

## TB-2009-001

### How Do I Properly Size a Fan?

Proper sizing of fans and blowers involves determining many system factors and prioritizing them into requirements versus preferences. Some of these factors are the static pressure the fan must overcome, the average air flow volume required, the shape and direction of the desired air flow, space limitations, audible noise allowances, available power, efficiency, air density, and cost. The first two of these, air flow and static pressure, along with available power considerations are generally the most critical for system designers. These three address the fundamental questions how much air do I need and what is it going to cost in system power to get it? Defining these three parameters is generally the first step a system designer must complete towards Sizing a fan or blower.

Once these three are defined it's much easier to look at available options to meet your need(s). Progressive fan manufacturers such as Dynamic-Air Engineering (for Aerospace and military platform fans and blowers) or TriNertia (for commercial and industrial fans and blowers) make this easier for the system designer by providing a web based Product Selector user interface. Using this interface the designer simply enters in these three parameters and the web browser will return a list of all fans and their attributes that meet or exceed these requirements. This interface also allows the user to enter other parameters such as type of air flow: line pattern, centrifugal (orthogonal to inlet), Vaneaxial (coincident with inlet), etc. to further narrow the field of options. Alternatively these manufacturers can recommend fan types and sizes in accordance with the fan curves that match the designers application requirements (Stevens, 2008). However in either case the designer must complete the system technical analysis required to determine these three factors-air flow, static pressure, and available power.

Airflow is generally determined first by the application need. For example this may be the amount of air needed to reach a desired steady state temperature or the velocity to separate particulates from air. In any case the needs of the system will determine how much air is needed. More is not always better. Too much airflow can be damaging or counter productive in certain sensitive applications or may drive up size or cost of the fan.

In open system applications such as using a line blower to blow a cushion of air across a material processing bed or to provide general cooling in a large electronics cabinet static pressure is negligible. In these cases the static pressure can be set at normal atmospheric pressure and there is little air movement resistance.

However in closed systems installations the design can greatly increase static pressure and is therefore important to the success of the fan. An obstruction, a flow direction change (elbow) or a narrowing of the duct will act to increase the resistance of the system decreasing fan performance by increasing the static pressure. More power is required and the fan has a greater potential to stall (Alexander, 2007). Ducting installed on the fan outlet should be designed to enable asymmetrical flow from the fan to diffuse into fully developed symmetrical flow. This is sometimes accomplished by installing vanes inside the outlet duct. Inlet and outlet ducting has a profound affect on fan performance. A duct restriction caused by improper ducting that alters fan performance is known as “system effect factors” (Alexander, 2007).

Static Pressure can either be directly measured if the system already exists, can be modeled using CFD finite element software, or can be calculated using published guidelines. Dynamic-Air Engineering can assist the designer in the development process by using the designer’s available 3D CAD models and modeling the system pressure drops in their CFD program as a service.

The Air Movement and Control Association International (AMCA) publish guidelines on system effect factors if the designer prefers hand calculations to determine static pressure. In addition, the AMCA created the term “effective duct length” this means the duct length is 2.5 duct diameters when the duct velocity is 2,500 fpm or less. One duct diameter is added for each additional 1,000 fpm (Stevens, 2008). A centrifugal fan needs 100% of an effective duct length on the fan outlet to avoid system effect. A vaneaxial fan needs 50% effective duct length to avoid system effect.

Air density and air temperature are inversely proportional to each other. Both affect fan pressure and power requirements. Regardless of the density of the gas the flow rate remains constant (Alexander, 2008). The fan laws are applied to compensate for the change in density when a fan operates at high altitude or non-ambient temperature. Where the air volume remains constant the RPM and CFM are proportional as:

$$\frac{RPM_1}{RPM_2} = \frac{CFM_1}{CFM_2}$$

CFM DOES NOT CHANGE WITH DENSITY

When the density changes the pressure changes as:

$$\left( \frac{\text{RPM}_1}{\text{RPM}_2} \right)^2 = \frac{P_1}{P_2}$$

10% Increase in RPM = 21% Increase in Pressure.

When the density changes the power changes as:

$$\left( \frac{\text{RPM}_1}{\text{RPM}_2} \right)^3 = \frac{W_1}{W_2}$$

10% Increase in RPM = 33.1% Increase in Power.

The efficiency remains constant and the noise level remains constant.

The aforementioned fan laws serve to identify changes in pressure and power relative to changes in density. Fan sizing includes operating performance throughout a spectrum of density changes relative to a change in altitude, temperature, or both. Known parameters such as (CFM) at sea level density are required to apply the fan laws.

Another parameter that is important to understand is flow rate in CFM. This is described by the formula:

$$Q = A \times V$$

Where: Q = volume of flow in cubic feet / minute

A= area of duct in feet<sup>2</sup>

V= Velocity in feet per minute (Bleier, 97).

Fan curves are plotted with the pressure (inches of water) verses cubic feet per minute on the “x” and “y” axis. Static pressure and CFM at a specific point on the fan curve is referred to as the “design point” of the fan. If an obstruction exists the fan will not operate at its design point and air flow (CFM) will be reduced.

Static pressure is defined as the difference between total pressure and velocity pressure. Total pressure is the difference between the pressures at the fan inlet and the outlet. The velocity pressure is the pressure we feel inside the air stream and is described by the following formula:

$$VP = \left( \frac{V}{4005} \right)^2$$

(Bleier, 1998).

The formula to define static pressure is:

$$SP = TP - VP$$

These formulas are used to determine critical parameters when selecting a fan. The fan curves enable accurate fan selections based on static pressure and flow rate (CFM). The fan laws enable pressure and power adjustments with a change in density relative to temperature and altitude. Installation type is paramount to fan application success because even though the fan may be specified correctly if the inlet or outlet ducts restrict air flow fan performance suffers. Other factors such as noise, efficiency, space restrictions, and cost should be considered during the fan sizing process.

Once the fan is sized the ducting arrangement interfacing to the fan can change performance. In order for the fan to achieve its rated performance the inlet air flow must be fully developed, symmetrical, and swirl free. For a centrifugal fan a minimum of one inlet diameter of free area around the fan inlet is recommended.

#### References

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