WHITEPAPER

The Venturi effect and how it affects your data center efficiency

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1. Introduction to the Venturi effect

If you have ever watched a fast-flowing river funnel into a narrow channel or paraglided through the gap between two peaks, you have probably either experienced, or utilized, the phenomena described by Giovanni Battista Venturi in 1797, namely the Venturi effect.

As winds rolling over a landscape meet constricted flow, for instance a gap between two mountains, all that air is forced to pass through the small gap. Air speed (v) increases and pressure (P) drops as pressure-related potential energy is transformed into kinetic energy. As the air flows through the constriction with increased velocity, the low pressure is a driving force for the surrounding air to be sucked into its tail, covering up the tracks. The pressure differential and the resulting suction effect to restore balance can be experienced when cold and warm weather fronts collide. It is an effect that causes problems in a data center.

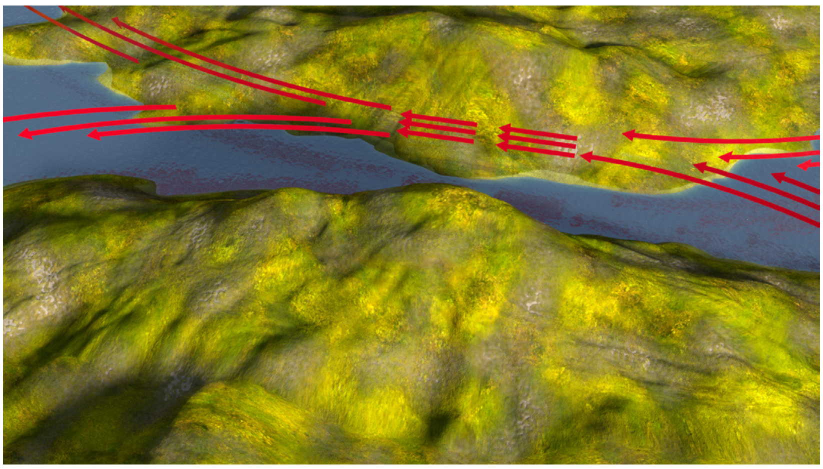


Figure 1: The Venturi effect in nature: narrow channels lead to increased wind speeds, which in turn lead to lower air pressure.

2. The Venturi effect in data centers

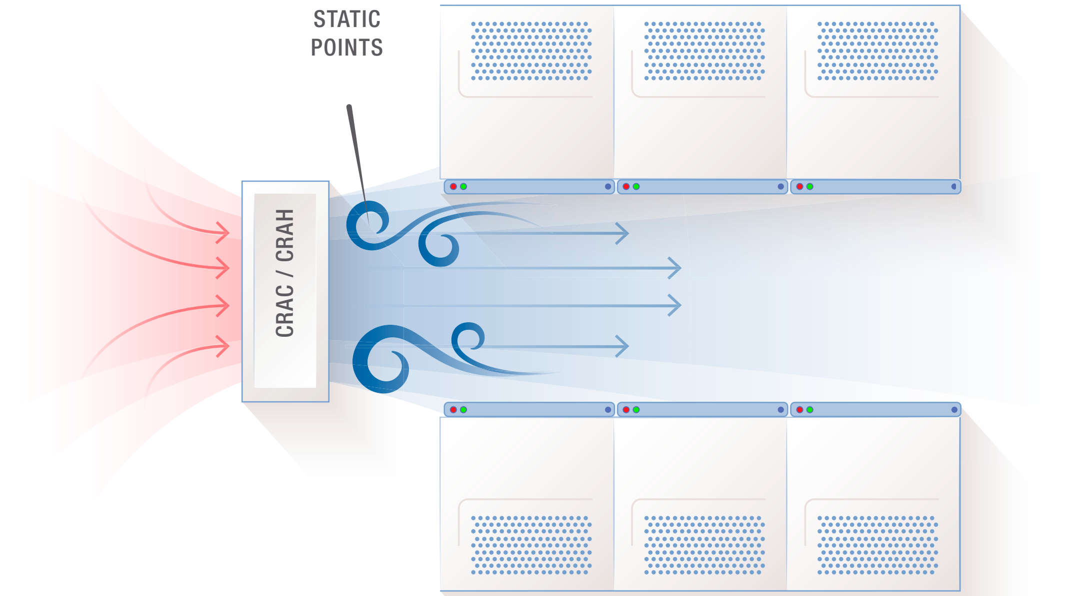


Figure 2: The Venturi effect in data centers

One of the most critical challenges in the industry is maintaining efficient thermal management while meeting greater IT load demand. Conventional climate control systems utilize air as the main vehicle of heat removal and typically Computer Room Air Conditioners (CRAC) or Air Handlers (CRAH) are the preferred methods to condition rooms. However effective they are at their immediate job (removing server heat)—looking at the wider picture—they are also very inefficient.

2.1 Air velocity and volume

CRAC units are designed to do their job within confined spaces—and that is what they do. To cool 3414 KBTU/hr of server heat, 2500 ft^3/s of air is needed (given 22°F delta temperature between supply and return). In reality many installations do not reach 22°F dF and therefore more air is needed. The air volume needed to sufficiently remove heat from racks of servers is impossible to provide with CRAC units without high air velocity, as CRAC units are usually small and cannot deliver the required amount of air without accelerating the speed.

The highest air velocities in data centers occur within the smallest sections of air trajectory, which are in most cases found at the outlet of CRAC units—i.e. in the area under the raised floor or in the corridors between the server aisles. Air velocity in data centers with conventional climate solutions frequently exceeds 16.5 ft/s, often reaching up to 26 - 33 ft/s.

This might also be the case also when the load of the data center lies well below the maximum design capacity. These inefficiencies can sometimes stem from poorly designed airflow between aisles and rows in the data center. The air volume needed per time unit is directly related to the energy dissipated in the servers and to the temperature increase of the air in the server.

In most data centers, the volume of circulated air reaches a level of 1038 ft^3/s per 1000 KBTU/hr.

Due to air leakage, the volume of circulated air reaches a level of 1038 ft^3/s per 1000 KBTU/hr in most data centers. Needless to say, massive volumes of air need to circulate data centers in order to maintain the required temperature.

2.2 Air pressure

The local drop in static air pressure as a result of large volumes of air with high velocity has a momentous impact on pressure conditions in the room.

The drop in pressure quadruples with a doubling of velocity.

Air velocity of 26 ft/s will have a pressure drop effect of approximately 0.058 Psi. In a badly designed server room, these pressure differences are significant, as they will influence the cooling capacity of the server fans and might easily produce hot spots. It also contributes to the server cooler fans' high electricity consumption, as they need to compensate and overcome the airflow resistance.

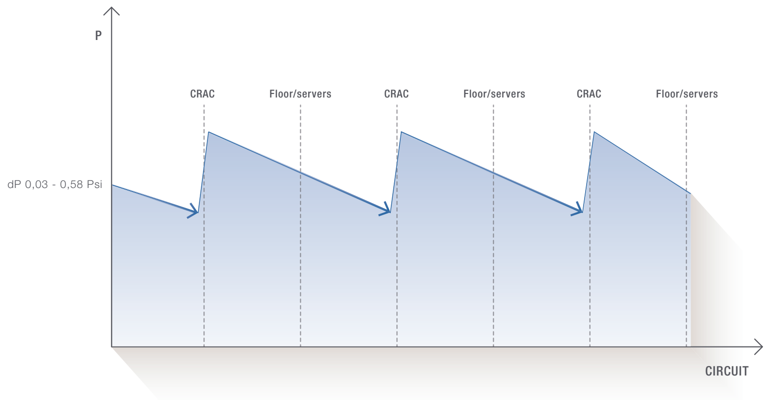


Figure 3: Pressure differences related to high air velocity

3. Enter the Venturi effect

The large volumes of air flowing from the CRAC unit at high air velocities into the white space under the raised floor create undesired pressure variations in the room. Local occurrences of low pressure can influence the working of the servers in two ways when the low pressure is at the inlet side of the server:

1. It makes it harder, or impossible, for the cooling fans in the server to suck a sufficient amount of air through the server,
2. Hot air might find a way to the inlet side of the server due to the driving force this low pressure exercises on the surrounding air, diminishing the amount of cold air available.

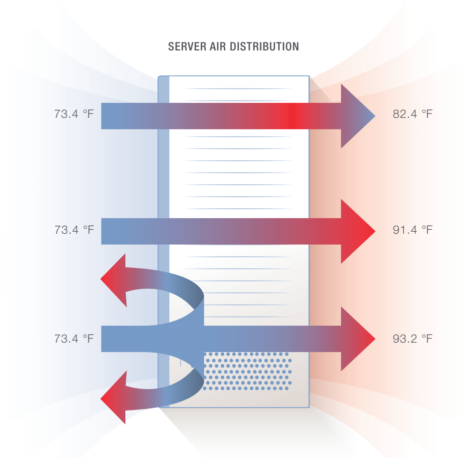


Figure 4: Due to the Venturi effect and pressure differences, underpressure occurs in the lower part of the rack, sucking air from the back to the front. At the same time, there is normal pressure in the middle section and overpressure in the upper part. As a consequence, hot spots and insufficient cooling occur in the lower and upper parts of the server rack.

Figure 5 represents a CFD simulation where a hot spot can be seen at the bottom of the cold aisle, just in front of the server at the inlet side. This situation occurs typically at locations close to the air outlet of CRAC units. The low pressure makes it hard for the server fans to suck in cold air, while hot air finds a way to the front side to fill the void.

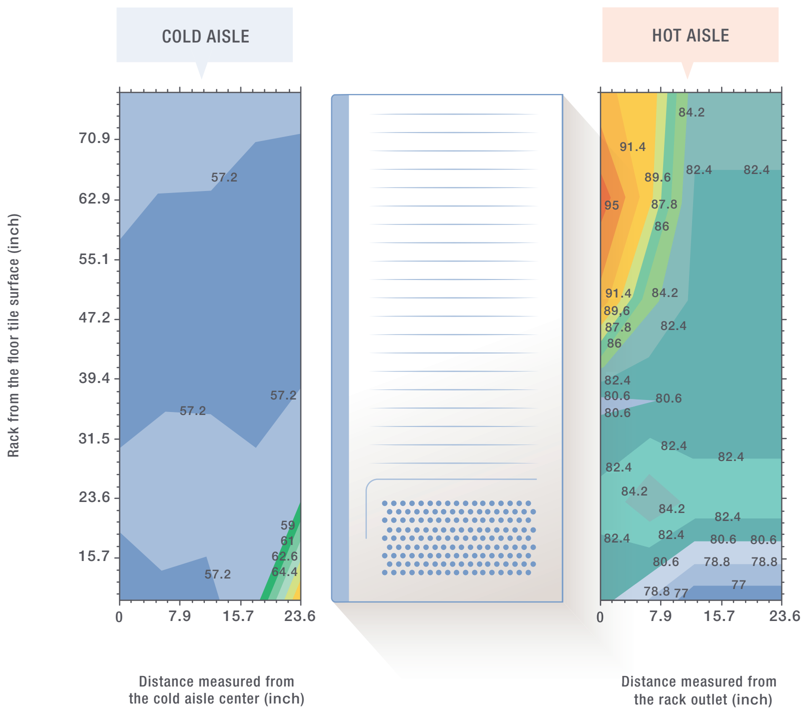


Figure 5: CFD simulation

4. Conventional solutions for dealing with pressure differentials

Applying overpressure

One of the most widely utilized solutions to combat these unwanted pressure differentials is to apply overpressure. However, the applied pressure will not completely compensate for the pressure drop in every part of the server room, and hot spots will therefore remain.

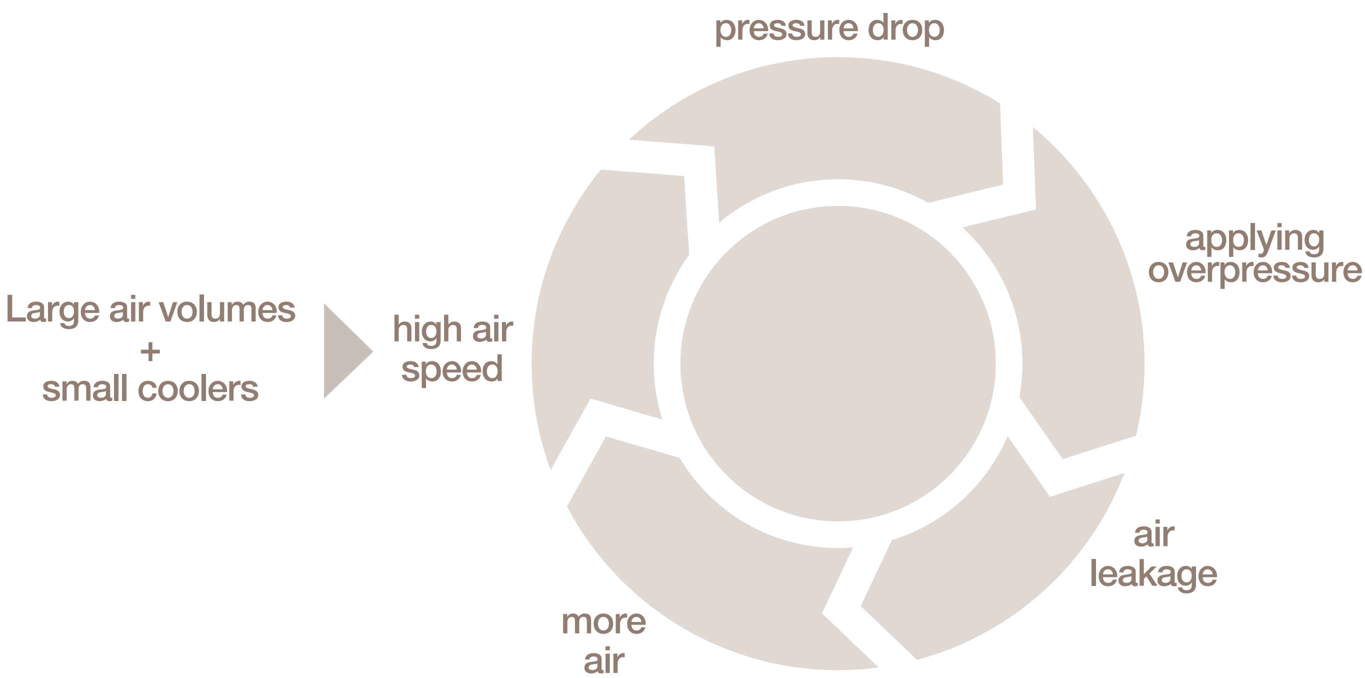
Furthermore, applying overpressure in data centers inadvertently leads to air leakage. Not only is preventing leakage a costly business, but in order to make up for pressure losses, upwards of 40% more air has to be circulated in the room. Ironically, this will generate even higher air velocity levels and with it, a snowball effect.

Applying overpressure dramatically increases energy consumption for obvious reasons, causes wear on the fans and leads to lower return temperatures, which in itself leads to even lower energy efficiency in the mechanical or free cooling process, depending on the outdoor temperature.

In a constant airflow system it is possible to control the air airflow by adjusting control devices (air dampers, adjustable floor tiles, etc.). However, in modern data centers, the airflow is far from constant, leading to a dynamic situation concerning air demand and airflow, requiring ongoing adjustments of the device that is supposed to control the airflow and/or pressure.

Applying overpressure adds costs:

- Waste of energy
- Ineffective cooling
- Pressurized system
- Complicated control



Fan energy consumption as function of pressure variations						
		Temperature difference over server cooler				
		9	13.5	18	22.5	[F]
Airflow corresponding to 17 KBTU/**hr** server cooling		29 ft³ / s	19 ft³ / s	14.5 ft³/s	11.6 ft³/s	[ft³/s]
Pressure difference airflow circulation	[P**si**]	Partial PUE of the fans (IT-load = 1,0) 70% fan/motor efficiency Power consumption fans: $P = \Delta p \times \Phi_v / \eta$				
CRAC/CRAH	0.058	9.6%	6.3%	4.7%	3.9%	
CRAC/CRAH	0.029	5.3%	4.4%	3.6%	2.9%	
Low Speed Ventilation, full re-circulation	0.004	0.9%	0.71%	0.53%	0.39%	
Low Speed Ventilation, outside air	0.002	0.61%	0.49%	0.37%	0.24%	

Figure 7: Energy consumption related to pressure drop in the server room

5. How Low Speed Ventilation deals with pressure differentials

Moving from pressure control to air availability.

The increasing need of cost-efficient and safe climate control systems puts Low Speed Ventilation solutions at the forefront of a massive paradigm shift. The way Low Speed Ventilation combats the list of problems associated with CRAC units, high air speed and the Venturi effect is simple and effective—get rid of the high air speed. The task at hand still remains the same—to cool servers with massive amounts of air per second. The solution is simple and provides a lot of benefits: the large cross-sectional area for cooling in an LSV system enables the air speed to be kept low and no Venturi effects occurs.

In a data center using LSV technology, the air moves at a speed of 3.3 - 4.9 ft/s. The negative impact of pressure differences and the Venturi effect begin to occur at higher air speeds. Conventional climate control systems are based on the idea of imposed circulation of air. In such systems, the steering parameters for a CRAC unit are temperature and pressure. This steering principle is almost unavoidable, due to the fact that control of the pressure situation in the data center plays such a vital part in preventing hot spots and therefore in the reliable operation of servers. However, using the Low Speed Ventilation approach, pressure-related issues do not play an important role, as pressure can be set according to the client’s wishes (0 - 0.0007 Psi). Basically, pressure differences are prevented and apart from the obvious fact that this will significantly reduce the amount of energy involved in circulating the air, it also makes climate control far easier.

The approach of data center climate control requires a paradigm shift from ‘induced air circulation’ to ‘air availability’. The control system can be considerably simplified and the system becomes more robust.

Just like healthy—breathing—creatures, servers need sufficient amounts of air. When provided with the adequate amount, servers can take care of themselves, but this requires a new way of looking at climate control—a perspective in which the only relevant criterion is whether cool air is available to the servers or not.

There are two main conditions for implementing Low Speed Ventilation:

1. The cross-sectional area along the air circuit trajectory, in the Air Handling Units as well as in the data center, must be sufficient enough to ensure low air speeds. This prevents unwanted and unnecessary pressure differences, and completely eliminates the need to apply pressure.

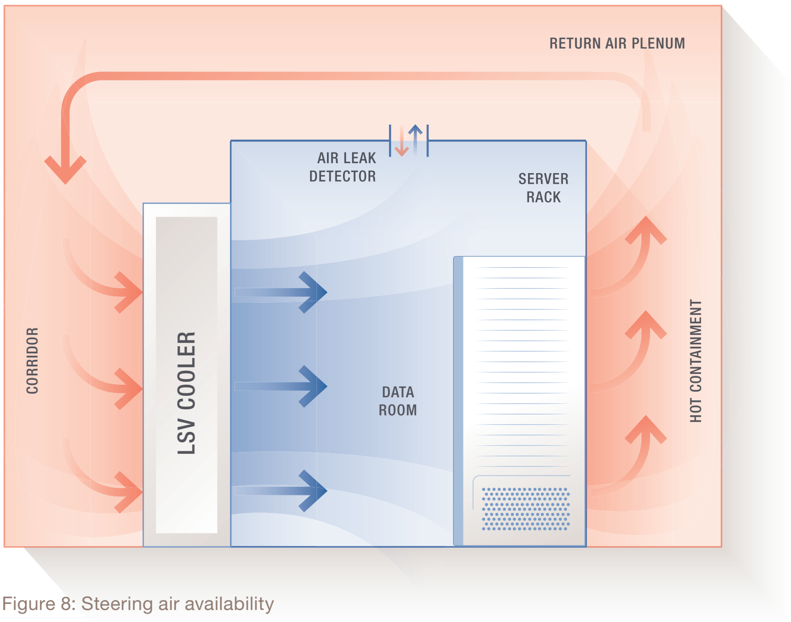


Figure 8: Steering air availability

2. A climate control system that ensures sufficient amounts of air are delivered, and measures the flow balance between cold air supply and hot air return. Increased air demand from the servers would be detected by the system’s smart tube and the LSV system would start supplying more air.

Reducing air velocity at constant airflow means increasing the cross-sectional area along the air circuit trajectory. In particular, the LSV server cooling technology requires a different air-returning geometry, namely the separation corridor.

Within the data room, an airflow measurement in a leak is placed between the server room and the hot air plenum—indicating a shortage, or surplus, of cold air. The steering of the fans in the LSV coolers will balance the supply and demand of cold air in the data room.

6. Conclusion

High air velocities from the narrow outlets of CRAC units create pressure differences within the white space, which lead to additional expenses for data centers. Applying overpressure to compensate for loss in pressure will not only increase the wear on fans, but also increase the energy bills and necessitate additional expensive solutions to minimize further air leakage—capital that could have been utilized more efficiently elsewhere.

What if you could minimize these pressure differentials altogether? The Alfa Laval Low Speed Ventilation system lets you do just that, and as less control equipment and electrical infrastructure is needed, and leakage prevention is not required, the initial investment is generelly lower than for existing solutions.

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