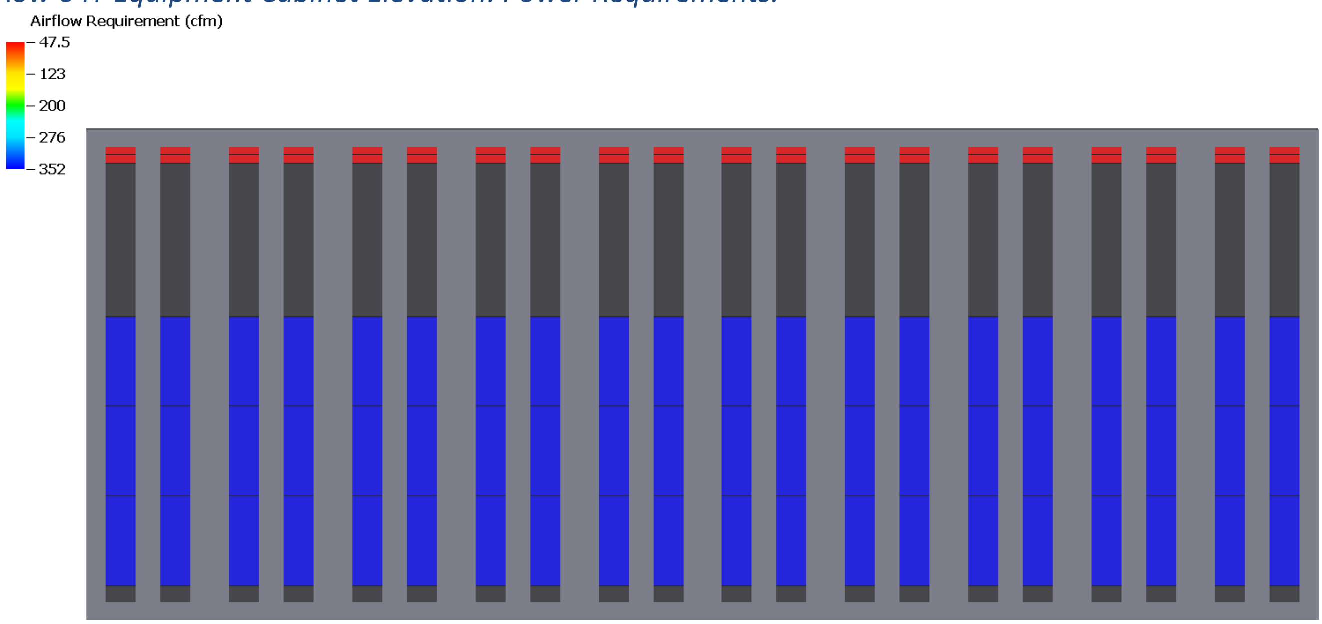
Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
6	1	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	2	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	3	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	4	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	5	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	6	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	7	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	8	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	9	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
6	10	HP	C7000	3	4520	352	40.4	14340
		Cisco	UCS 5548P	2	390	47.5	25.8	
						Row Total Power		**143400**

Row 6 IT Equipment, Power, and Airflow Details

Row 6 IT Equipment Cabinet Elevations.



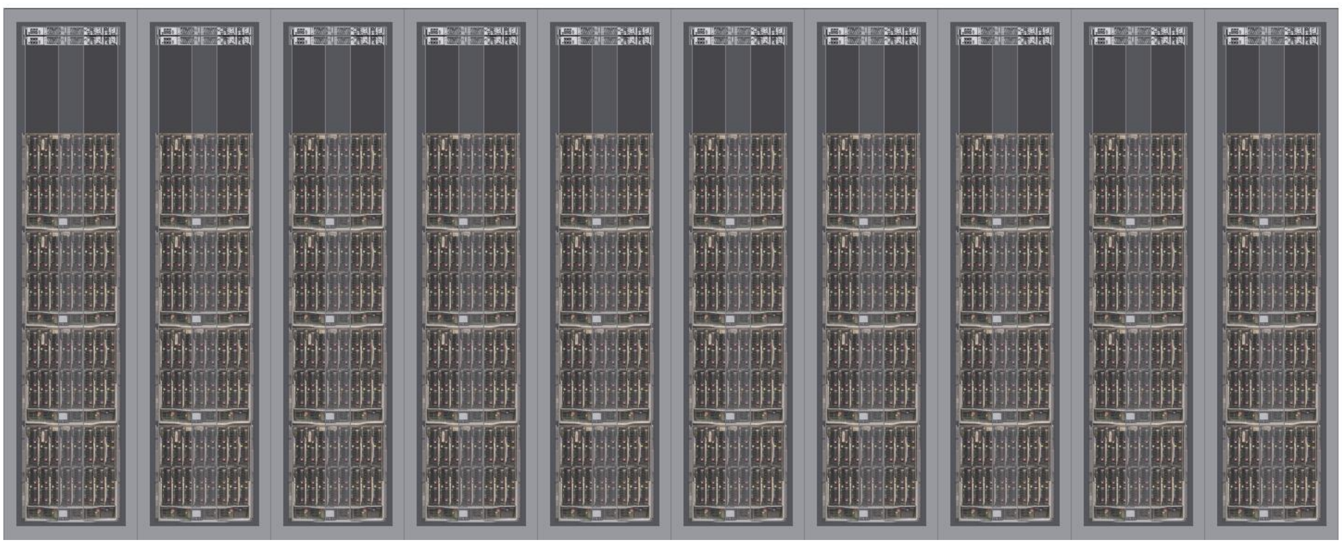
Row 6 IT Equipment Cabinet Elevation: Power Requirements.



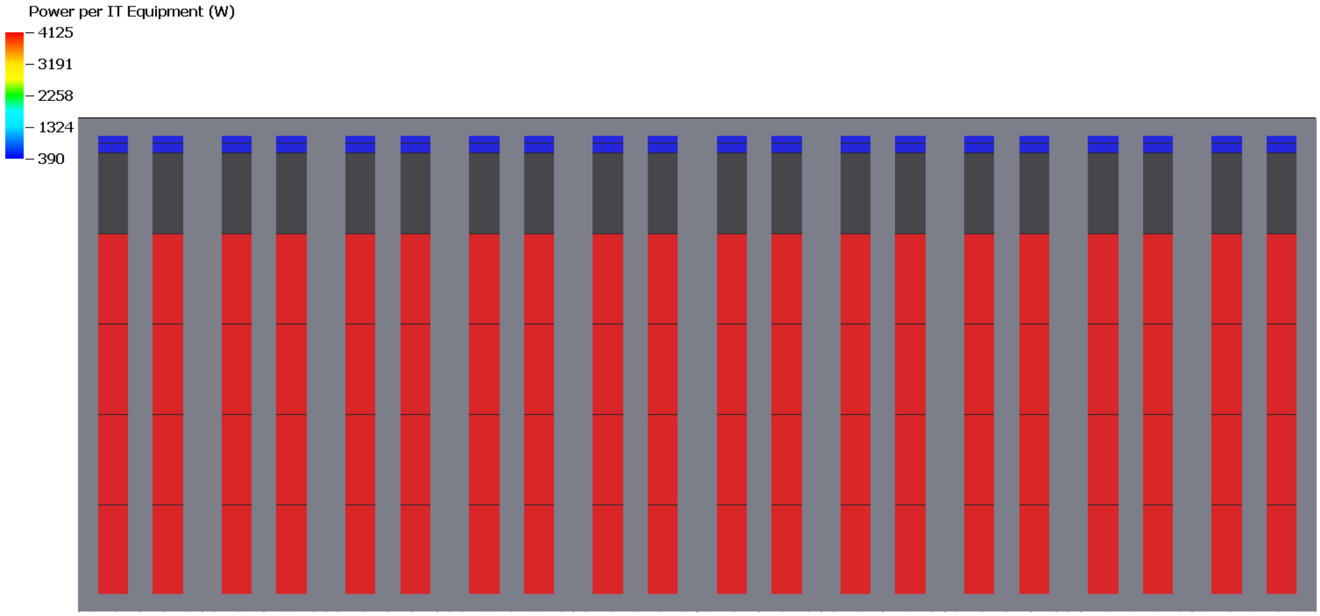
Row 6 IT Equipment Cabinet Elevation: Airflow Requirements.

Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
7	1	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	2	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	3	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	4	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	5	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	6	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	7	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	8	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	9	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
7	10	HP	C7000	4	4125	321	40.4	17280
		Cisco	UCS 5548P	2	390	47.5	25.8	
						Row Total Power		**172800**

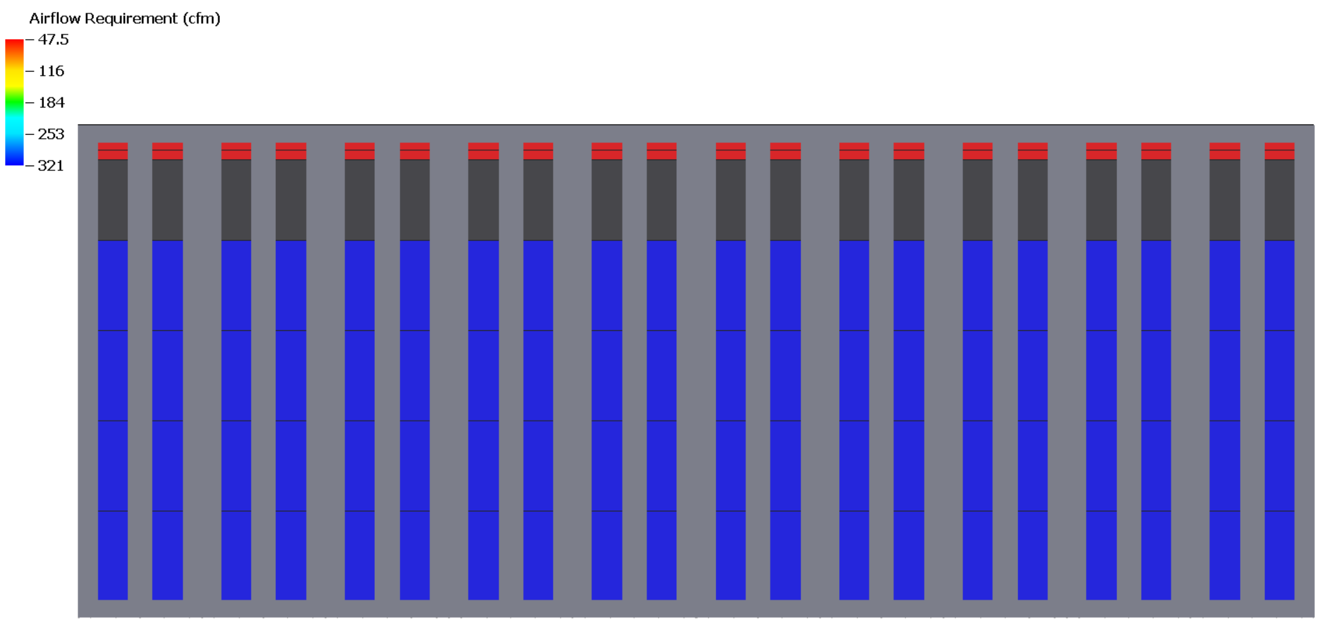
Row 7 IT Equipment, Power, and Airflow Details



Row 7 IT Equipment Cabinet Elevations.



Row 7 IT Equipment Cabinet Elevation: Power Requirements.

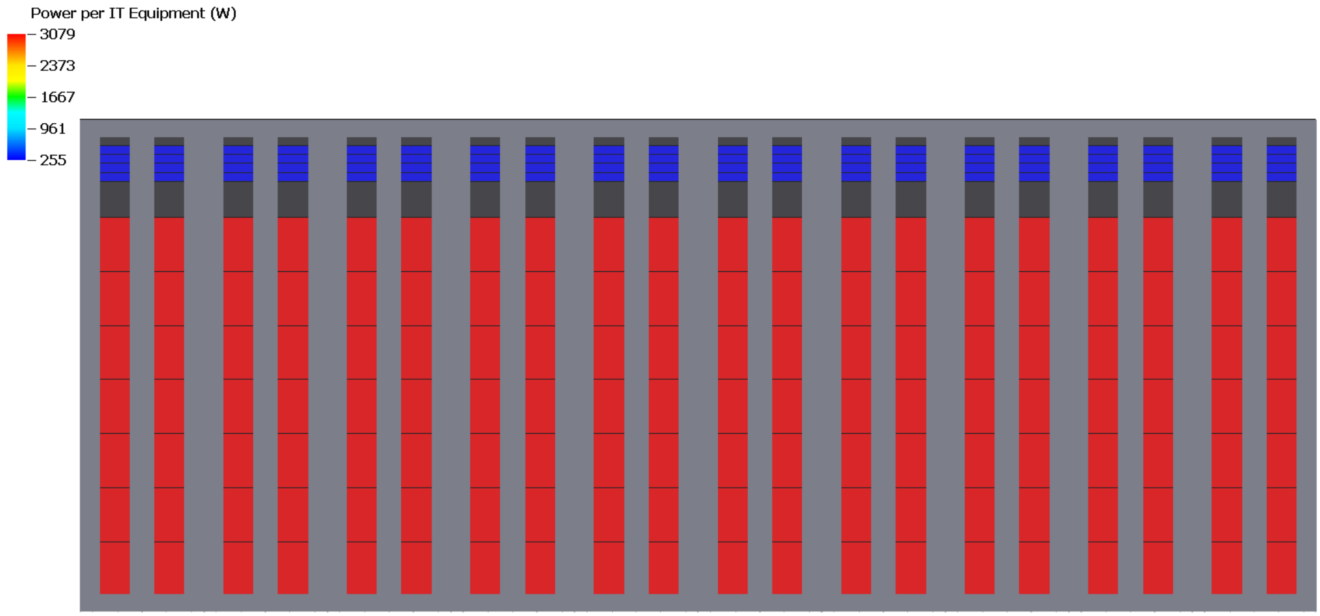


Row 7 IT Equipment Cabinet Elevation: Airflow Requirements.

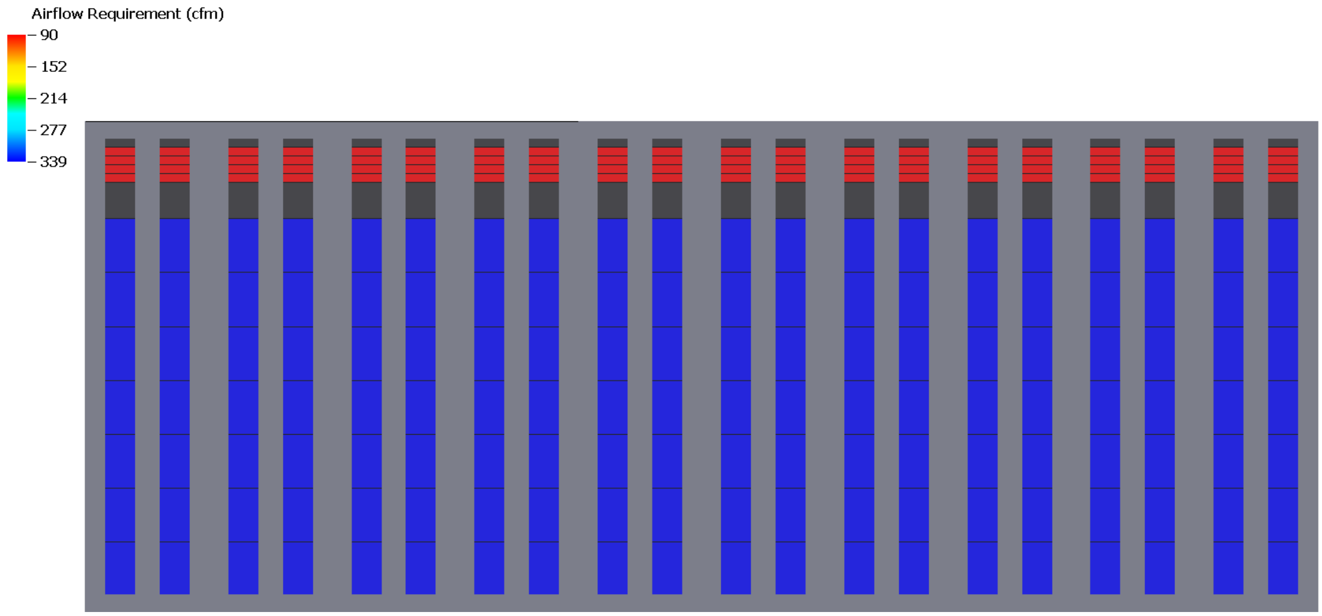
Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
8	1	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	2	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	3	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	4	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	5	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	6	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	7	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	8	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	9	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
8	10	Cisco	UCS5108	7	3079	339	28.6	22573
		Cisco	UCS 6248	4	255	90	8.9	
						Row Total Power		**225730**

Row 8 IT Equipment, Power, and Airflow Details

Row 8 IT Equipment Cabinet Elevations.



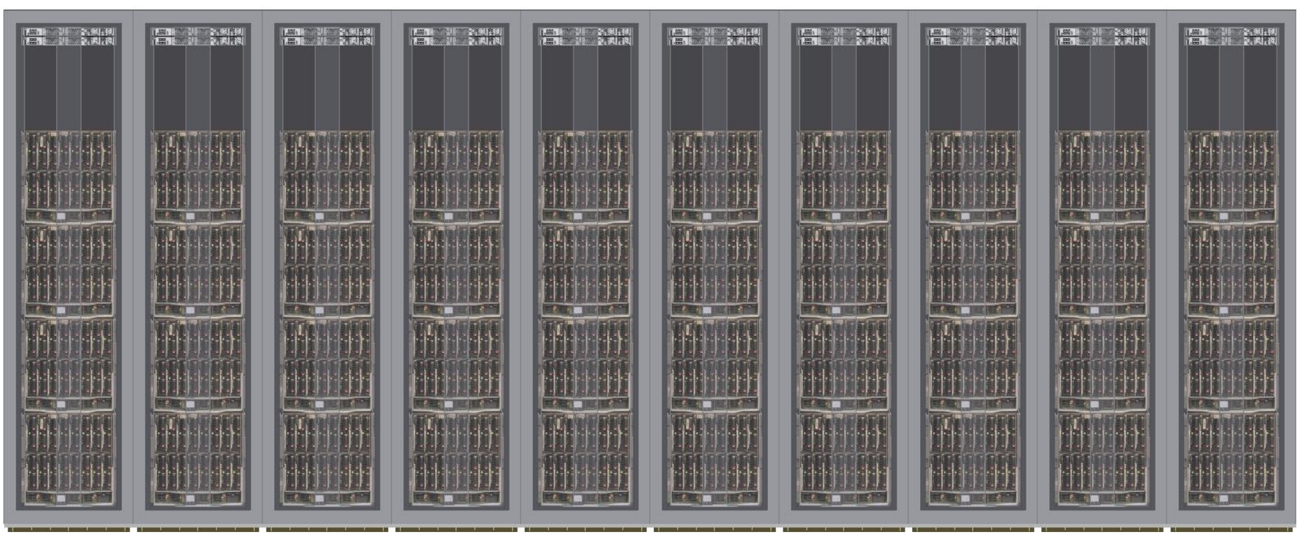
Row 8 IT Equipment Cabinet Elevation: Power Requirements.



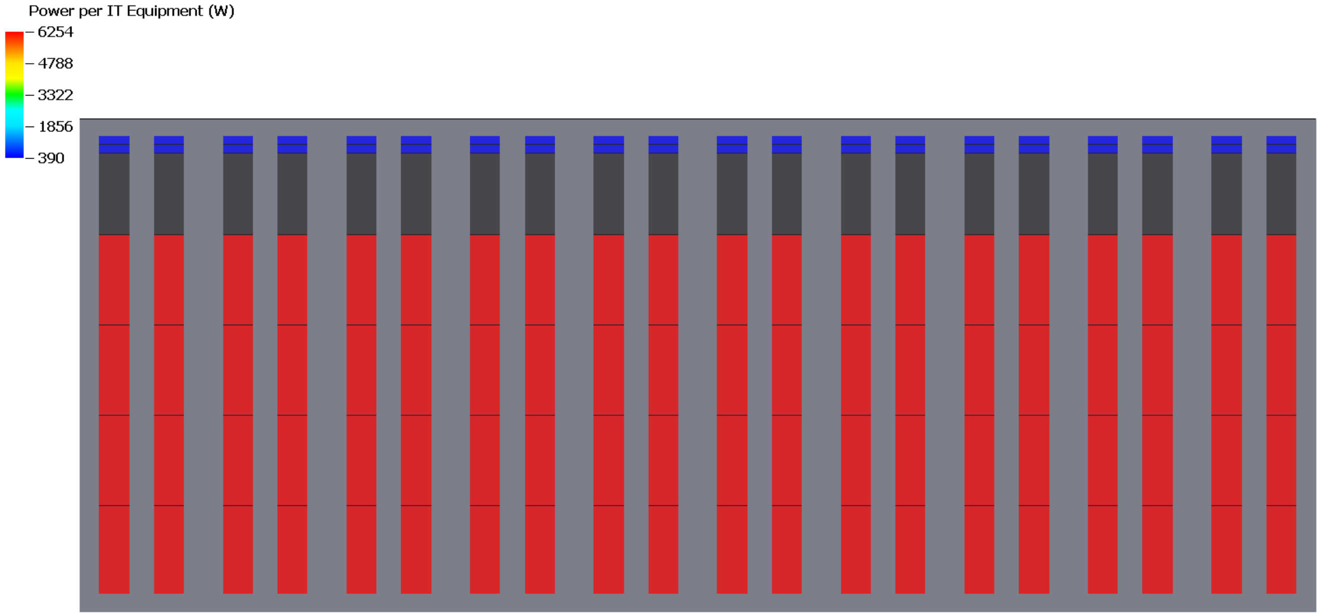
Row 8 IT Equipment Cabinet Elevation: Airflow Requirements.

Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
9	1	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	2	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	3	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	4	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	5	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	6	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	7	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	8	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	9	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
9	10	HP	C7000	4	6254	468	42.0	25796
		Cisco	UCS 5548P	2	390	47.5	25.8	
						Row Total Power		**257960**

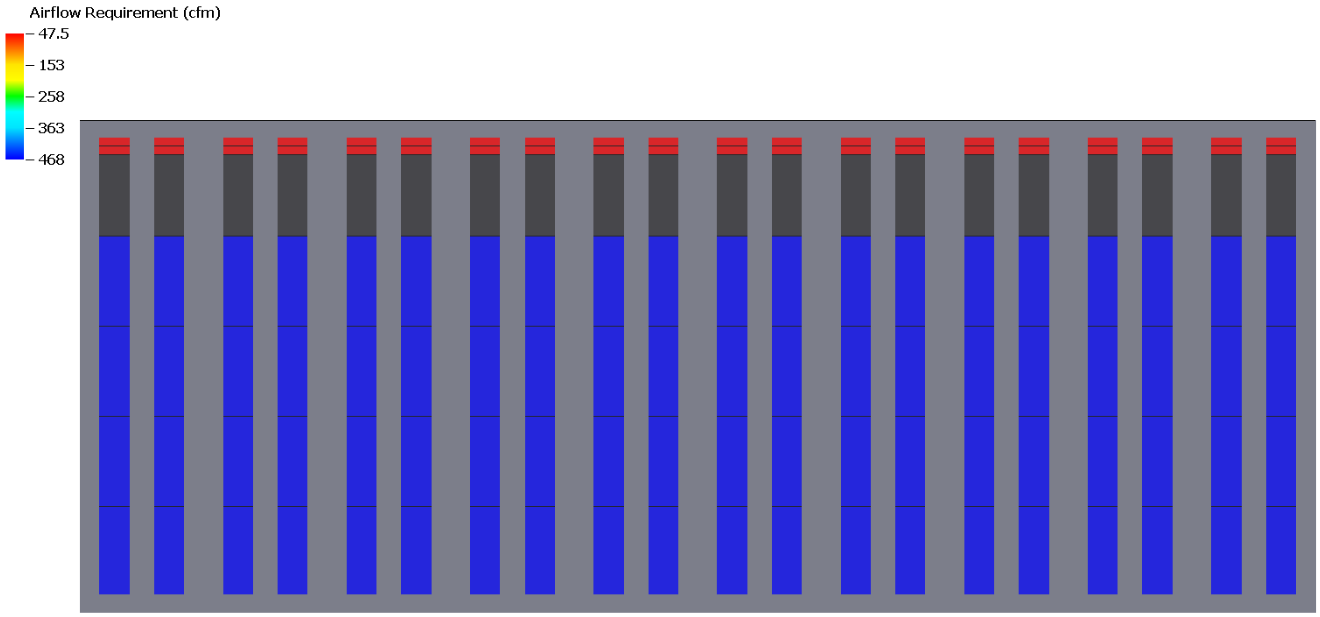
Row 9 IT Equipment, Power, and Airflow Details



Row 9 IT Equipment Cabinet Elevations.



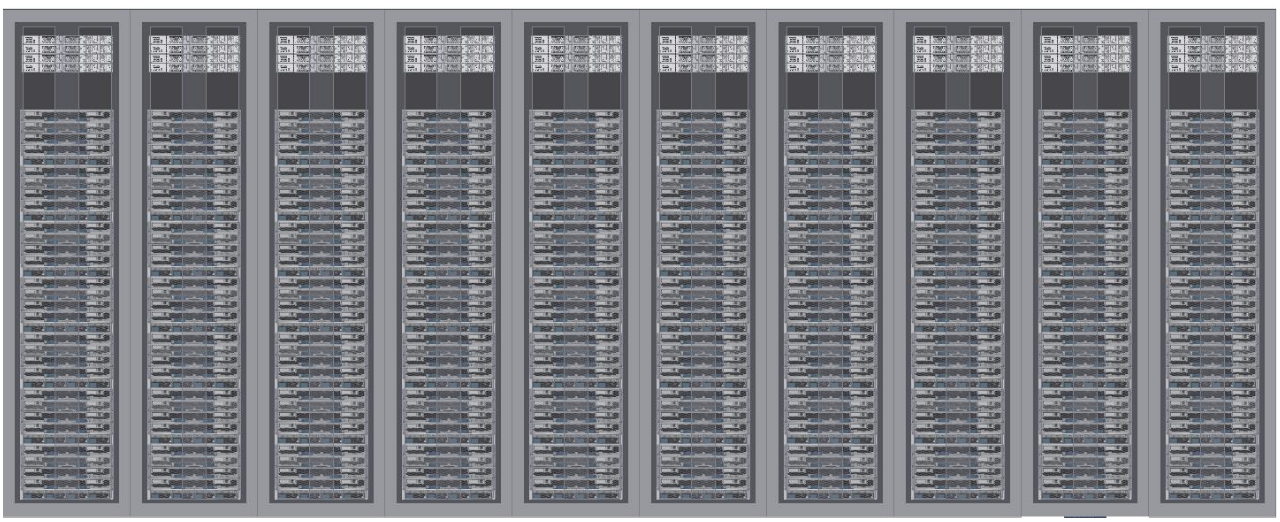
Row 9 IT Equipment Cabinet Elevation: Power Requirements.



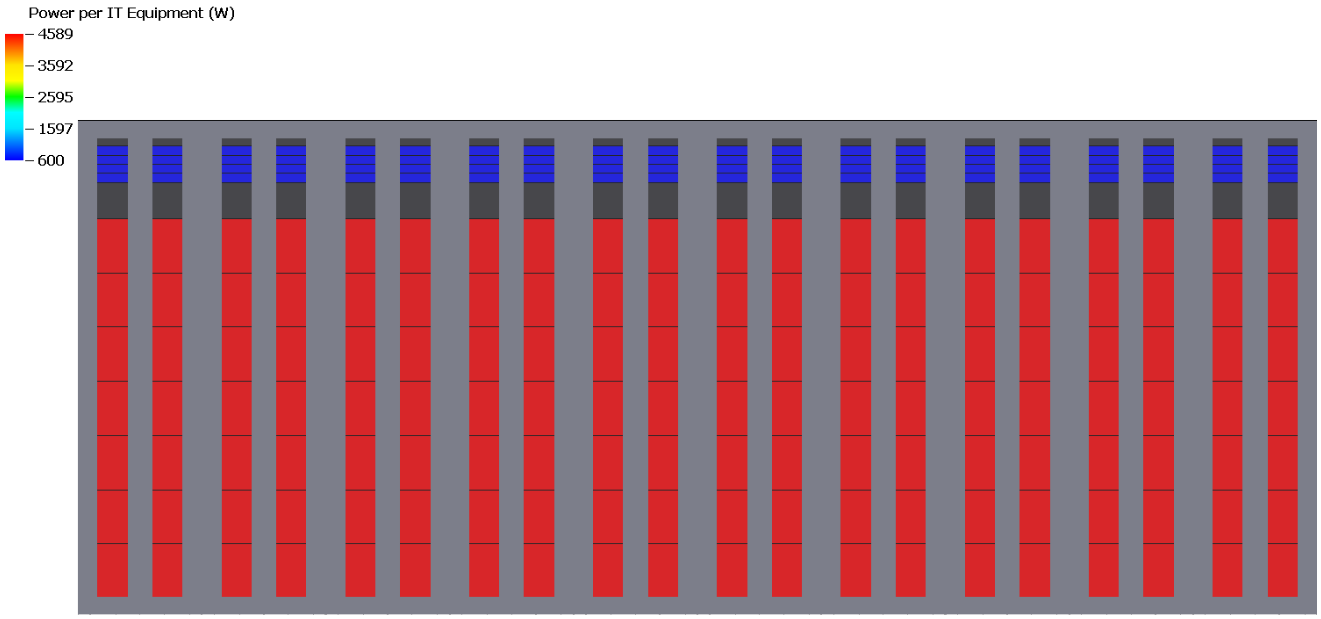
Row 9 IT Equipment Cabinet Elevation: Airflow Requirements.

Row	Cabinet	IT Equipment Manufacturer	Model	Quantity	Individual Power (W)	Individual Airflow (CFM)	Temperature Rise (°F)	Total Cabinet Power (W)
10	1	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	2	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	3	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	4	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	5	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	6	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	7	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	8	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	9	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
10	10	Cisco	UCS5108	7	4589	559	25.8	34523
		Cisco	UCS 6248	4	600	90	21.0	
						Row Total Power		**345230**

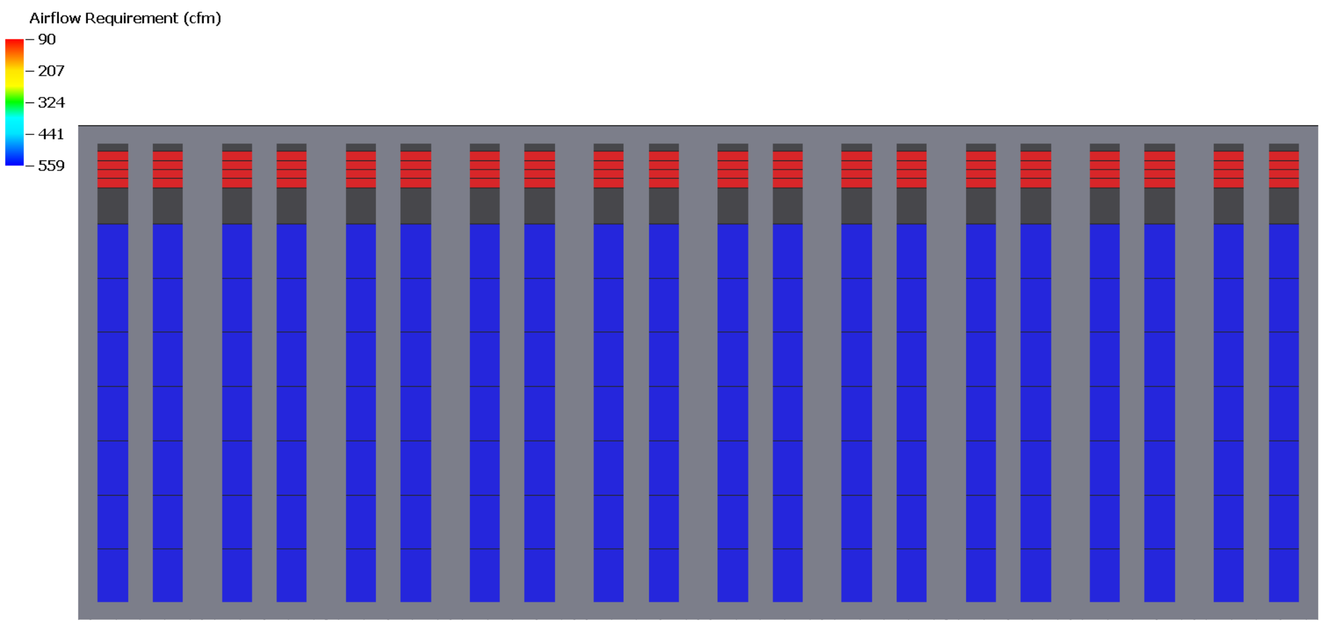
Row 10 IT Equipment, Power, and Airflow Details



Row 10 IT Equipment Cabinet Elevations.



Row 10 IT Equipment Cabinet Elevation: Power Requirements.



Row 10 IT Equipment Cabinet Elevation: Airflow Requirements

Appendix B: IT Equipment Performance Configurations

Data From Dell Energy Smart Solution Advisor

http://essa.us.dell.com/DellStarOnline/DCCP.aspx?c=us&l=en&s=biz&Template=6945c07e-3be7-47aa-b318-18f9052df893

Poweredge R420

PowerEdge R420		
Input Power:	293watts	999.8btu/h *
Power Supply Capacity:*	550watts	1876.7btu/h *
Maximum Potential Power:*	535.7watts	1827.9btu/h *
Input Current:		1.3amps
Sound Power Level:		6.8bels *
Airflow Rate:	13.5l/s	28.5CFM
Weight:	19.9kg	43.9lbs
Air Temperature Rise:	18.5°C	33.3°F

Configuration		
CPU Loading:	70%	
Workload:	Transactional	
PowerEdge R420	PowerEdge R420	
Processor	Intel® Xeon® E5-2470 2.30GHz, 20M Cache, 8.0GT/s QPI, Turbo, 8C, 95W, Max Mem 1600MHz	
Additional Processor	Intel® Xeon® E5-2470 2.30GHz, 20M Cache, 8.0GT/s QPI, Turbo, 8C, 95W	
Memory DIMM Type and Speed	1333 MHz RDIMMs	
Memory Configuration Type	Performance Optimized	
Memory Capacity	8 x 16GB RDIMM, 1333 MT/s, Low Volt, Dual Rank, x4 Data Width	
RAID Configuration	RAID 1 for H710P/H710/H310 (2 HDDs)	
RAID Controller	PERC H310 Integrated RAID Controller	
Hard Drives	4 x 1TB 7.2K RPM Near-Line SAS 6Gbps 3.5in Hot-plug Hard Drive	
Embedded Systems Management	iDRAC7 Enterprise	
PCIe Riser	PCIE Riser for Chassis with 2 Proc	
Add-in Network Adapter	On-Board Broadcom 5720 Dual Port 1Gb LOM	
Host Bus Adapter/Converged Network Adapter	QLogic 8262, Dual Port 10Gb SFP+, Converged Network Adapter, Low Profile	
Power Supply	Dual Hot Plug Power Supplies 550W	
Internal Optical Drive	DVD+/-RW, SATA, Internal for 4HD Chassis	

PowerEdge R620

PowerEdge R620		
Input Power:	289watts	986.1btu/h *
Power Supply Capacity:*	750watts	2559.1btu/h *
Maximum Potential Power:*	588.2watts	2006.9btu/h *
Input Current:		1.3amps
Sound Power Level:		6bels *
Airflow Rate:	10.1l/s	21.4CFM
Weight:	19.8kg	43.6lbs
Air Temperature Rise:	24.3°C	43.7°F

Configuration	
CPU Loading:	70%
Workload:	Transactional
PowerEdge R620	PowerEdge R620
Chassis Configuration	Chassis with up to 4 Hard Drives and 3 PCIe Slots
Shipping	PowerEdge R620 Shipping - 4/8 Drive Chassis
Processor	Intel® Xeon® E5-2670 2.60GHz, 20M Cache, 8.0GT/s QPI, Turbo, 8C, 115W, Max Mem 1600MHz
Additional Processor	Intel® Xeon® E5-2670 2.60GHz, 20M Cache, 8.0GT/s QPI, Turbo, 8C, 115W
Memory DIMM Type and Speed	1600 MHz UDIMMS
Memory Configuration Type	Performance Optimized
Memory Capacity	8 x 4GB UDIMM, 1600MT/s, Low Volt, Dual Rank, x8 Data Width
RAID Configuration	RAID 1 for H710P/H710/H310 (2 HDDs)
RAID Controller	PERC H710P Integrated RAID Controller, 1GB NV Cache
Hard Drives	4 x 1TB 7.2K RPM Near-Line SAS 6Gbps 2.5in Hot-plug Hard Drive
Embedded Systems Management	iDRAC7 Enterprise with Vflash, 8GB SD Card
Select Network Adapter	Intel Ethernet X540 DP 10Gb BT + I350 1Gb BT DP Network Daughter Card
Power Supply	Dual, Hot-plug, Redundant Power Supply (1+1), 750W
Power Cords	2 x NEMA 5-15P to C13 Wall Plug, 125 Volt, 15 AMP, 10 Feet (3m), Power Cord
Power Management BIOS Settings	Power Saving Dell Active Power Controller
Rack Rails	ReadyRails™ Sliding Rails With Cable Management Arm
Bezel	Bezel - 4/8 Drive Chassis
Internal Optical Drive	No Internal Optical Drive

PowerEdge R720

PowerEdge R720		
Input Power:	911watts	3108.5btu/h *
Power Supply Capacity:*	1100watts	3753.4btu/h *
Maximum Potential Power:*	1100watts	3753.3btu/h *
Input Current:		4.1amps
Sound Power Level:		6.7bels *
Airflow Rate:	26.2l/s	55.4CFM
Weight:	29.5kg	65lbs
Air Temperature Rise:	29.6°C	53.2°F

Configuration	
Workload:	Computational
PowerEdge R720	PowerEdge R720
Chassis Configuration	2.5" Chassis with up to 8 Hard Drives
Shipping	PowerEdge R720 Shipping
Processor	Intel® Xeon® E5-2670 2.60GHz, 20M Cache, 8.0GT/s QPI, Turbo, 8C, 115W, Max Mem 1600MHz
Additional Processor	Intel® Xeon® E5-2670 2.60GHz, 20M Cache, 8.0GT/s QPI, Turbo, 8C, 115W
Memory DIMM Type and Speed	1600 MHz UDIMMS
Memory Configuration Type	Performance Optimized
Memory Capacity	4GB UDIMM, 1600MT/s, Low Volt, Dual Rank, x8 Data Width
Warranty & Service	ProSupport Plus: 3 Year Mission Critical 4 hr Onsite Service
RAID Configuration	RAID 1 for H710P/H710/H310 (2 HDDs)
RAID Controller	PERC H710P Integrated RAID Controller, 1GB NV Cache
Hard Drives	2 x 146GB 15K RPM SAS 6Gbps 2.5in Hot-plug Hard Drive 4 x 1.6TB Solid State Drive SAS Read Intensive MLC 6Gpbs 2.5in Hot-plug Drive
Embedded Systems Management	iDRAC7 Enterprise with Vflash, 8GB SD Card
Select Network Adapter	Intel Ethernet X540 DP 10Gb BT + I350 1Gb BT DP Network Daughter Card
PCIe Riser	Risers with up to 6, x8 PCIe Slots + 1, x16 PCIe Slot
Add-in Network Adapter	2 x Intel Ethernet I350 QP 1Gb Server Adapter
Power Supply	Dual, Hot-plug, Redundant Power Supply (1+1), 1100W
Power Management BIOS Settings	Power Saving Dell Active Power Controller
Internal Optical Drive	DVD+/-RW, SATA, Internal
System Documentation	No Systems Documentation, No OpenManage DVD Kit
GPU	2 x NVIDIA® TESLA™ K20X GPU

Data From Dell Datacenter Capacity Planner

http://www.dell.com/html/us/products/rack_advisor_new/

DELL Datacenter Capacity Planner

Name	Location (RU)	Weight (lbs)	Thermal (watts)	Amps @ 208	Flow Rate (CFM)
PowerEdge M1000e @ U1 - U10	U1 - U10	433.20	4227.60	20.33	319.00

Name	Location (RU)	Weight (lbs)	Thermal (watts)	Amps @ 208 volts	Flow Rate (CFM)
PowerEdge 2950 III - HE 3.5 in. drives @ U1 - U2	U1 - U2	66.20	380.00	1.83	43.50

Data From HP Power Advisor Revision 4.6.4

Name	VA Rating (VA)	BTU HR (BTU)	System Current (A)	System Wattage (W)	idle power (W)	Circuit sizing (W)
Enclosure c-7000	6381.9	21327.04	17.71	6254.26	2492.82	7470.06
ProLiant DL160 Gen8	353.43	1203.46	1.7	352.92	119.74	434.66
ProLiant DL360 G7	338.06	1136.22	1.63	333.2	181.08	387
ProLiant DL380p Gen8	490.05	1666.5	2.36	488.71	214.81	581.95
ProLiant DL380e Gen8	448.1	1522.6	2.15	446.51	211.39	526.35

Data From Cisco UCS Power Calculator Report

Summary

Results	Max Watts	95% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Blade Servers	33,607	32,121	10,502	1,610.0	171.9	6.9	109601.4 BTU/hr, 9.1 Tons

Total Blade Server Chassis = 7

3533.3 cfm

* at 95% power

Setting	Value
System Load Factor:	95%
Power Characterization:	High Performance Computing

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Blade Servers

Cisco UCS B-Series Blade Servers	Max Watts	95% Load Watts	Idle Watts	Max Amps	95% Load Amps	Idle Amps	Weight	Cooling BTU/hr
Chassis 1: 7 of Chassis Configuration #1 with 4 Power Supplies.	33607	32121	10502	171.9	164.3	53.8	1610.0	109601.4
8 Cisco B200M3 with 2 Intel E5-2690 2.90 GHz/135W 8C/20M Cache, 768 GB Mem, 2 HDD, and 2 Mezz.								
Per Chassis Power of Chassis #1	4801	4589	1500	24.6	23.5	7.7	230	15657.3

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Summary

Results	Max Watts	95% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Blade Servers	25,773	24,723	9,916	1,610.0	131.8	6.9	84358.4 BTU/hr, 7 Tons

Total Blade Server Chassis = 7

2719.5 cfm

* at 95% power

Setting	Value
System Load Factor:	95%
Power Characterization:	High Performance Computing

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Blade Servers

Cisco UCS B-Series Blade Servers	Max Watts	95% Load Watts	Idle Watts	Max Amps	95% Load Amps	Idle Amps	Weight	Cooling BTU/hr
Chassis 1: 7 of Chassis Configuration #1 with 4 Power Supplies.	25773	24723	9916	131.8	126.4	50.9	1610.0	84358.4
8 Cisco B200M3 with 2 Intel E5-2680 2.70 GHz/130W 8C/20M Cache, 576 GB Mem, 2 HDD, and 2 Mezz.								
Per Chassis Power of Chassis #1	3682	3532	1417	18.8	18.1	7.3	230	12051.2

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Summary

Results	Max Watts	75% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Blade Servers	25,773	21,556	9,916	1,610.0	131.8	6.9	73552.1 BTU/hr, 6.1 Tons 2371.2 cfm

* at 75% power

Total Blade Server Chassis = 7

Setting	Value
System Load Factor:	75%
Power Characterization:	High Performance Computing

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Blade Servers

Cisco UCS B-Series Blade Servers	Max Watts	75% Load Watts	Idle Watts	Max Amps	75% Load Amps	Idle Amps	Weight	Cooling BTU/hr
Chassis 1: 7 of Chassis Configuration #1 with 4 Power Supplies.	25773	21556	9916	131.8	110.2	50.9	1610.0	73552.1
8 Cisco B200M3 with 2 Intel E5-2680 2.70 GHz/130W 8C/20M Cache, 576 GB Mem, 2 HDD, and 2 Mezz.								
Per Chassis Power of Chassis #1	3682	3079	1417	18.8	15.7	7.3	230	10507.4

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Summary

Results	Max Watts	50% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Blade Servers	25,773	17,596	9,916	1,610.0	131.8	6.9	60040 BTU/hr, 5 Tons 1935.6 cfm * at 50% power

Total Blade Server Chassis = 7

Setting	Value
System Load Factor:	50%
Power Characterization:	High Performance Computing

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Blade Servers

Cisco UCS B-Series Blade Servers	Max Watts	50% Load Watts	Idle Watts	Max Amps	50% Load Amps	Idle Amps	Weight	Cooling BTU/hr
Chassis 1: 7 of Chassis Configuration #1 with 4 Power Supplies.	25773	17596	9916	131.8	90.0	50.9	1610.0	60040.0
8 Cisco B200M3 with 2 Intel E5-2680 2.70 GHz/130W 8C/20M Cache, 576 GB Mem, 2 HDD, and 2 Mezz.								
Per Chassis Power of Chassis #1	3682	2514	1417	18.8	12.9	7.3	230	8577.1

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Summary

Results	Max Watts	5% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Blade Servers	25,773	10,491	9,916	1,610.0	131.8	6.9	35796.8 BTU/hr, 3 Tons

Total Blade Server Chassis = 7

1154 cfm

* at 5% power

Setting	Value
System Load Factor:	5%
Power Characterization:	High Performance Computing

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Blade Servers

Cisco UCS B-Series Blade Servers	Max Watts	5% Load Watts	Idle Watts	Max Amps	5% Load Amps	Idle Amps	Weight	Cooling BTU/hr
Chassis 1: 7 of Chassis Configuration #1 with 4 Power Supplies.	25773	10491	9916	131.8	53.8	50.9	1610.0	35796.8
8 Cisco B200M3 with 2 Intel E5-2680 2.70 GHz/130W 8C/20M Cache, 576 GB Mem, 2 HDD, and 2 Mezz.								
Per Chassis Power of Chassis #1	3682	1499	1417	18.8	7.7	7.3	230	5113.8

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Summary

Results	Max Watts	50% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Rack Servers	566	375	196	312.2	2.4	6.9	1279.6 BTU/hr, 0.1 Tons 41.3 cfm * at 50% power

Setting	Value
System Load Factor:	50%
Power Characterization:	High Performance Computing

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Rack Servers

Cisco UCS C-Series Rack Servers	Power Supply Redundancy	Max Watts	50% Load Watts	Idle Watts	Max Amps	50% Load Amps	Idle Amps
1 of Server Configuration #1 with Cisco C220SFF M3 Server Model.	**Yes**	**566**	**375**	**196**	**2.4**	**1.6**	**0.9**
2 Intel E5-2680 2.70 GHz/130W 8C/20M Cache with 320 GB Mem, 6 HDD, and 2 Adapters.		566	375	196	2.4	1.6	0.9

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Summary

Results	Max Watts	95% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Rack Servers	410	398	177	326.2	1.7	6.9	1358 BTU/hr, 0.1 Tons 43.8 cfm * at 95% power

Setting	Value
System Load Factor:	95%
Power Characterization:	High Performance Computing

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Rack Servers

Cisco UCS C-Series Rack Servers	Power Supply Redundancy	Max Watts	95% Load Watts	Idle Watts	Max Amps	95% Load Amps	Idle Amps
1 of Server Configuration #1 with Cisco C210M2 Server Model.	**Yes**	**410**	**398**	**177**	**1.7**	**1.7**	**0.9**
2 Intel X5670 2.93 GHz/6.40 GT/s/95W/6C/12M Cache with 16 GB Mem, 2 HDD, and 2 Adapters.		410	398	177	1.7	1.7	0.9

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Summary

Results	Max Watts	75% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Rack Servers	410	351	177	326.2	1.7	6.9	1197.7 BTU/hr, 0.1 Tons 38.6 cfm

* at 75% power

Total Rack Servers = 1

Setting	Value
System Load Factor:	75%
Power Characterization:	High Performance Computing

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Rack Servers

Cisco UCS C-Series Rack Servers	Power Supply Redundancy	Max Watts	75% Load Watts	Idle Watts	Max Amps	75% Load Amps	Idle Amps	Weight
1 of Server Configuration #1 with Cisco C210M2 Server Model.	**Yes**	**410**	**351**	**177**	**1.7**	**1.5**	**0.9**	**51.0**
2 Intel X5670 2.93 GHz/6.40 GT/s/95W/6C/12M Cache with 16 GB Mem, 2 HDD, and 2 Adapters.		410	351	177	1.7	1.5	0.9	51.0

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Summary

Results	Max Watts	50% Power	Idle Watts	Weight (lbs)	Max Amp Draw	Floor Space (SqFt)	Cooling Needed*
Rack Servers	410	292	177	326.2	1.7	6.9	996.3 BTU/hr, 0.1 Tons 32.1 cfm * at 50% power

Total Rack Servers = 1

Setting	Value
System Load Factor:	50%
Power Characterization:	High Performance Computing

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Rack Servers

Cisco UCS C-Series Rack Servers	Power Supply Redundancy	Max Watts	50% Load Watts	Idle Watts	Max Amps	50% Load Amps	Idle Amps	Weight
1 of Server Configuration #1 with Cisco C210M2 Server Model.	**Yes**	**410**	**292**	**177**	**1.7**	**1.3**	**0.9**	**51.0**
2 Intel X5670 2.93 GHz/6.40 GT/s/95W/6C/12M Cache with 16 GB Mem, 2 HDD, and 2 Adapters.		410	292	177	1.7	1.3	0.9	51.0

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Fabric Interconnects & FEX

Fabric Interconnect FEX	Max Watts	In-Use Watts	Idle Watts	Max Amps	Is-Use Amps	Idle Amps	Weight	Cooling BTU/hr
Cisco UCS 6248UP 48-Port Fabric Interconnect with 32 Ports and Fully Redundant Power Supply	300	256	250	1.5	1.3	1.2	35.0	874.4
Cisco Nexus 2232PP FEX	275	175	175	1.4	0.9	0.9	18.3	597.1

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