# Rack Enclosures

## A Crucial Link in Airflow Management in Data Centers

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Rack enclosures that host servers are not only cabinets; they are an integral part of the airflow system of data centers. The cold air supplied from the air-conditioning units must freely pass through rack enclosures without any obstructions. If the rack enclosures excessively restrict airflow, it can adversely affect the cooling performance of the servers and disturb the overall balance of the entire airflow system.

Air is the main carrier of heat and moisture in the data center. Proper management of cold and hot airstreams in the data center is crucial for maintaining acceptable levels of inlet air temperatures to the servers as recommended in the recent ASHRAE thermal guidelines.[1] However, following only best practices for data center design, without properly considering rack enclosure design, is not sufficient to obtain desired cooling performance of a data center.

### Interactions with Server Fans

Servers are equipped with their own fans to move the air through the server chassis. Design airflow rates determined through bench tests of servers generally cannot anticipate and account for all the obstructions surrounding the servers when placed in the racks. Thermal tests conducted on a fully loaded 42U rack showed as much as 9°F (5°C) increase in the server inlet air temperatures due to surrounding obstructions.[2,3] These obstructions in the path of air reduce the airflow rates through the server fans, which can reduce the cooling and increase the

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exit air temperature from the servers. The extent of such a reduction in the fan performance depends on the individual design of the racks.

*Figure 1* illustrates the hypothetical interaction between the server fan and the system resistance offered by the racks. The intersection between the system performance curve and the server fan performance curve determines the operating airflow rate for the server rack system. The dotted curve shown in this figure represents the system curve for a single server during the bench test analysis. This figure further indicates, due to increased resistance to airflow, that the operating airflows through the server rack systems can be lower than the desired airflow rate of the bench test of a single server. As the restrictions in the rack enclosures increase, the operating airflow through the servers can decrease. More restrictive rack enclosure designs can reduce the operating airflow rates through the servers.

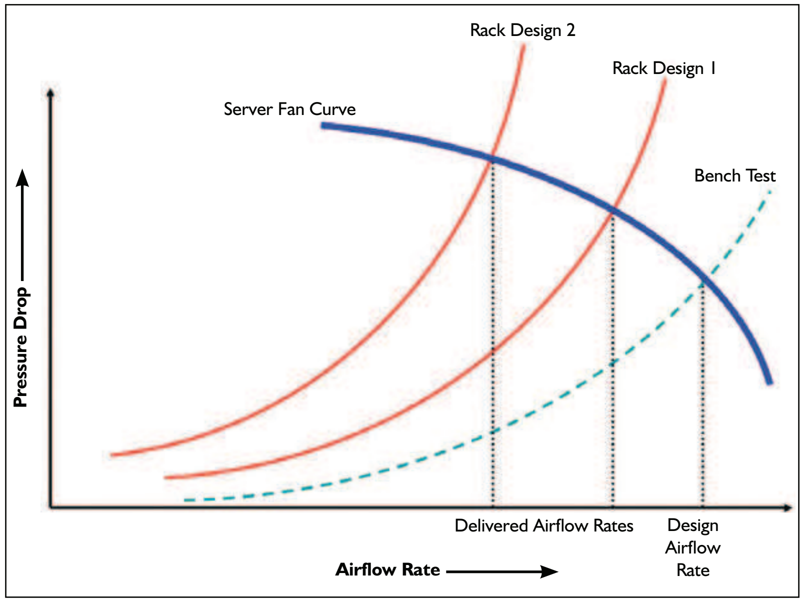


***Figure 1:** The intersection between the server fan curve and the system curve determines the operating airflow rates through the system. This illustration shows operating airflow rates through the server rack system are lower than the desired airflow rates determined for a single server during the bench test. More restrictive rack enclosure designs allow less airflow through the system.*

### Rack Enclosure Designs Play Important Role

As mentioned previously, the design of a rack enclosure plays an important role in determining the airflow rate through the servers. Some of the factors that can affect the performance of server fans due to the design of racks are as follows. A typical rack enclosure consists of front and back perforated doors, railings to hold the servers, and several cables that occupy the space between the back perforated door or blind panel. All of these components create obstructions to the airflow through the racks.

In addition, the airflow paths within rack enclosures are crucial. Most racks are designed for a front entry and back exit flow path for the cooling air. Other variations of the flow paths are front entry and top exit or bottom entry and top exit. As air takes more turns before exiting the rack, it induces pressure loss in the system for which a server fan must compensate.

A few manufacturers offer a total containment of hot air within the rack enclosures by using ducted exhaust. In these racks the hot air is exhausted from the top either into the room or into a ceiling return. This type of system avoids short-circuiting and mixing of hot air with the room air. Since the air must pass through narrow spaces, the server fans are required to work harder to overcome these additional resistances. If this type of system is not designed properly, it can result in reduced fan performance.

Another design offers a rear door heat exchanger to provide instant cooling of exiting hot air. The heat exchanger can create additional resistance to the airflow, which can deteriorate the server fan performance. Other designs offer additional fans in the cabinets to assist in exhausting the hot air. All fans in the data center, including the fans of the air-handling units, should work in harmony with other fans to deliver desired airflow rates and cooling performance. In the ducted exhaust with ceiling plenum return (closed loop) system, all the fans (including fans of air-handling units, server fans, and any additional fans in the racks) operate in series, fans in the cabinets can become a bottleneck in delivering desired airflow from the air-handling units.

Rack heat loads and how the loads are distributed within the racks can be another factor that can affect airflow through the rack enclosures. Several combinations of these design concepts are available in the market. Consider all of these factors and evaluate their effect on server fan performance before selecting rack enclosures for data centers.

### Pressure Buildup and Air Recirculation

Pressure can build up in the gap between the back perforated door and back of servers from where hot air exits from the servers. Such a pressure buildup can cause internal recirculation of hot air within the cabinet that can be entrained into the servers. Computational fluid dynamics (CFD) analysis was performed for a typical rack enclosure with a front-to-back airflow path to illustrate how such a pressure buildup can affect airflow within the racks and the cooling performance of servers. This model considered a 42U rack with 63% open area ratio of front and back perforated doors. The heat load in the model varied from 5 kW to 20 kW. Accordingly, the airflow rates through servers and the total supply airflow rates were proportionately adjusted to maintain a 20°F (11°C) rise ($\Delta T$) across the servers.

CFD analysis predicts the pressure distribution, temperature distribution, and airflow patterns within the rack enclosure. As shown in *Figure 2*, CFD analysis predicts higher pressure

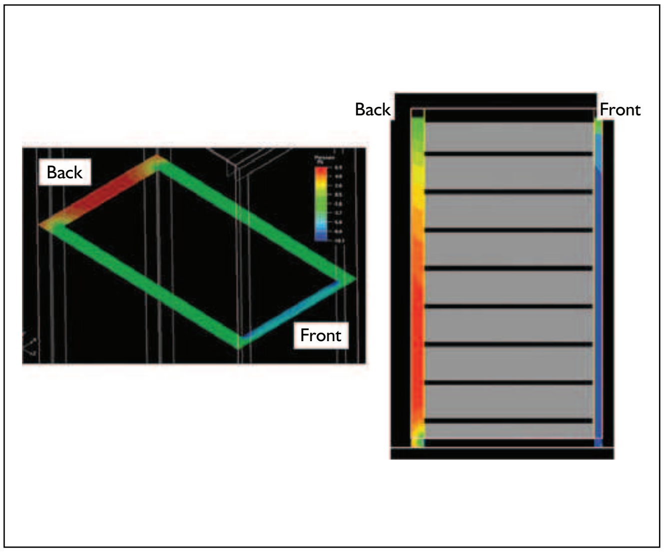


*Figure 2: As hot air exits from the back of the servers, air pressure can build up in the gap between the back perforated door and the servers. The CFD analysis predicts higher pressure behind the servers.*

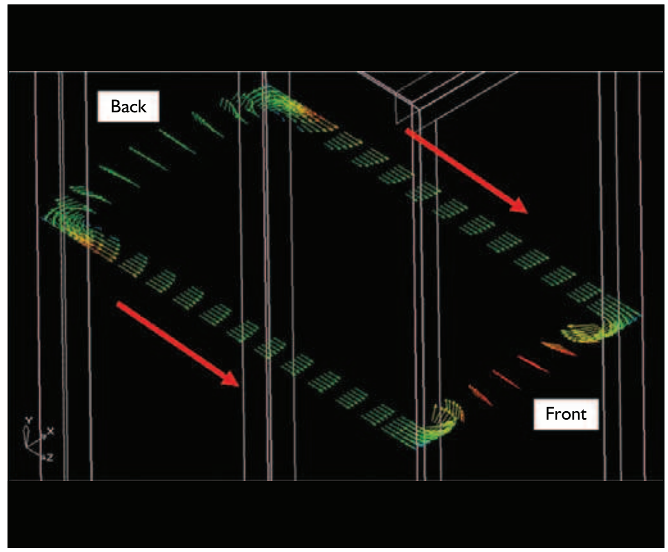


*Figure 3: Pressure buildup behind the servers drives the hot air from the back to the front of the servers where it is picked up by the server fans causing higher air inlet temperatures.*

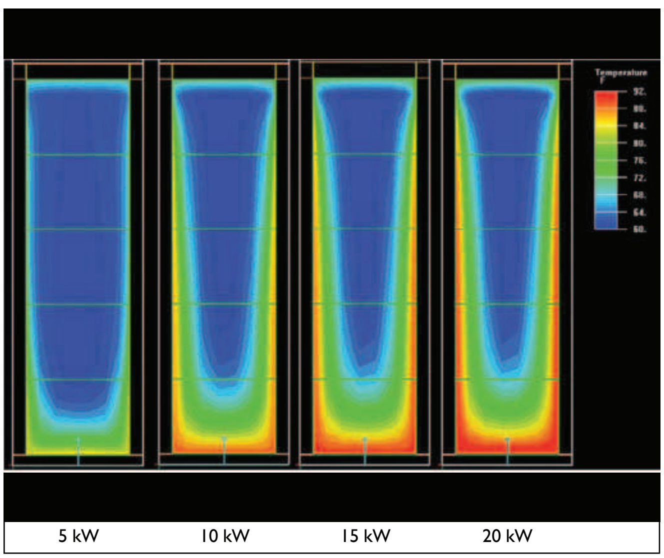


*Figure 4: Front view of the distribution of inlet air temperature to servers behind the front door. Air recirculation within rack enclosures results in higher inlet air temperatures than the desired supply air temperatures. The desired supply air temperature is 60°F (16°C) as indicated by the blue color. Increasing heat loads within the same rack enclosure increases the pressure buildup, air recirculation, and inlet air temperatures of air to servers.*

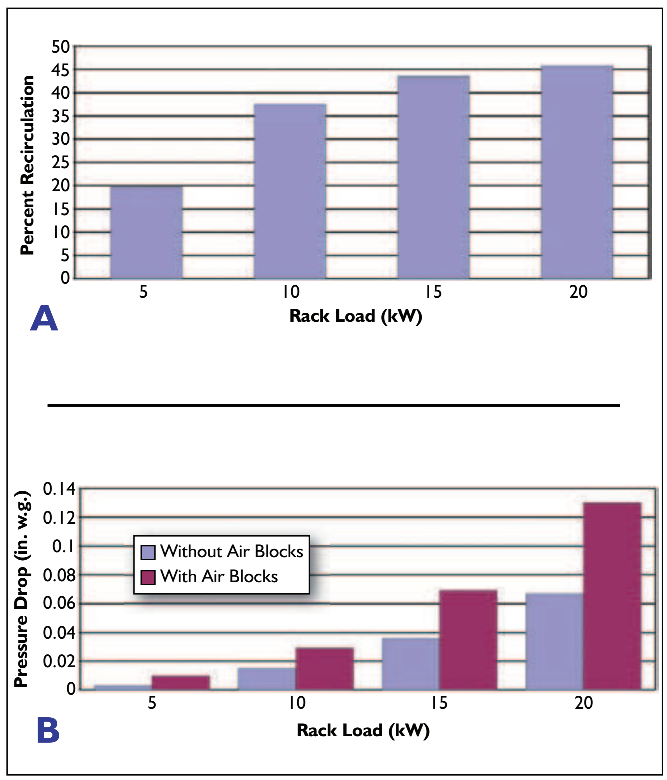


*Figure 5a (top): CFD analysis indicates higher pressure buildup and higher air recirculation with rack enclosures with increasing heat loads. Figure 5b (bottom): Placing blocking panels to block the air recirculation can further increase the pressure buildup, which can deteriorate the server fan performance.*

in the gap between the back perforated door and the server. Such a pressure buildup as shown in *Figure 3* drives the hot air from the back to the front of the servers where it is picked up again by the server fans. This recirculation of hot air results in the higher inlet air temperatures than the desired supply air temperature.

*Figure 4* shows the distribution of inlet air temperatures at server inlets at various levels in the rack. It shows a rim of higher temperatures at both edges of servers. Higher inlet air temperatures at the bottom servers are due to additional entrainment of hot air from the back and under the cabinets. Castors raise the level of the cabinet and create a gap between the floor and the cabinet bottom. Hot air from the back finds its way through this gap and enters into the bottom servers from the front.

CFD analysis was performed with a 20% excess of cold supply air than what is required for a 20°F (11°C) rise through the servers. In spite of such an excess supply, the predicted inlet air temperatures are higher than the supply air temperature and exceeded ASHRAE recommended higher temperature limit of 80.6°F (27°C).[1] This is due to the recirculation of air within the rack and entrainment of hot air under the rack.

### Rack Heat Load Matters

As shown in *Figures 5a* and *5b*, air recirculation becomes worse with increasing heat loads in the rack. With increase in the rack heat loads from 5 kW to 20 kW and proportionate increase in the airflow rates through the servers, the pressure difference between the back and front of the rack increases by 21%. As a result the extent of air recirculation into the server intakes increases from 20% to 45%. Recirculation within the rack is avoided by placing additional plates to block the flow of air from the back of the servers. However, *Figure 5b* shows such a blocking can further increase the pressure buildup that, in turn, can adversely affect the server fan performance and reduce the airflow rate through the server. The design of the back plenum is crucial to avoid such a pressure buildup.

To achieve adequate cooling, the speed of a server fan increases with the increase in the temperature of electronic components and with a rise in the inlet air temperature. However, such a ramp up in the fan speeds can increase energy consumption (fan energy is proportional to the cube of the fan speed). The dc fan power of servers can increase 3.5 to 7 times when server inlet air temperature increases from around 80°F to 95°F (44°C to 53°C).[4] In addition, increased airflow rates, such as at ramp up, can further promote pressure buildup behind the servers, which can affect fan performance.

### Summary

Rack enclosures are a crucial link between data center air-handling units and servers. Design of rack enclosures can impact the fan performance, and therefore, cooling performance of servers. Careful consideration should be given before selecting the rack enclosures for a certain data center. Just following the best practices for the design and layout of data centers is not enough to obtain the optimum cooling performance. This article illustrates the importance of rack enclosure design and airflow management within the rack enclosures.

### References

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