YASKAWA

There are two basic types of air moving devices: the centrifugal fan or blower, and the axial flow fan. Generally speaking, the centrifugal fan creates higher pressures than that of the axial flow fan and is applied on jobs with higher resistance to the air flow.

Centrifugal Fan or Blower. The centrifugal fan consists of a wheel with small blades on the circumference and a shroud to direct and control the air flow into the center of the wheel and out at the periphery. The blades move the air by centrifugal force, literally throwing the air out of the wheel at the periphery, creating a suction inside the wheel. The basic types of wheel blades in centrifugal blowers are forward-curved (FC) and backward-inclined (BI).

A centrifugal blower with forward-curved blades has blades that are curved in the direction of wheel rotation and, is primarily an impulse device. It accelerates the air to a high velocity, while rotating at a speed that is usually low compared to that of a backward-inclined blower. The forward-curved type is known as a "volume" blower, and is more common because it delivers the greatest air volume in relation to blower size and speed. It has static efficiency in the range of 60 to 68%.

FC blower wheels are operated at relatively low speeds and are used to deliver large air volumes against relatively low static pressures. The inherently light construction of the forward curved blade does not permit this wheel to be operated at speeds needed to generate high static pressures.

Notice in Figure 1 on this typical FC fan curve, how the brake horsepower lines cross the fan performance curves. Therefore, if the system resistance were to drop from 2 inches to 1.5 inches of static, in this example, the fan brake horsepower requirement would rise from 3 bhp to something over 3.5 bhp, possibly overloading the motor. Consequently, the FC fan is referred to as an overloading type fan.

The backward inclined blower wheel design has blades that are slanted away from the direction of wheel travel. The term applied to this type of blading is BI or backward inclined. (An AF fan, or air foil fan, is a subset of the BI fan with, as the name implies, more efficient fan blades.)

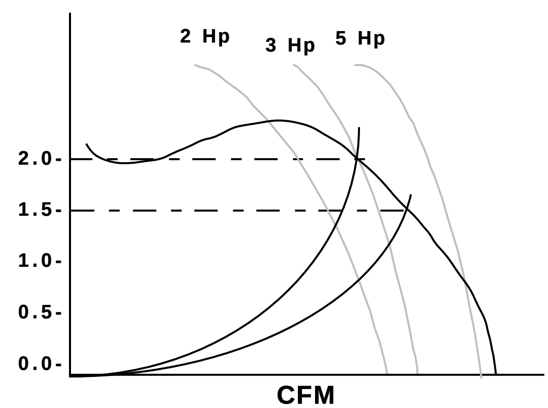

Figure 1

The performance of this wheel is characterized by high efficiency, high cfm and its rugged construction makes it suitable for high static pressure applications.

The maximum static efficiency of the BI wheel is approximately 75 to 80 %. When a BI fan is selected to handle a given air quantity, it must be operated at approximately twice the speed of a similarly selected FC fan. In spite of this, the horsepower requirement of the BI fan is less, making it a more efficient design.

Unlike the FC fan, the brake horsepower lines of a BI fan are, for the most part, parallel to the fan performance curves. Therefore, if the system resistance were to drop from 4 to 2 inches static, as in Figure 2, the fan brake horsepower would change only slightly. For this reason, BI fans are referred to as non-overloading fans.

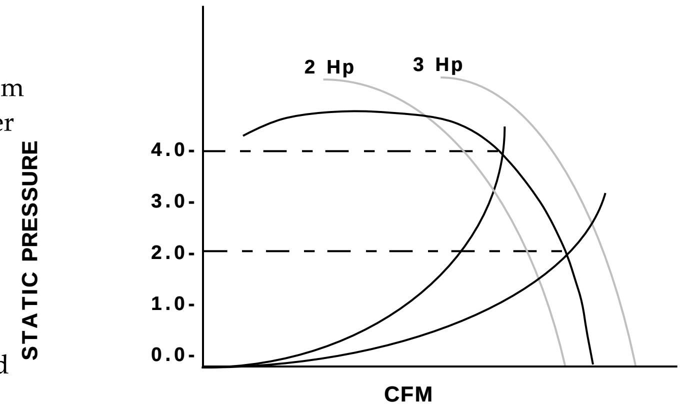

Figure 2

Axial Flow Fan. There are three basic types of axial flow fans: The propeller fan, the tube-axial fan and the vane-axial fan. The first of these is probably the most familiar. The propeller fan consists of a propeller blade and an associated aperture to restrict "blow-back" from the output side. Without the aperture, the fan is not truly a propeller fan, since it cannot positively move air from one space to another. The aperture is usually sheet metal, designed to fit closely around the periphery of the propeller. The tube-axial fan is literally a propeller fan in a tube. In this case the tube replaces the aperture. The tube-axial fan, an extension of the propeller fan, increases flow quantity, pressure and efficiency, due to the reduced air leakage at the blade tips. The vane-axial fan is a tube-axial fan with the addition of vanes within the tube to straighten out the air flow. The air flow changes from helical flow imparted by the propeller into a more nearly straight line flow and, in the process, increases the pressure and efficiency while reducing noise.

In general, the propeller fan operates at the lowest pressure. The tube-axial fan is somewhat higher; and the vane-axial fan supplies the highest pressure output of the three. Vane axial fans are used when available space for fan installation is limited.

Static efficiencies of 70 to 72 % are achieved with vane axial fans. The cfm and static performance range of the vane axial fan is similar to that of the BI and airfoil fans.

Similar to the BI fan, the horsepower lines are essentially parallel to the fan curves, therefore the vane axial fan, shown in Figure 3, is considered a non-overloading design.

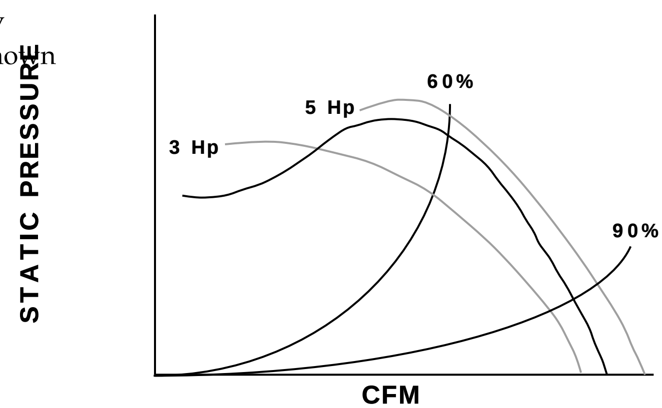

Figure 3

Horsepower vs Speed Characteristics. There are three basic principles of fan operation which can serve to aid in understanding and finding solutions to motor application problems. These are speed, pressure and air density.

It can be stated that the horsepower input to a fan varies as the cube of the speed, with the other factors held constant.

$$HP_2 = HP_1 \times \frac{(N_2)^3}{N_1}$$

Where N = specified speed (RPM)

Thus, if a customer wishes to increase the speed of a fan by 10%, the horsepower required increases by 33%.

Because of the cube law relationship between horsepower and speed, it is important to pay attention to motor full-load RPM and make certain that the operating load point between the motor and the fan are correctly matched. Often, belted fan units are shipped with variable pitch motor sheaves (pulleys) so that the fan load can be field adjusted for system balancing. If the sheave is not adjusted when installed (it normally comes in a closed position), the load on the motor can be tremendous. Remember, the motor and fan speeds are proportional to the sheave pitch diameters:

$$\frac{\text{Motor Sheave Dia.}}{\text{Fan Sheave Dia.}} = \frac{\text{Fan RPM}}{\text{Motor RPM}}$$

Horsepower vs Pressure Characteristics. No all-encompassing statement can be made about the effect of varying the pressure while holding other variables constant. However, with most centrifugal fans, as the pressure of the system increases (resistance to the air movement increases), the horsepower input decreases. This can be explained by pointing out that as the pressure builds up, the fan moves a smaller volume of air (see Figure 4), and this decrease more than offsets the increase in pressure.

Therefore, less power is required. In all air-moving units, the magnitude of the air-flow rate produced by a unit operating at a constant speed decreases as the pressure needed to overcome the total flow resistance of the system increases, and vice versa.

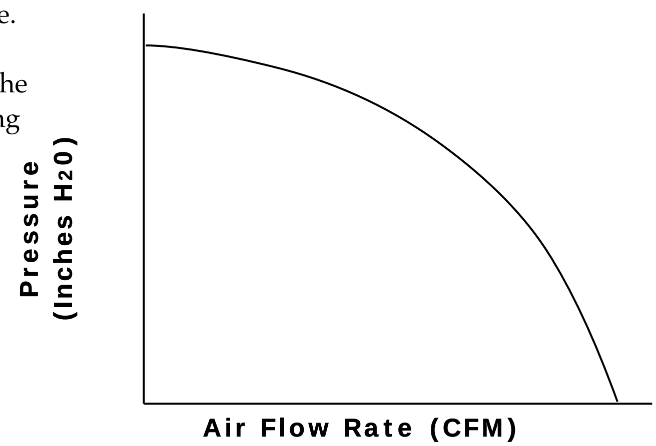

Figure 4

System pressure (or total pressure) in an air-moving system is the sum of the static and velocity pressures. Static pressure is the compressive pressure in a fluid, and represents its potential energy. Velocity pressure is produced by the velocity of fluid flow, and represents its kinetic energy. In air-moving systems, static pressure differences are usually below 10 inches (H_2O), and the air is considered incompressible. The total absolute pressure at any point in the system is the sum of the total pressure at that point and the atmospheric pressure. (Pressure in an air-moving system is usually measured in inches of water.)

With the axial-flow fan and backward inclined fan, the horsepower input tends to remain relatively constant as the pressure changes.

Horsepower vs Air Density, Temperature and Humidity. Again, with other remaining factors constant, the horsepower input to a fan varies directly with the air density. This is to be expected, because if the fan is handling heavier air, it will be doing more work and require more input. This can be carried further and tied in with temperature and relative humidity, since these are two factors which affect the density when pressure is held constant. Since density decreases as temperature and relative humidity increase, it follows that the warmer the air or the more humid the air being handled by a fan, the less horsepower input is required.

Horsepower Correction for Air Density.

Standard air density is established as .0750 lb/ft^3 at 70°F. Finding the density at other temperatures requires converting the new temperature reading to **absolute** ($T_a = T_F + 460$; note that 70°F equals 530° absolute) and then using the following formula:

$$\frac{530 \times .0750}{\text{new } T_a} = \frac{39.75}{\text{new } T_a} = \text{new density}$$

At 125°F, the new air density is:

$$\frac{530 \times .0750}{585} = \frac{39.75}{585} = .0679 \text{ lb/ft}^3$$

And at 45°F, the new air density is:

$$\frac{530 \times .0750}{505} = \frac{39.75}{505} = .0787 \text{ lb/ft}^3$$

Table 1 lists a number of air temperatures with the associated air densities and horsepower ratios (i.e. correction factors). All horsepower ratios are based upon a one horsepower motor at 40°C (104°F).

Table 1

AIR TEMP. °F	AIR DENSITY LB/FT^3	HORSEPOWER RATIO
–60	.0994	1.41
–50	.0970	1.38
–40	.0946	1.34
–30	.0924	1.31
–20	.0903	1.28
–10	.0883	1.25
0	.0864	1.23
10	.0846	1.20
20	.0828	1.17
30	.0811	1.15
40	.0795	1.13
50	.0779	1.10
60	.0764	1.08
70	.0750	1.06
80	.0736	1.04
90	.0723	1.03
100	.0710	1.01
104 (40°C)	.0705	1.00
110	.0697	.99
120	.0685	.97
130	.0674	.96
140	.0663	.94
150	.0652	.92