Using Fan Trays

In Electronic Systems

Despite rampant increases in power dissipation, the use of liquid for cooling electronics remains sporadic. Air cooling continues to be the dominant mode for most electronics applications. Higher power dissipation in ATCA enclosures, PICMG telecomm chassis, medical electronics, laser equipment, etc. mean that a single fan is no longer adequate to provide the airflow required for system thermal management. Therefore, an aggregate of fans in a tray is required. Figure 1 shows varied examples of fan trays used for different electronic systems

Figure 1. Different Fan Trays Used in Electronic Systems, Source: Web.

In previous articles we have discussed the characteristics and operations of a single fan as applied to its implementation in an enclosure [1,2]. In this article we will discuss the use of fan trays in such enclosures and highlight the pertinent issues facing such undertaking.

Fan Types

While only tube axial fans are shown in Figure 1, there are five broad categories of fans. These are:

- **Propeller** — used where the required pressure is low (less than 187 Pa).
- **Tube-axial** — develop high pressure, but have low efficiency.
- **Vane-axial** — similar to tube-axial fans; tend to be cheaper and require less space than centrifugal fans.
- **Centrifugal** — typically require bends in duct work for flow introduction. They are typically very quiet (noise decreases with the increase in number of blades).
- **Impeller** — typically known as flat packs; result in smaller aspect ratios with good flow rate and pressure drop.

Figure 2 shows the fan types previously mentioned.

The tube axial fan is by far the most common in electronic equipment. Flat pack and impeller (blower) fans have excellent pressure drop characteristics and are commonly seen in densely packed electronics. Axial and centrifugal fans have limited application for moving air through electronics systems because of their low pressure drop characteristics. However, because of their large volumetric flow rates, they play a pivotal role in cooling buildings or large cabinets that house electronic systems.

Fan Placement Configuration

Before we discuss the design issues involved with a fan tray implementation, we must review the characteristics of fans when placed in parallel and in series:

- **Parallel** — the total system flow is divided among the fans. Pressure drop remains the same, but the flow rate increases according to the number of fans.

Figure 2. Different Fan Designs [3].

- **Series** — the flow through all fans is the same, while the total system pressure drop is divided among them.

Figures 3a and 3b depict the P-Q curves (pressure drop and volumetric flow rate) for fans in series and parallel.

When fans are placed in parallel, Figure 3a, the volumetric flow rate is added together. If the fans are identical, the flow rate at zero pressure will be doubled. When fans are placed in series, Figure 3b, the pressure drop will be added together, and if they are identical at zero flow rate the pressure drop is doubled. Obviously, the system flow rate and pressure drop for a fan or an assembly are determined by where the system curve intersects the P-Q curve.

Based on the above explanation, the use of either parallel or series fans, or a combination of the two, becomes obvious. If the thermal requirements of the system mandate a higher volumetric flow rate, the parallel configuration is used. If the system is flow-resistive, and thus has a larger pressure drop, the series combination is used. If both conditions are present, i.e., a high flow resistance system with high power dissipation, then a combination of parallel and series is used. This is the so-called Push-Pull system that is commonly seen in telecom and datacom applications.

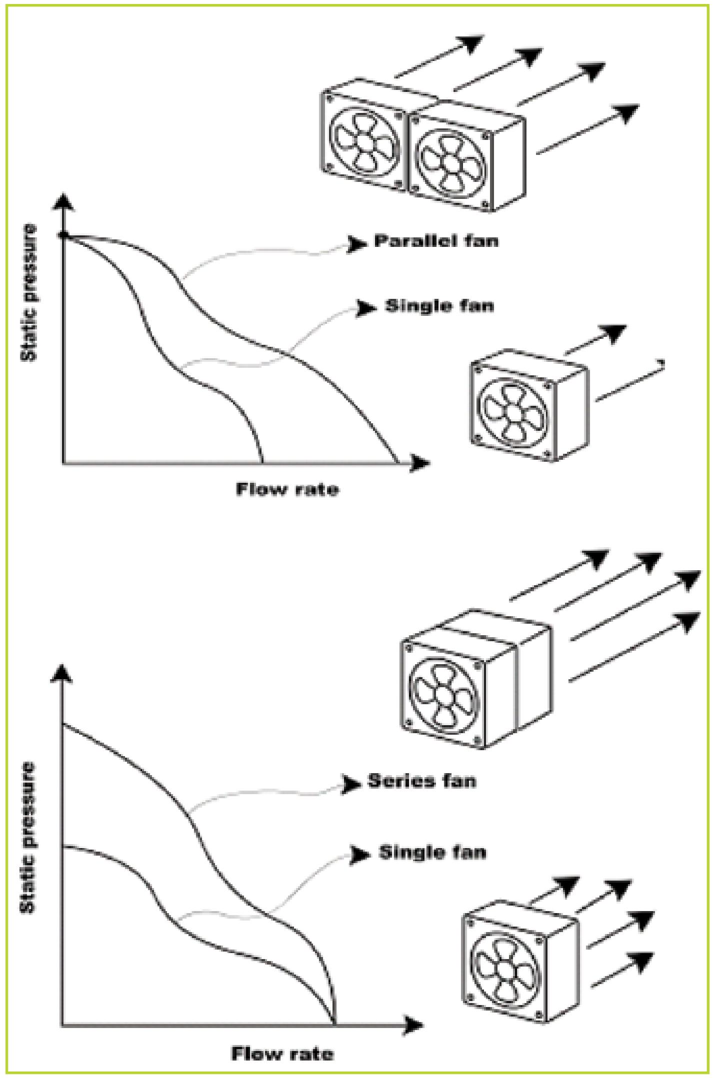

Figure 3. P-Q Curve for Fans in Parallel (3a) and in Series (3b) [4].

Fan Trays

This notion can now be transferred to fan trays and their unique characteristics when implemented in a system.

First, we'll define the characteristic lengths. Figure 4 shows a schematic of a system with fan tray and the supporting electronics.

Here, the characteristic lengths used in the design process are

D = fan diameter or width

H = fan thickness

L = distance between the fan and the adjacent object, e.g., PCBs or another fan.

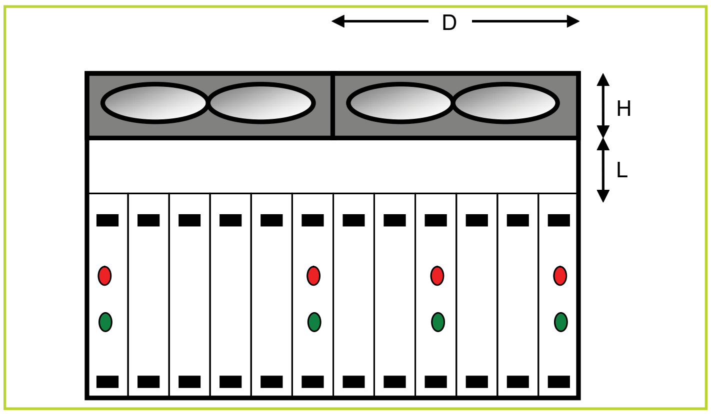

Figure 4. Schematic Definition of Characteristic Lengths.

When placing the fan next to another fan (i.e., in series) or a card rack, the simple rule of thumb is: **H≤L≤D**.

This means the farther you place the fan from an obstruction, the better it performs. At shorter distances, the airflow out of the fan will meet flow resistance created by obstacles, e.g., filter or PCBs. This will subsequently impact the intake of the fan, resulting in diminished performance. One needs to remember that the air flow out of a fan is radial and not axial. Therefore, the larger the plenum space for the fans to breed, the better the performance. The above scenario addresses the issue of fans in series or the location of an obstruction in the exhaust or intake of the fan.

When we place fans in parallel, there is a strong possibility that the flow from one fan will shunt through a neighboring fan. This depends on their proximity, the fans' RPM and design. Another issue is that acoustic noise may result from the fans' proximity to each other. Harmonics can be created from flow shunting or flow interference between neighboring fans, and often sounds like a heart beat. And, as indicated above, radial fan flow will cause flow interference in a fan tray environment. Because the fan is an airfoil-driven device, and proper pressure differential across its hub is essential to performance, improper fan placement and fan/exhaust-flow mixing will cause fan tray performance degradation. Figure 5 shows one example of how to remedy such a situation.

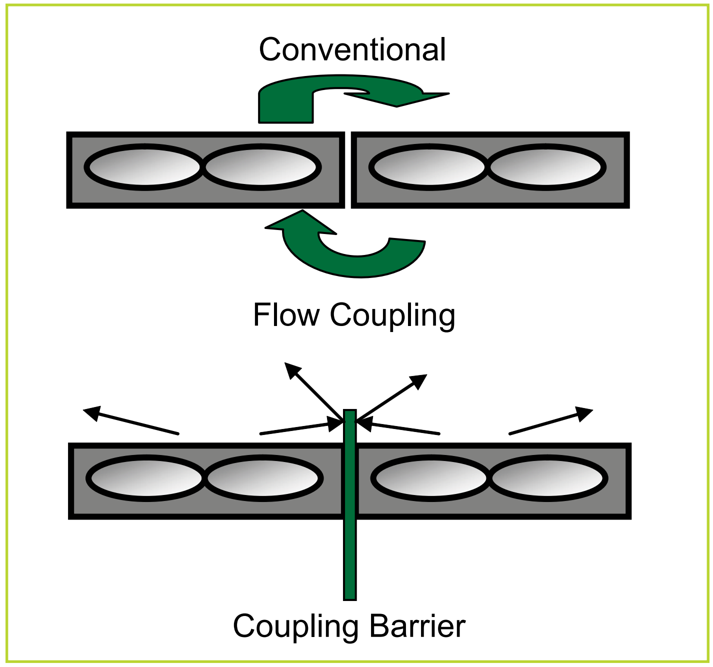

Figure 5. Parallel Fan Flow Coupling and Respective Remedy [3].

Therefore, it is highly recommended that when selecting or designing a fan tray, special care be taken to ensure that the above basic design requirements are implemented.

In addition to these requirements, here are some general guidelines for fan and fan tray implementation:

A-Elbows - When placed close to a fan inlet, an elbow can cause non-uniform distribution of air. This results in flow starvation of some parts of the blade.

B-Sharp-edged entrance - This may result in vena contracta, with a loss of flow area.

C-Swirling flow at the inlet - The fan intake design may cause swirling airflow. If the direction of the swirl is the same as the blade, it affects upstream pressure and decreases fan effectiveness (decreases the pressure). If the swirl is in the opposite direction of the blade rotation, more power consumption by the fan is needed to reach the same performance.

D-Obstruction at inlet - This will reduce the flow area.

When placing fan trays in typical electronics enclosures the question of Push, Pull, or Push-Pull always arises. Push implies that air is being pushed into the electronics enclosure, i.e., the fan tray resides on the top or bottom of the chassis and pushes the air into the PCB cage. Pull means that air is drawn into the system whether the fan tray is on the top or bottom. Push-Pull is when two fan trays are placed on the top and bottom of the electronic system. With a Push or Pull system, there is no acceptable industry best practice. The implementation is very much chassis dependent. However, the Pull option uses the chassis as a plenum and provides a better pressure distribution for the enclosure. When the Push option is used, high turbulent flow exiting the fans is forced through a filter, honeycomb and the PCB channels (system configurations may vary). If a large plenum is not provided, the fan tray efficiency will drop significantly because highly turbulent flow must negotiate the added resistances.

As apparent from the above, the successful use of a fan tray in any configuration is plenum size dependent. If the plenum and the subsequent resistances are designed properly, the fan tray will operate at its highest performance point and deliver the required airflow for the cooling of the electronics.

Pressure Drop and Resistance

In designing a fan tray for cooling an electronic system, knowing the velocity head loss and the resistance to flow created by the fan tray is required. The following equations can be used for these calculations:

$m_{tot} = N_{CP} \times m_{CP} = N_{CP}\, V_{mean} A_{CP}\, \rho$ which is the total mass flow rate from all fans.

Head Loss, H_L is given by

$$H_L = 2P_{fan} - \left[\frac{2P_{fan} \times \dot{m}_{max}}{N_{fan} \times \dot{m}_{tot}} \right]$$, where m

And the individual fan resistance and fan tray resistance is provided by the following:

$$R_{fan} = \frac{H_L}{\left[\frac{\pi D_{fan}^2}{4} V_{fan}\right]^2} \quad \text{and} \quad R_{fan,tray} = \frac{2R_{fan}}{N_{fan}^2}$$

In the above equations,

A_{CP} - Card-to-card cross sectional area
H_L - Velocity head loss
m_{tot} - Total mass flow rate
m_{CP} - Mass flow rate in a circuit pack (PCB)
m_{max} -Maximum mass flow rate created by a fan
N_{CP} - Number of channels formed by the PCBs
N_{fan} - Number of fans
P_{fan} - Fan pressure capacity
R - Resistance to flow movement
ρ - Density

Acoustic Noise

Generally, the noise created by a fan is the result of the collision of air molecules. The subsequent mechanical vibration is the result of mixing in the physical system. When a fan is running, the blade is rotating, moving a mass of air from intake side to exhaust side. There are relative motions between the air and the blades, the air and the housing, and the air and the ribs supporting the motor. Consequently, the air exiting and entering the fan is highly turbulent, and this turbulence is the source of noise in the fan.

The sound created by fans is a major point of concern for system implementation at a customer's premises. For example, a fan with 7 blades rotating at 4200 RPM creates a noise with an approximate 490 Hz frequency (7 × 4200 ÷ 60(sec)= 490 Hz). Therefore, much effort is put forth to measure and manage this noise to make the electronics more acceptable on location. By using the following equations, we can measure the noise and its acceptability before the fan tray is designed. Two parameters play a direct role in the acoustic noise generated by a fan: airflow and fan RPM.

The sound power as a function of RPM is calculated by:

$$L_{w2} = L_{w1} + 5Log(N_2/N_1)$$

Where,

L_{w2} & L_{w1} = sound power level at conditions 1 & 2
N_1 & N_2 = fan RPM at conditions 1 & 2

And the sound power as a function of airflow:

$$Lw = 3.71 \, Log \, V_t + 0.96 \, Log \, Q - 10.8$$

Where,

V_t = the tip speed of the impeller
N = impeller speed in RPM
Q = the volumetric flow rate, ft3/min (this non-dimensional equation must use Imperial units for volumetric flow rate)
D = the impeller diameter, inches (non-dimensional equation, must use the Imperial units for diameter)

A typical acceptable sound level is 58db. Beyond this, the noise is considered intrusive to people around the system. Of course, because of today's high power electronics, this limit is clearly violated and often reaches 68 db or higher.

In conclusion, fan trays clearly play a pivotal role in providing effective cooling solutions for many electronic enclosures. It is imperative that their functionality and operation is clearly understood and designed for a given system. It is often insufficient to simply place a fan tray in the system and assume it will provide the airflow necessary to cool the system to the acceptable operational levels. As seen above, the design of the fan tray, placement of the fans in the tray, effect of fan RPM and the airflow rate, all play major roles in the successful use of a fan tray in a chassis, and subsequently in system cooling, which is the ultimate objective.

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