



The Road to Passive Cooling

Why CPI's Ducted Exhaust Cabinets are More Efficient than Alternatives

With today's increasing density requirements, it is often assumed that liquid cooled server cabinets are the only feasible option for high-density data centers. In reality this assumption is not true; there are more efficient and superior alternatives to high-priced liquid cooling solutions, specifically ducted exhaust cabinets ([F-Series TeraFrame Cabinet](#) & [T-Series SteelFrame Cabinet](#)). Industry research measures the cost per unit for ducted exhaust cabinets in the hundreds of dollars, while liquid cooled server cabinets range in the thousands of dollars and also require the additional installation and maintenance expense of process chilled water systems to cool the cabinets. On average you can save about 70% in building costs by using a ducted exhaust system compared to a liquid cooled system.

Working with one of our major customers we discovered new and efficient solutions to achieve high-density cooling results by employing [simple airflow management techniques](#) in cabinet spaces to maximize cooling unit efficiency, reduce energy consumption and minimize total cost of ownership.

- **New knowledge** – Ducted exhaust cabinets provide an innovative technique for removing heat from the cabinet and data center without the use of added electricity or plumbing. By using passive airflow strategies to achieve complete isolation of hot exhaust and cold supply air, ducted exhaust cabinets increase airflow efficiency and allow AC supply air temperatures to be increased, resulting in decreased energy consumption while offering the ability to cool higher heat densities.
- **Knowledge transferability** – Anyone can achieve savings by applying passive cooling techniques to their data center. Simple solutions of reducing bypass air, isolating hot and cold air or installing a fully ducted return provides a scalable solution for a wide range of kilowatt requirements.
- **Measurability** – Three test scenarios were conducted and the results were measured based on the kilowatt use and cooling capabilities.
- **Impact** – The AC system efficiency was improved overall by 43% allowing for a higher kilowatt of equipment without having to resort to the expense of liquid cooled cabinets. Airflow management allows for higher density equipment without the expense of higher energy costs or exposing equipment to the risk of liquids in the data center. A major accomplishment was to go from 7.5 – 8.2 AC system efficiency and an additional 4.5 kilowatt capacity which means you can add more equipment without the addition of CRAC units. There is also the benefit of being able to cool more kilowatts per cabinet without increasing the footprint of the data center.

The Airflow Issue Exposed

While evaluating the airflow present in their data centers, this customer found that their server exhaust air was becoming trapped in the data center, causing hot exhaust and cold supply air to mix, creating inefficient results. In order to maintain safe server inlet temperatures, they were forced to drastically drop their CRAC temperatures so that the cold supply air mixing with the hot exhaust air would provide temperatures within server specifications, which presented a very expensive and wasteful method of cooling.

To overcome these issues, our top thermal experts began working with this customer to design a solution that would offset their increasing densities, improve air-conditioning airflow efficiencies and increase watts of heat removed per CFM (cubic foot of air per minute) of cooling. After extensive modeling and experimentation it became apparent that

the utilization of airflow management strategies employing passive cooling techniques to isolate hot and cold air in the cabinet and data center would solve their airflow management problems.

The Journey to Improved Airflow Efficiency

Before coming to this conclusion a series of tests were conducted. The testing began in a 1,248 square foot data center that contained 28 conventional cabinets (fourteen 2 kW and fourteen 4 kW) and three air handling units rated at approximately 10,000 CFM. It was estimated that in this situation bypass airflow was over 35 percent with an Air-Conditioning Airflow Efficiency (ACAEE) number of 4.7, which is a typical efficiency number for most data centers today. ACAEE is defined as the amount of heat that can be removed per cubic feet per minute (CFM) of cooling air.

Data Appendix: Table 1, Figure 1.

With the desire to reduce bypass airflow and improve airflow efficiency, it was decided to remove the unused cable management arms, from the back of the servers and add solid filler panels inside of the cabinets to seal the gaps between servers. The cable management arms were blocking airflow and acting as a heat sink, therefore removing them and adding filler panels reduced hot air re-circulation to the front of the cabinet, which increased cooling capacity of the cooling system and allowed for better airflow management.

Since the removal of the cable management arms and addition of solid filler panels was successful, it was decided to drastically increase the heat load per cabinet by replacing all of the 2 kW and 4 kW servers in the data center with 8 kW and 14 kW servers. To remove the server exhaust from the cabinet and further prevent bypass airflow, a duct was added to the top of the cabinet space so that the hot exhaust air could be removed from the top of the cabinet and pushed through the plenum above the drop ceiling. This transition increased the watts per square foot substantially, but required only two additional cooling units to manage the temperature change. The data center then exhibited a 37 percent improvement over the original setup, with a new ACAEE number of 7.5, and only 10 percent bypass airflow.

Data Appendix: Table 1, Figure 2.

Although thrilled with the progress to this point, it was decided to push it a step further and switch out the previous servers with 14 kW and 25 kW servers. Still using ducted exhausts to channel exhaust air out of the cabinet space, we designed the solution to direct-duct the hot exhaust air back to the cooling units hot air return. This configuration completely prevented the mixing of hot exhaust and cool supply air, which reduced the bypass airflow to only 1% and increased the ACAEE number to 8.2; a 43 percent improvement from the original efficiency number of 4.7. *Data Appendix: Table 1, Figure 3.*

Conclusion

Having achieved complete airflow isolation, reduced bypass airflow and the re-circulation of hot exhaust air, temperature variations no longer existed in the data center and the supply room temperature could be raised while still providing safe server inlet temperatures. Not only did our airflow management techniques help this company achieve efficient cooling results to offset their increasing densities, but in the process transformed the traditional server cabinet from a box for housing servers into an architectural feature in the data center that could achieve high-density cooling results without the addition of cost-prohibitive liquid cooled server cabinets.

Pioneered in 2004, these innovative passive airflow management solutions are now implemented in major data centers across the US and abroad including (but not limited to) hosting and co-location facilities, financial institutions, telecom providers, network and technology companies, health institutions and major high-tech universities.



If you have comments or questions, or would like to have a CPI Thermal Expert speak with your further about these findings, please call 800-834-4969 or email techsupport@chatsworth.com.

Data Appendix

Table 1:

	Data Center Size	Number of Cabinets 28 total split 50/50 between the kW loads	Number of Air Handling Units at 10,000 CFM	Bypass Airflow	ACAЕ	ACAЕ Improvement Over Test 1
Test 1	1248	2 - 4 kW	3	35%	4.7	-
Test 2	1248	8 - 14 kW	5	10%	7.5	37%
Test 3	1248	14 - 25 kW	8	1%	8.2	42%

Test 1 Summary:

Test 1 took place in a 1,248 square foot data center that contained 28 conventional cabinets (fourteen 2 kW and fourteen 4 kW) and three air handling units rated at approximately 10,000 CFM. In this situation bypass airflow was over 35 percent with an Air-Conditioning Airflow Efficiency (ACAЕ) number of 4.7, which is a typical efficiency number for most data centers today.

Test 2 Summary:

Test 2 took place in a 1,248 square foot data center with 28 ducted exhaust cabinets (fourteen 8 kW and fourteen 14 kW) and five air handling units rated at approximately 10,000 CFM. The cable management arms are removed and solid filler panels are installed within the cabinet to decrease bypass airflow, which is now only 10%. The new ACAЕ number is 7.5, which is a 37 percent improvement over the previous test.

Test 3 Summary:

Test 3 took place in a 1,248 square foot data center with 28 ducted exhaust cabinets (fourteen 14 kW and fourteen 25 kW), and 8 air handling units rated at approximately 10,000 CFM. The cable management arms are still removed and solid filler panels are situated within the cabinet to reduce bypass airflow, which is now measured at only 1 percent. The ducted exhaust in this test is direct-ducted back to the cooling units hot air return, resulting in a new ACAЕ number of 8.2, a 42 percent improvement over our original 2-4 kW test.

Figure 1:
2-4 kW Conventional Data Center

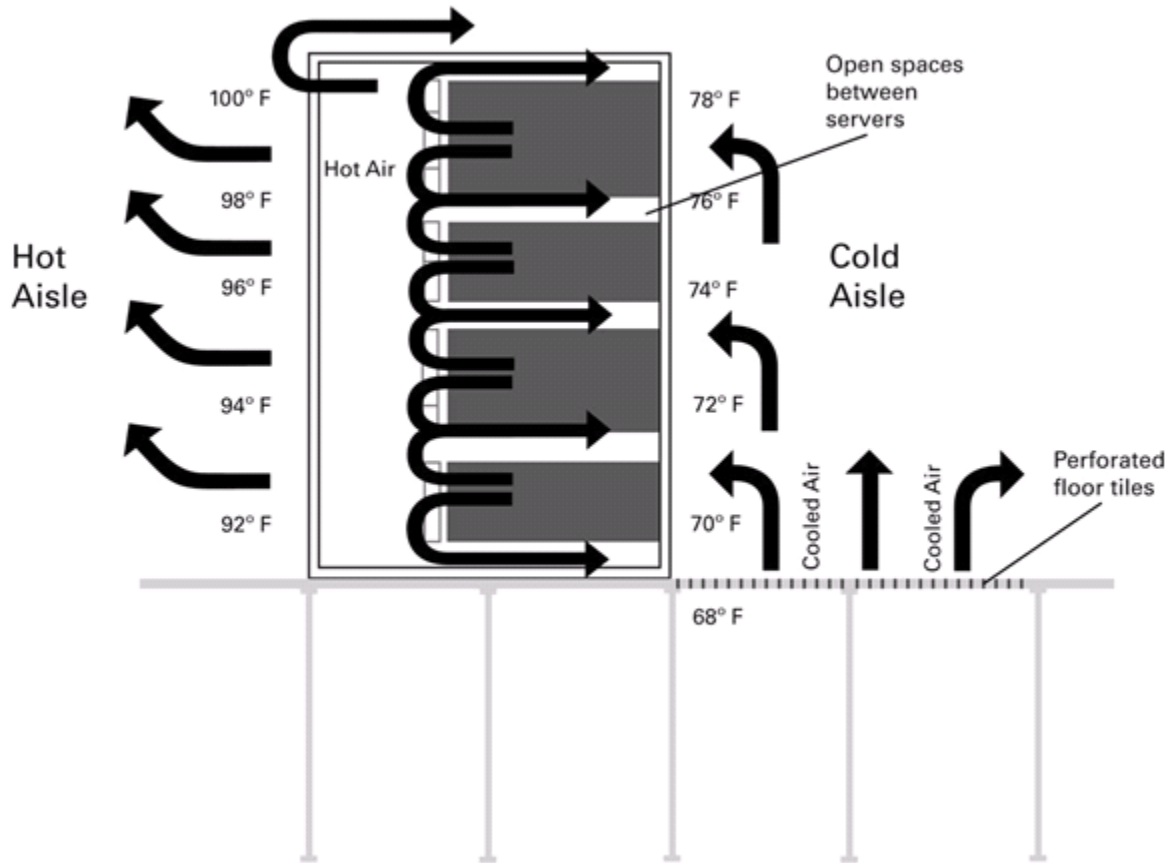


Figure 1 Summary:

Figure 1 shows how the cable management arms serve as airflow barriers in the cabinet space. There are no filler panels installed to block bypass airflow, therefore open spaces exist between servers and hot exhaust air is re-circulated from the rear of the cabinet to the front, mixing with the cool air. This reduces the effective cooling capacity and increases the temperature of air entering servers, especially at the top of the cabinet.

Figure 2:
8-14 kW Upgrade

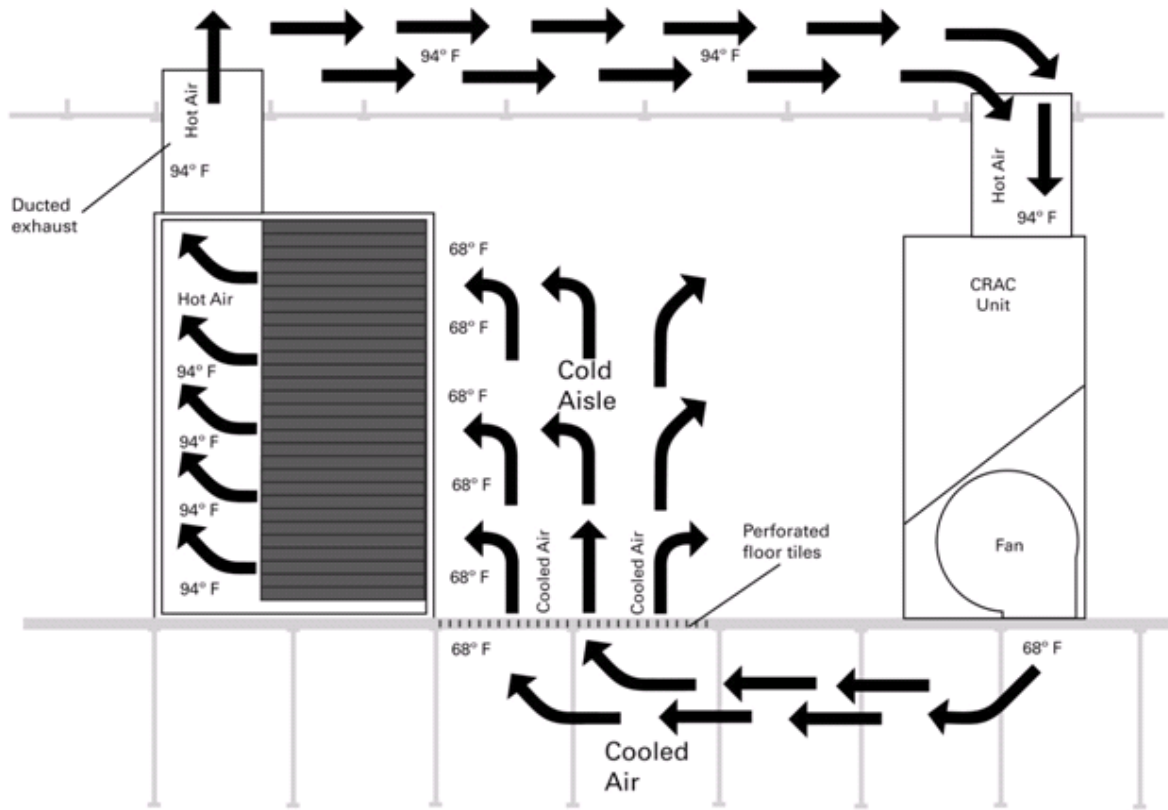


Figure 2 Summary:

Figure 2 shows the cable management arms removed and filler panels and a ducted exhaust installed. The filler panels close off all open spaces between the servers, isolating hot air from cold air within the cabinet space, while the ducted exhaust directs hot exhaust air out of the cabinet space and through the plenum above the drop ceiling, no longer allowing the hot air to re-circulate from the back to the front of the cabinet. Since the heated exhaust air is now contained and isolated from the supply air, servers installed at both the top and bottom of the cabinet receive the same inlet air temperature of 68°F.

Figure 3:
14-25 kW Upgrade

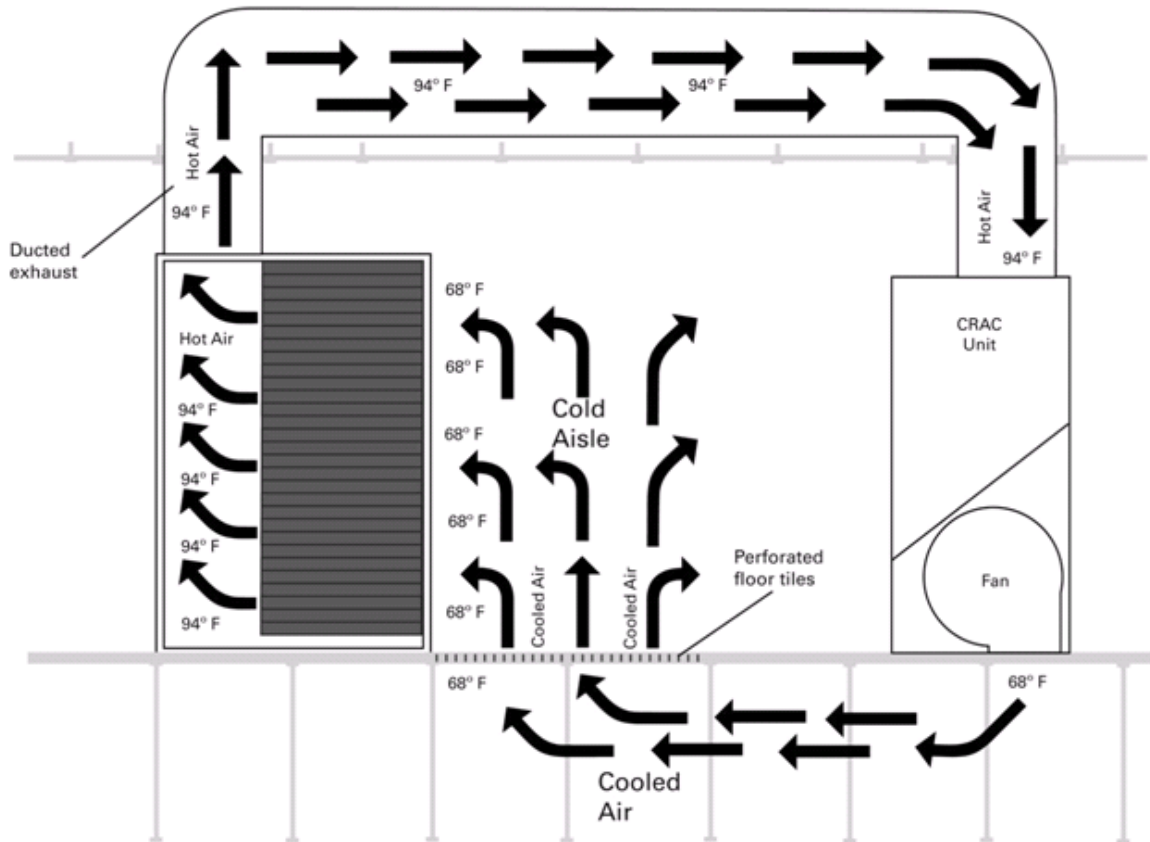


Figure 3 Summary:

Figure 3 shows the cable management arms removed and filler panels and a ducted exhaust installed. The ducted exhaust is direct-ducted back to the cooling unit, which creates a closed loop system. By drawing heat out of the cabinet and pushing it through the cooling unit with a higher negative pressure, the amount of cold air delivered to the servers and cabinet is increased, allowing for maximum kilowatts per cabinet.