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WHITE PAPER: Cooling Industrial Enclosures with Filter Fans

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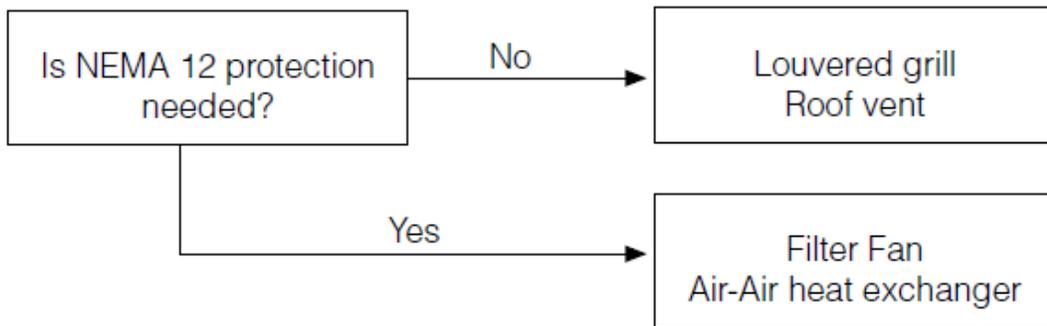# Cooling Industrial Enclosures With Filter Fans

Introduction

As electronic components get smaller and more densely packed into enclosures, systems are becoming increasingly sensitive to external factors including dust, oil, and temperature. Heat in particular is a fatal enemy of sensitive electronics. In order to protect the proper functioning of the electronic components, this heat must be dissipated. There are many different ways to dissipate this heat from industrial enclosures including natural convection, fans, air-to-air heat exchangers, air-to-water heat exchangers, and air conditioners. There are design advantages and trade-offs for each of these climate control options. This white paper will focus on cooling with filter fans, demonstrating why it may be beneficial to choose a fan over other climate control options. A sample calculation will be included, along with a review of some filter fan data sheets and an explanation of what this information tells us.

For applications that are exposed to acids and alkalines, stainless steel and fiberglass are recommended. In applications that are exposed to solvents, stainless steel, fiberglass, aluminum, and powder coated steel offer acceptable protection. In general, stainless steel provides superior protection against almost all corrosives.
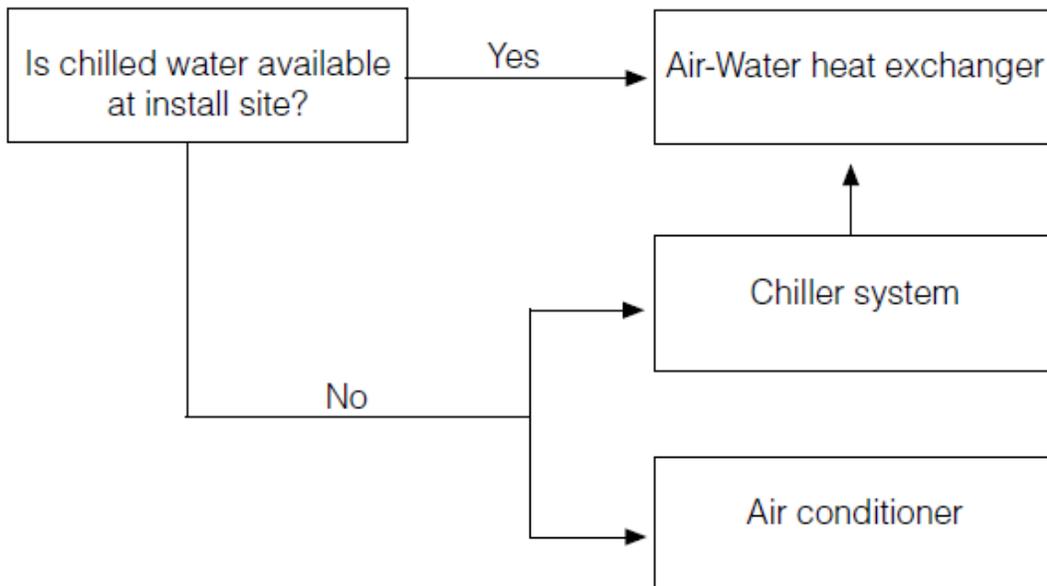
When to Use a Filter Fan

One of the most important considerations in choosing a fan for your cooling needs is whether the ambient, or surrounding air, is cooler than the desired temperature to be maintained inside the enclosure. If so, a filter fan may be right for your application

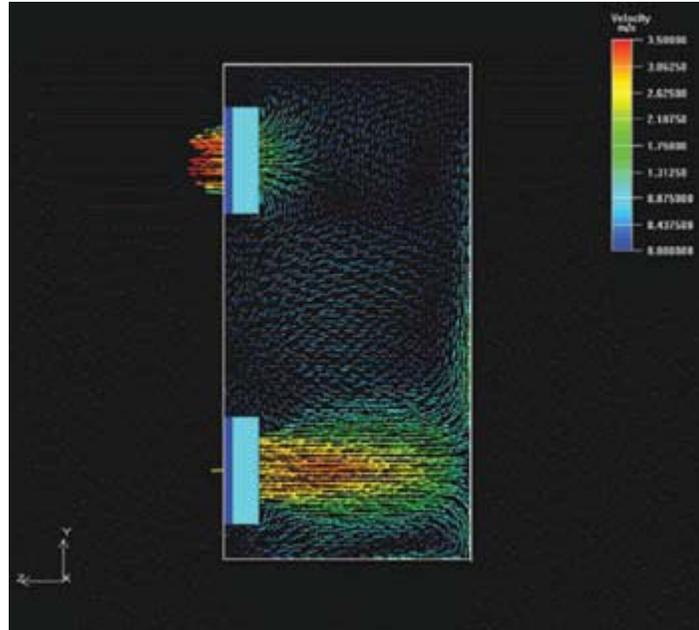Ambient Temperature < Enclosure Temperature

```
┌────────────────────┐    No     ┌────────────────────┐
│ Is NEMA 12 protection │ ───────→  │   Louvered grill   │
│      needed?       │           │     Roof vent      │
└────────────────────┘           └────────────────────┘
         │
         │         Yes            ┌────────────────────┐
         └───────────────────────→ │     Filter Fan     │
                                  │ Air-Air heat exchanger │
                                  └────────────────────┘
```

Ambient Temperature >= Enclosure Temperature

```
┌────────────────────┐    Yes    ┌────────────────────────┐
│ Is chilled water available │ ──────→ │ Air-Water heat exchanger │
│    at install site?     │         └────────────────────────┘
└────────────────────┘                         ↑
         │                          ┌────────────────────┐
         │                          │   Chiller system   │
         │         No               └────────────────────┘
         └──────────────────┐              ↑
                            └──────────────┘
                            │
                            └──────────────┐
                                           ┌────────────────────┐
                                           │   Air conditioner  │
                                           └────────────────────┘
```

Using the simple flow chart above, we have determined that we need to cool our system with filter fans. Why? Because using fans is the "simplest" and most cost effective way to dissipate heat from our system, and the temperature inside the enclosure can be greater than the surrounding, or ambient temperature. We have decided to use filter fans because we want to protect our system from dirt and other impurities—one of the reasons that we have our system in an enclosure in the first place. Now that we have determined that we are going to use filter fans, we need to decide on the required airflow.

We can do this (computational software, with CFD fluid dynamic)

Screen shot of a CFD calculation.

RiTherm, a general (note: Rittal offers free download at sizing program Therm software for
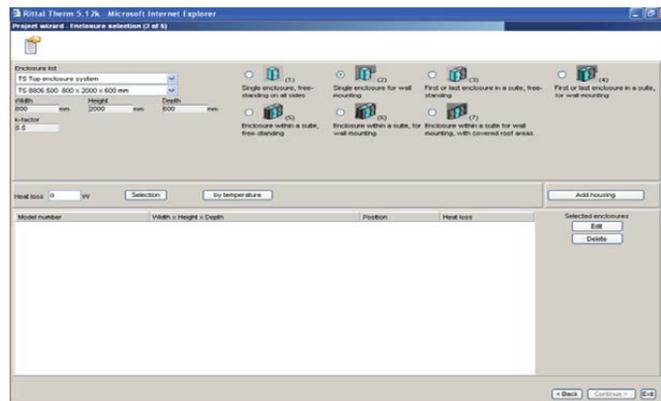
http://www.rittal.us/support/index1.cfm?n1=17),

or determine the required airflow with a pencil and paper. To calculate the required airflow, there arethree variables that need to be taken into account: Surface Area, Installed Heat, and Airflow

Surface Area

What does the surface area have to do with airflow? Without expending any outside energy, heat flows in only one direction—from hot to cold. This phenomenon is why coffee cools down after a few minutes as it sits on a table. The room is cooler than the coffee, so the heat "leaves" the cup and is diffused (spread out) throughout the entire room. In the case of required fan airflow, we need to find out if heat from our surroundings is going to move into our enclosure or if the heat from our enclosure is going to be dissipated. The surface of the enclosure is where this interaction takes place. Like the coffee cup, the heat will flow from the sides, top, and bottom. We could calculate this surface area by adding up the area of all 4 sides of our enclosure, but this may not be exactly where the heat is leaving—for instance, if the rear an enclosure is against a wall. By sitting the enclosure against the wall, the wall will heat up in that spot, creating a smaller temperature difference between the wall and the enclosure—slowing down or preventing the heat from flowing out of the enclosure. The difference in temperature is what allows the heat to flow, so if there isn't any difference in temperature, there isn't any heat flow. Because of this, it was decided by an international convention (DIN 57 660 part 50 and VDE 660 part 500) to modify the surface area of an enclosure to take this into account (since this was an international convention, the units will be in metric).

Enclosure installation type to IEC 890

☐ Single enclosure, free-standing on all sides	☐ First or last enclosure in a suite, for wall-mounting	☐ Enclosure within a suite, for wall-mounting
☐ Single enclosure for wall mounting	☐ Enclosure within a suite, free-standing	▨ Enclosure within a suite, for wall-mounting, covered roof surface
☐ First or last enclosure in a suite, free-standing		

Installation type to IEC 890	Formula for calculating A [ft²]	
☐	A = 1.8 x H X (W + D)	+ 1.4 x W x D
☐	A = 1.4 x W x (H + D)	+ 1.8 x D x H
☐	A = 1.4 x D x (H + W)	+ 1.8 x W x H
☐	A = 1.4 x H x (W + D)	+ 1.4 x W x D
☐	A = 1.8 x W x H	+ 1.4 x W x D + D x H
☐	A = 1.4 x W x (H + D)	+ D x H
▨	A = 1.4 x W x H	+ 0.7 x W x D + D x H

A = Effective enclosure surface area
W = Enclosure width [ft]
H = Enclosure height [ft]
D = Enclosure depth [ft]

Installed Heat

Once the surface area of the enclosure is found, it is possible to either calculate the heat "contained" in the enclosure with a temperature difference (if we already have a completed system), or to add up the heat loss from installed components.

Heat calculation for a previously completed system

$Qv = A \times k \times \Delta T$
Where
A is the effective surface area from calculation above
K is .51 w/ft2 Celsius (sheet steel, different numbers for different materials)
ΔT is the temperature difference $\dfrac{T_{out} - T_{in}}{1.8}$ in Fahrenheit

Airflow
Now, all the pieces are in place to solve for airflow.
$V = f \times$
V = Volume in cfm
f = 2.06
Qv = installed heat from above
ΔT = temp difference $\dfrac{T_{out} - T_{in}}{1.8}$ in Fahrenheit

in Fahrenheit

Now that the heat flow has been determined, the specifications of a filter fan can be examined.

| Part No. filter fan unit SK	3325.107	3325.117	3325.027	3325.047
Voltage V, Hz	230, 50/60	115, 50/60	24 (DC)	48 (DC)
Dimensions in inches (mm)	H1/B1	10.0 (255)		
	H2/B2	8.8 (224)		
	T1	0.5 (12)		
Max. installation depth in inches (mm)	T2	4.2 (105)		
Air displacement unimpeded airflow	135/156 cfm (230/265 m³/h)		135 cfm (230 m³/h)	
Air displacement with outlet filter including standard filter mat	1 x SK3325.207: **100/121 cfm (170/205 m³/h)** 2 x SK3325.207: **118/135 cfm (200/230 m³/h)** 1 x SK3326.207: **112/127 cfm (190/215 m³/h)**			

Specification Tables

Above is a specifications table for the SK3325.XXX series of filter fans present in many Rittal product catalogs. The first specifications to note are the voltage and frequency. AC fans are dual-rated at 50/60Hz to reflect the global market that uses them. Keep the dual frequency ratings in mind, when looking at the air displacement (airflow) portion of the table. The first rating is for 50Hz and the second is for 60Hz. As the frequency applied to the fan motor increases, the fan turns faster, resulting in higher airflow at 60Hz. The next lines are air displacement unimpeded airflow and air displacement with outlet filter including the standard filter mat and there are three different ratings. Why are these numbers so different? In order to understand this

you must take a closer look at a filter fan and introduce a chart called the "fan performance curve."

A Closer Look at a Filter Fan

A filter fan consists of the filter housing, a motor, and the fan blades. The motor turns the fan blades, and the housing directs the flow of air. One can think of the spinning fan blades pushing the air from the front to the back of the filter fan. This pushing creates pressure, and at a certain pressure, the fan can move a certain amount of air known as air displacement, or airflow. The pressures and airflows are directly related to each other.
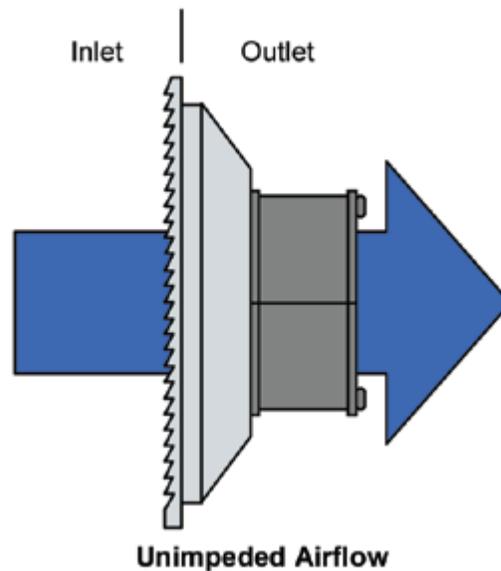

Above is a simple model of a filter fan and housing depicting "unimpeded airflow." The unimpeded airflow is how much air a fan can move if it is sitting on a table. Although a popular measure of performance, this is not a very good indication of how much airflow will be generated when the filter fan is mounted in an enclosure. Back pressure has to be taken into account. Along with back pressure, another important factor to take into consideration is impedance. Impedance is the resistance of the air to flow. When we put the filter fan on the table and run it, there is little or no impedance, resulting in unimpeded airflow.

Impeded Airflow
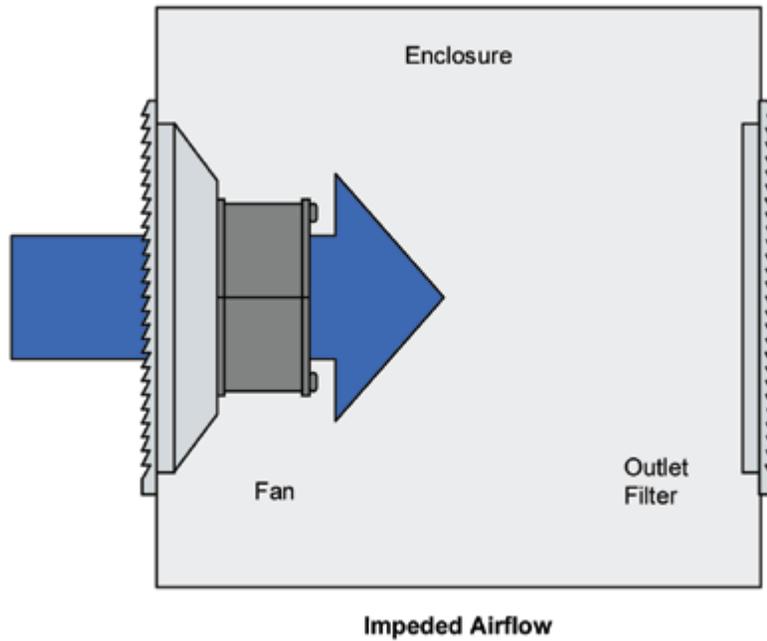
In most application scenarios, there is a fan, an enclosure, and an outlet louver that the fan has to pull the air in, pushing against all of the air that is inside the enclosure, and then forcing the air out through the exhaust louver. Since pressure and flow are related, the fan slows, reducing the flow and increasing the pressure. To show how a fan operates as flow and pressure change, we have a diagram called a "fan curve." The pressure is represented on the Y-axis and airflow on the X-axis.


Single Fan Performance
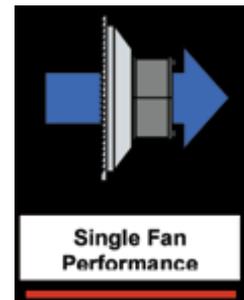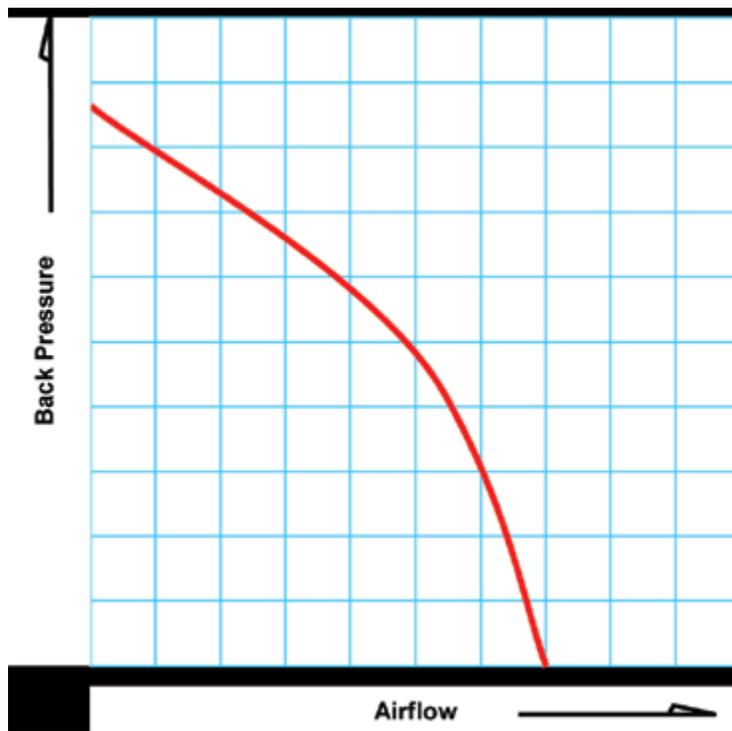
To be completely accurate, impedance has to be factored in. To do this, an impedance curve can be placed on the same chart as the fan curve. The point where the two curves intersect is the actual airflow.
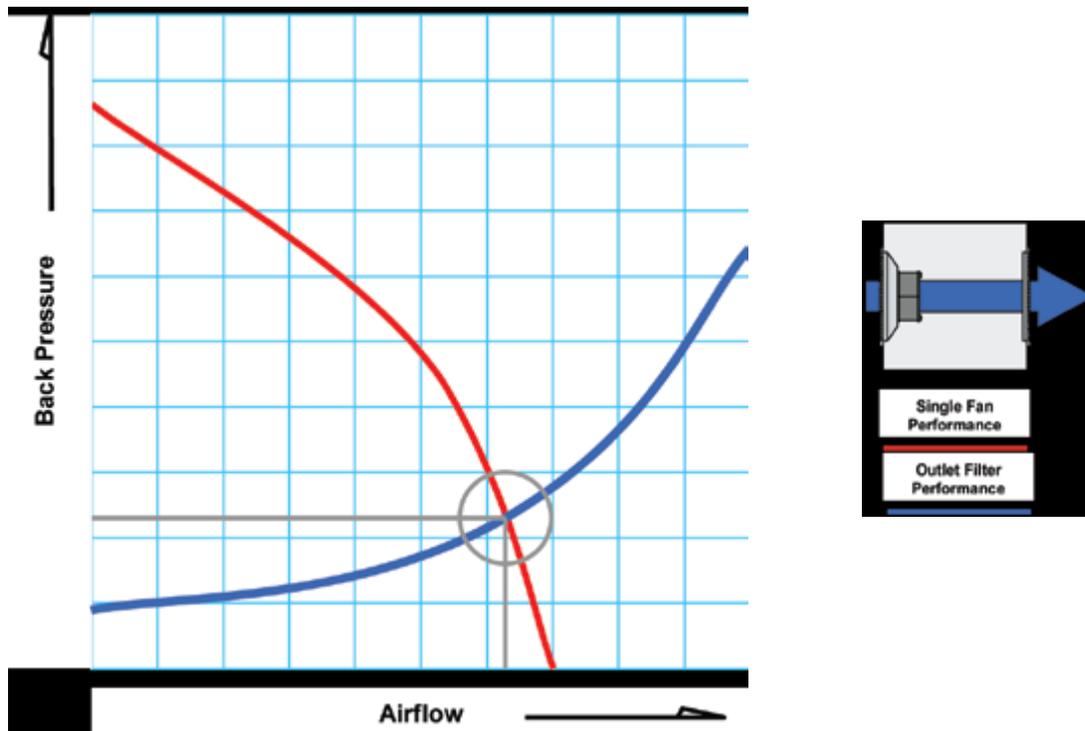
Using Multiple Fans

Is there a benefit to using two fans on an enclosure instead of one? Since airflow and pressure are related, there should either be more airflow or more pressure. Depending on where the fans are mounted, both are true.
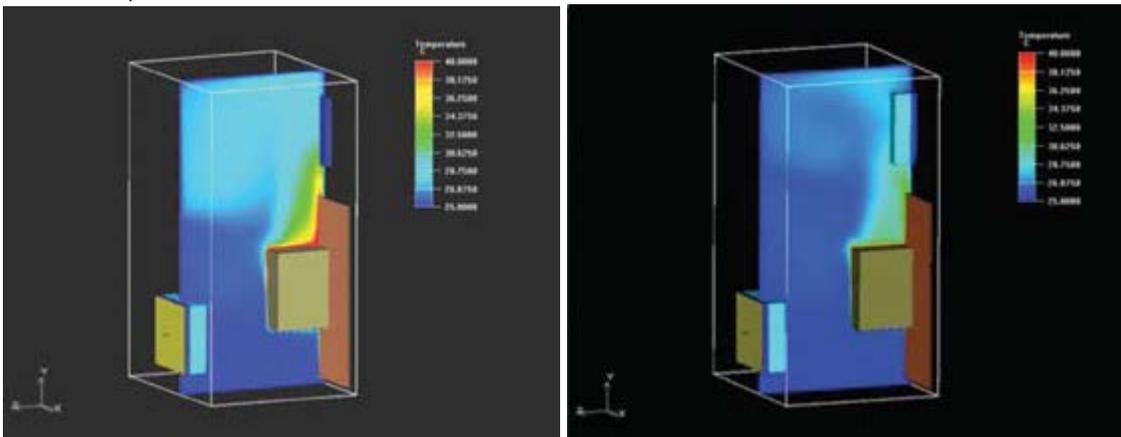
Series operation can be defined as using multiple fans in a push-pull arrangement (see illustrations above). In this case, the impedance of the system is reduced because the exhaust fan is lowering the pressure inside the cabinet. This allows the system impedance to move up

the intake fan's fan curve line, which leads to more airflow. It doesn't double the airflow, however, because the highest possible airflow a filter fan can have is unimpeded airflow. Despite this limitation (present with any fan), series operation does get the airflow closer to the unimpeded flow in a heavily impeded system. Rittal completed a CFD analysis to compare a general case with fans mounted in series and a single filter fan and filter. The model consisted of a Rittal enclosure 40" H X 24" W X 20" mm D with an ambient temperature of 77° Fahrenheit and an internal component that is dissipating 200 W of heat into the enclosure. In the final analysis, the airflow increased from 58.78 cfm to 103.08 cfm—a 75% increase in airflow. We can look at the temperature distribution in the enclosure in the pictures above. This increase in airflow provides much better cooling of the installed components. Two or more fans blowing together side by side is referred to as "parallel operation." In this configuration, if there is low to medium impedance, both fans are able to provide close to twice the airflow of a single fan.
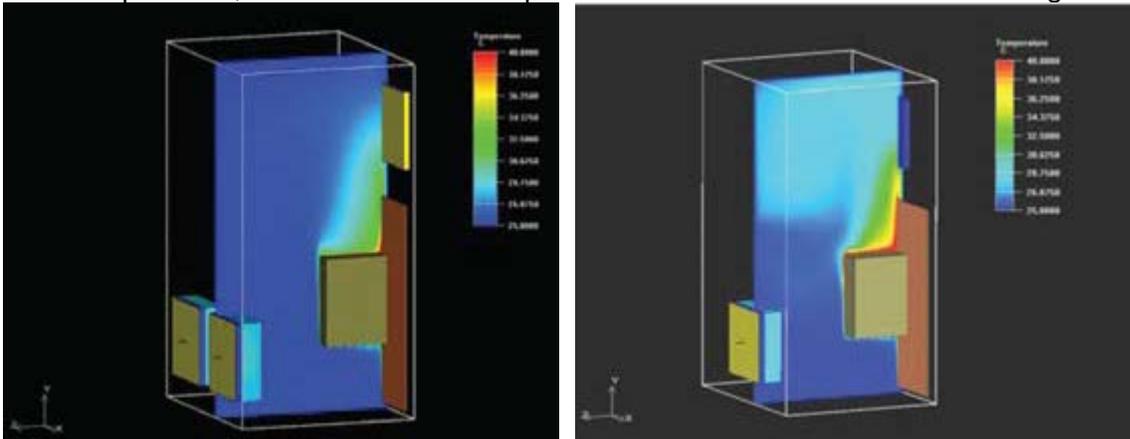
Rittal completed a CFD analysis to compare a general case with fans mounted in parallel and a single filter fan and filter. The model consisted of a Rittal enclosure 40" H X 24" W X 20" D with an ambient temperature of 77° Fahrenheit and an internal component that is dissipating 200 W of heat into the enclosure. In the final analysis, the airflow increased from 58.78 cfm to 117 cfm—a 100% increase in airflow. We can look at the temperature distribution in the enclosure in the pictures above. This increase in airflow provides much better cooling of the installed components. Please remember that this doubling will only occur in a medium to low impedance system.

Conclusions

In order to protect the proper functioning of electronic components, heat must be dissipated from the enclosure, and this can be done in a variety of ways including: natural convection, fans, air-to-air heat exchangers, air-to-water heat exchangers, and air conditioners. If fans are to be used, it is important to consider how much airflow is needed, and how much airflow the proposed filter fan solution will actually provide.

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