VERTIV WHITE PAPER

Overcoming the Challenges in Cooling Non-Raised Floor Data Centers

Executive Summary

The trend away from raised floors in large data center builds

In an effort to build data centers more quickly to keep up with growing demand while controlling costs, the industry is increasingly moving away from what once was a staple in large data centers: raised floors.

While the elimination of raised floors does simplify data center construction, it brings with it challenges in terms of cooling. Raised floors serve a practical purpose in cooling by creating a uniform space that allows for a constant level of air pressure. Without that well-defined space, it becomes more difficult to measure pressure differential, which is important to determining where and when you need additional cooling capacity.

But the benefits of eliminating raised floors are too great to ignore, prompting the need for a fresh approach to cooling design in a non-raised floor data center environment. This paper describes such an approach, based on a methodology for primarily measuring temperature, not static pressure, to achieve accurate, efficient data center cooling.

Making the case for non-raised floors

For years, the demand for data center capacity has been nearly insatiable, and there's no end in sight.

Continued adoption of cloud services by enterprises, the rising adoption of Internet of Things (IoT) devices and analytics, as well as investments in 5G cellular technology are all serving to increase demand for data centers and data storage, according to Infiniti Research Limited. Infiniti predicts the data center market will experience a compound annual growth rate (CAGR) of more than 17% from 2019 through 2023.[1] Researchers at Technavio arrived at the same CAGR figure, noting the market will grow by more than $284 billion during the forecast period.[2]

That kind of growth means colocation companies and other data center providers need to rapidly build out new data center capacity to meet demand and expand their businesses. As such, they are interested in any techniques that can help them build data centers more quickly and, of course, cost-effectively.

Doing away with raised floors meets both objectives.

- **Cost:** Raised floors involve more extensive engineering as well as higher costs for materials and installation versus non-raised floors. What's more, it's difficult to clean underneath a raised floor without disturbing dust and particles that can damage IT equipment. That may result in the need to pay for periodic professional cleaning. It's also likely that the raised floor will be installed to cover the maximum data center space available, even if it's not going to be used in the near term. That raises not only initial capital costs but also ongoing costs for cooling the unused space.

- **Deployment speed:** The more extensive engineering required for raised floors also increases the time it takes to install them versus a hard floor. Extensive bracing is required to balance out the expected weight loads, which can be difficult to predict. For colocation providers, adding time to data center builds means the loss of potential revenue and a longer time to realize a return.

Another cost consideration is the increased cooling efficiency that non-raised floors can offer, leading to lower operating costs over the long term, but these benefits can only be realized by taking a fresh approach to data center cooling.

Traditional raised floor cooling

Let's first consider how the traditional approach to cooling works when using a raised floor and a perimeter cooling system.

The first challenge to overcome in a raised floor environment is ensuring positive pressure is maintained under the floor. The space underneath the raised floor is largely uniform. Think of it like a large balloon that you can inflate as needed to maintain whatever air pressure is required to cool the data center.

[1] "Global Data Center Market 2019-2023," July 2019, Infiniti Research Limited
[2] "Global Data Center Market 2019-2023," August 2019, Technavio

The next challenge is ensuring each rack is receiving the proper amount of airflow and cooling. This is achieved via specification of the floor tile perforation. As more air is needed at the rack level, larger openings or additional perforated floor tiles are required. The pressure differential across the floor tile becomes a measurable item that is used to influence cooling unit fanspeed. Because the space is largely uniform, it's also relatively easy to accurately measure the air static pressure.

In this scenario, there's generally a uniform relationship between cooling capacity and air flow. As servers heat up, their fan speeds increase, which changes the balance of air pressure in the data center space and more air is expelled from under the floor through the floor tiles. If the air entering the data center space becomes too warm, the cooling system will simply open a water valve and/or increase the air conditioning compressor load to increase cooling capacity.

In either case, the air conditioning fan speed must increase to maintain positive pressure under the floor in order to distribute the additional cool air throughout the data center via perforated floor tiles and meet the target service level agreement (SLA). This method of control is a standard approach for raised floor applications.

For a deeper dive on how variable speed drives can improve efficiency with respect to fan speeds, download the following application note: **Adoption of Variable Cooling Based System in Data Center to Optimize Cooling Infrastructure**

By measuring the pressure differential, it's relatively simple to ensure the air flow leaving the cooling system matches the demand for air flow at the rack/server level.

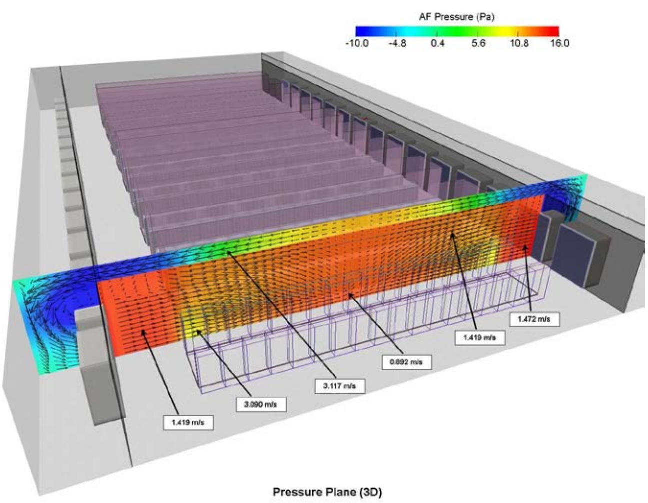
Non-raised floor cooling challenges with pressure control

Eliminating the raised floor changes the pressure equation dramatically. Measuring the pressure within the contained, uniform space beneath the floor is straightforward and works for fully or partially populated spaces because overall airflow control is managed via the floor tiles. Moving to a non-raised floor space, that uniform, balloon-like space that made it relatively simple to maintain a constant air pressure is now gone. Controlling airflow to the rack via perforated floor tiles is no longer possible since floor tiles are not used in this environment.

In effect, that space is replaced by the entire data center, which is filled with servers, racks, containment systems, columns, and other structural elements that may disrupt air flow. You now have a completely different airflow pattern to consider, especially as rack densities increase and hot aisle containment is required. Using the standard approach discussed in the previous section is no longer a valid option. Without a raised floor to use as a tool to maintain positive static pressure in combination with perforated floor tiles for airflow distribution, a new approach must be chosen.

In such an environment, it becomes challenging to implement accurate static pressure control measurements, largely because the space you're trying to measure is significantly larger. Instead of moving air through the underfloor "duct" to an open tile in front of a rack, you now must blow air down a cold aisle in front of all the racks.

The challenge here is you tend to witness high air velocities at the entrance of a cold aisle that reduce as the air moves towards the opposite end of the aisle. This presents large pressure variations across the aisle, making it difficult to establish a good baseline pressure measurement that can be used for control. In this case, the pressure sensors for control would be measuring the pressure differential across the hot aisle containment. Deployment of multiple static pressure sensors across this space to create an aggregated reading is possible, but this is no longer a reliable means of fanspeed control without the raised floor.



Pressure Plane (3D)

What's more, such a measuring system will be more costly than with a raised floor because it requires additional sensors located throughout the space and manual tuning to achieve an even close-to-accurate measurement.

The Temperature Approach

An alternate method to ensuring the right airflow is delivered to each rack is to measure the temperature up and down the cold aisle. Generally, you set a temperature control point at around 2 degrees F above the supply air temperature leaving the cooling unit. This will tell you if enough airflow is reaching each rack without warm air recirculating back to the front of the rack.

This approach takes into consideration numerous failure conditions like blocked cold aisles and provides monitoring to make sure you have the right temperatures to meet temperature SLAs. In the end, you are controlling the airflow to a temperature that can be linked to an SLA versus pressure, which can only determine whether you have a positive pressure between the cold and hot aisles.

The Delta T Approach

A further enhancement to the temperature control method with remote rack sensors is coupling it with a Delta T control across the cooling unit. Delta T is the difference in temperature between the return air temperature coming back to the cooling unit and the supply air temperature leaving the cooling unit headed to the rack. With this strategy, the cooling unit airflow is controlled to operate at the system Delta T. Thus, if the return air temperature is too high, the control will increase fanspeed, and if the return air temperature is too low, the control will decrease fanspeed.

For example, let's say the temperature of the cool air as it leaves the air handler and enters the data center is 75 degrees F (24 degrees C). When it returns from the data center, after doing its job of cooling servers, switches and other IT gear, the air temperature is now 95 degrees F (35 degrees C). That's a Delta T of 20 degrees F (11 degrees C)—a fairly common design target for data centers.

An alternative to focusing on the air pressure, then, is to focus on the Delta T, with the goal being to keep it within the original design goal of the data center.

By focusing on the air temperature up and down the cold aisle, you are more easily able to ensure adequate airflow is being provided to each server rack. By using temperature as a means of airflow control, the Delta T can be adjusted based on remote rack sensor temperature needs but also alerts the end-user when the unit has deviated from the "design intent" point. If we couple the Delta T process with measuring the air temperature at the rack level, not only can we achieve working to the design intent or design system efficiency, but we can also make sure all SLA temperature requirements are being met.

For colocation providers (and others), this strategy presents several advantages. For one, most customer SLAs are written to specify the data center be maintained at a certain temperature to protect the customers' IT equipment. From that perspective, focusing on meeting the data center supply air temperature requirement makes perfect sense, and ensures you're meeting your SLAs.

Secondly, in a non-raised floor environment, you'll almost certainly be using a hot-aisle containment system to prevent the hot exhaust air from mixing with the cool supply air. It's a simple matter to measure the temperature of the air coming out of the containment system to determine the Delta T and then determine whether you have too much or not enough cool air entering the data center.

To illustrate the point, we'll use an extreme example (which wouldn't likely happen with a quality air control system). Let's say your design target is a Delta T of 20 degrees F. As you measure the temperature of the air coming from servers and compare it to the temperature of the supply air, you find the actual Delta T is 23 degrees F. That means you don't have enough cool air to meet your target.

At this point, the fans in the cooling unit will increase speed at the rack level. If that's not enough, the system will increase the overall supply of cool air to the room until the Delta T is back in line.

Benefits of Delta T approach

Controlling temperature in the aisle based on static air pressure alone is difficult when there's no raised floor present. It requires lots of manual intervention, hunting for various fans to turn on and off, and tuning various sensors and systems to make it work properly. A raised floor with floor tiles provided an easy measuring point, which is above and below the floor tile (two dimensional).

When pushing cold air down an aisle as opposed to forcing it through floor tiles on a raised floor, the question now becomes "where do I mount my static pressure sensors and how many are required?"

The answer is there is no easy answer since the non-raised floor environment is so dynamic. The overall length, width, and height of the aisle (three-dimensional) must be taken into account. This space represents what the underfloor cavity used to be in a raised floor environment. Airflow now comes from the end of an aisle as opposed to precisely in front of the server rack. Pressure losses are experienced as air moves down the aisle farther away from the cooling equipment. There are also large differences in pressure across a rack from the floor to the ceiling.

Using the Delta T approach to cooling a non-raised floor data center presents a number of benefits as compared to focusing on air pressure. Using air pressure in combination with the Delta T approach goes one step farther than Delta T alone and brings additional benefits. Air pressure control can still be used to allow cooling units to provide a certain minimum amount of airflow while still allowing fanspeed to also be determined by temperature.

Focusing on the Delta T approach is simpler and less costly. Temperature sensors, unlike pressure sensors, are relatively inexpensive, simple devices that require virtually no tuning.

The Delta T approach represents a viable option for maintaining the proper temperature in your data center while eliminating the expense and time associated with installing raised floors. You'll be able to build data centers more quickly and realize a faster time-to-value and revenue.

At the same time, the approach provides more reliable control over the environment, enabling you to consistently meet customer SLAs.

Optimized control for non-raised floors

While the simplicity of the Delta T approach has its benefits, it does leave some gaps for data center operators looking to ensure consistent rack temperatures. The solution is to instrument the data center white space with wired and wireless temperature sensors every five or 10 racks to identify areas where temperatures are running high. Using these temperature sensors in combination with static pressure sensors for maintaining a minimum amount of airflow via an integrated cooling control system, such as the Liebert® iCOM™ system, enables coordinated control among all units in the data center.

Integrated control enables the system to override established setpoints when necessary and provide additional cooling or fanspeed capacity where it's needed. This ensures the correct cooling and airflow capacity is delivered for each individual server, not just for the data center overall. That's especially important now that it's common to have racks with far greater server density, and thus greater cooling requirements, than in years past.

While delivering additional cooling capacity to areas where it's needed may mean the Delta T deviates from the design standard at the cooling unit, it does so in favor of maintaining the design intent at the rack level, which is a better trade-off for most customers.

Part of this optimized approach involves installing a static air pressure sensor to ensure a certain pre-set minimum air pressure level to prevent air recirculation, which can diminish cooling efficiency. Establishing such a baseline ensures the data center is always operating in a positive pressure environment.

Keeping up with colocation demand

As a colocation provider, you know there's no end in sight to the increase in demand for data center capacity, which is both a great opportunity and a significant challenge. It's imperative that you be able to build new capacity quickly and cost-effectively.

Building data centers without raised floors helps on both the cost and speed fronts, but it does require a fresh look at data center cooling strategies. Focusing on Delta T is one such approach that delivers an efficient and less costly cooling solution when compared to using static air pressure monitoring, especially when it's optimized to ensure proper cooling at the rack and even server level.

To learn more about optimized cooling control strategies and the Liebert® iCOM™ system visit: https://www.vertiv.com/en-us/products-catalog/thermal-management/thermal-control-and-monitoring/#/.

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