



## UNDERSTANDING FAN PERFORMANCE CURVES

### INTRODUCTION

One of the most important documents customers request from fan manufacturers is performance curves. In addition to graphically depicting the basic fan performance data of CFM, RPM, and SP (on the static pressure curve) and BHP (on the brake horsepower curve), these curves also illustrate the performance characteristics of various fan types, like areas of instability, or the rate of change between flow and pressure. With some basic knowledge of performance curves, decisions can be made concerning fan selection, fan and system alterations, or the advisability of using a fan in a modulating system, for example.

Except for very large fans, performance curve information is generated by connecting the fan to a laboratory test chamber. Very specific test procedures are followed as prescribed in the Air Movement and Control Association's Standard 210 to assure uniform and accurate readings. Data points are collected at a given RPM while the flow is slowly modulated from full closed to full open. The information gathered is then used to develop computer selection programs and published capacity tables for use by system designers and end users.

### STATIC PRESSURE CURVE

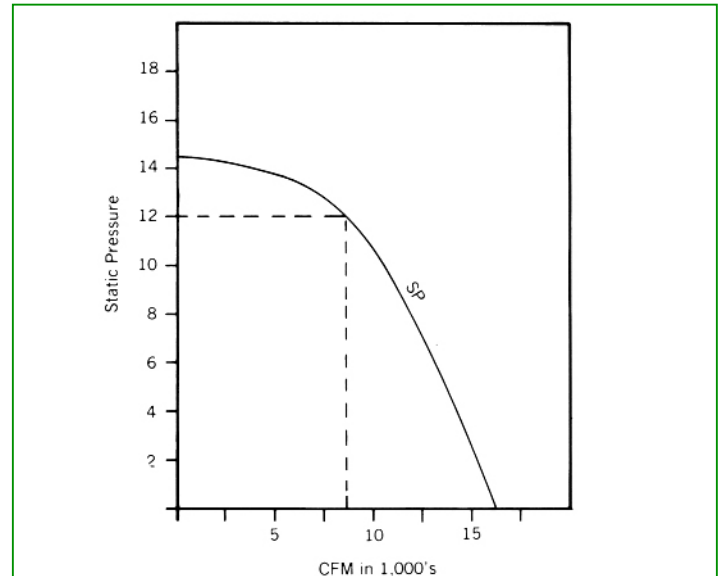
The static pressure curve provides the basis for all flow and pressure calculations. This curve is constructed by plotting a series of static pressure points versus specific flow rates at a given test speed. While the static pressure curve depicts a fan's performance at a given speed, it can be used to determine the fan's pressure capability at any volume.

In addition, it is also possible to approximate the fan's performance at other speeds by applying the following fan laws:

1. CFM varies as RPM
2. SP varies as  $(\text{RPM})^2$
3. BHP varies as  $(\text{RPM})^3$

To locate a fan's point of operation, first locate the required static pressure on the SP scale at the left of the curve. Then draw a horizontal line to the right, to the point of intersection with the SP curve. Next, draw a vertical line from the point of operation to the CFM scale on the bottom to determine the fan's flow capability for that SP at the given speed.

As shown in Figure 1, the performance for this fan is 8750 CFM and 12" SP at 1750 RPM.



**Figure 1 - Static Pressure Curve**

Assuming this same fan was intended to operate at 1200 RPM, the fan laws can be applied to obtain performance at this lower speed.

1. CFM varies as RPM

$$\frac{\text{CFM (new)}}{\text{CFM (old)}} = \frac{\text{RPM (new)}}{\text{RPM (old)}}$$

Therefore:

$$\text{CFM (new)} = \frac{1200}{1750} (8750) = 6000 \text{ CFM}$$

2. SP varies as  $(\text{RPM})^2$

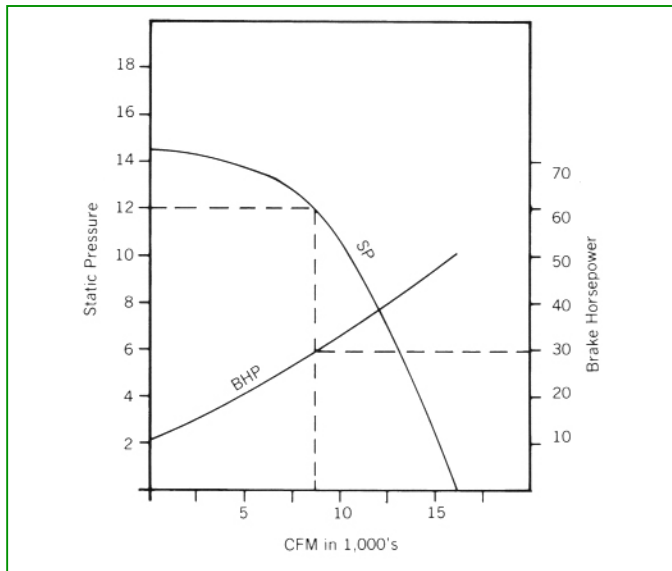
$$\frac{\text{SP (new)}}{\text{SP (old)}} = \left( \frac{\text{RPM (new)}}{\text{RPM (old)}} \right)^2$$

Therefore:

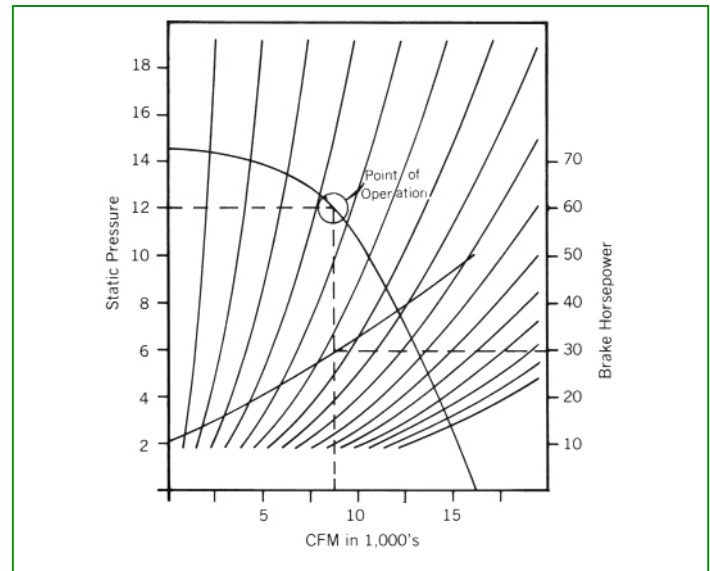
$$\text{SP (new)} = \left( \frac{1200}{1750} \right)^2 (12) = 5.6'' \text{ SP}$$

### BRAKE HORSEPOWER CURVE

Once the CFM and SP have been determined, a BHP rating can be established. An accurate BHP rating is necessary to properly size the motor or to determine the operating efficiency of one fan as compared to another. Performance curves contain a BHP curve from which the BHP rating can be determined for specific capacities. To determine BHP at a specific point of operation, a horizontal line is drawn to the right from the point of intersection of the vertical CFM line and the BHP curve.



**Figure 2 - Performance Curve**



**Figure 3 - Performance Curve with System Lines**

As shown in Figure 2, the fan operating at 8750 CFM and 12" SP at 1750 RPM is rated at 30 BHP. By employing the third fan law, the BHP rating can be determined for operation at 1200 RPM.

3. BHP varies as (RPM)<sup>3</sup>

$$\frac{\text{BHP (new)}}{\text{BHP (old)}} = \left( \frac{\text{RPM (new)}}{\text{RPM (old)}} \right)^3$$

Therefore:

$$\text{BHP (new)} = \left( \frac{1200}{1750} \right)^3 (30) = 9.67 \text{ BHP}$$

## SYSTEM LINES

Since fans are tested and rated independently from any type of system, a means of determining the fan's capabilities within a given system must be provided. The fan laws apply equally to any system; therefore, CFM and SP variations within the system are predictable. This enables system lines to be superimposed on performance curves to simplify performance calculations. The system line is nothing more than the sum of all possible CFM and SP combinations within the given system. Any combination of fan and system must operate somewhere along that system line.

Because a fan must operate somewhere along its SP curve and since the system has a known system line, their intersection is the point of operation. If the fan speed is changed, the point of operation must move up or down the system line. If the system is changed in some way, the point of operation must move up or down the SP curve. In practice, these principles can be used to check the accuracy of fan performance and system design.

## USING PERFORMANCE CURVES

Figure 3 illustrates the point of operation of a fan selected for 8750 CFM and 12" SP operating at 1750 RPM. Included in Figure 3 are a number of different system lines. If the system does not operate properly upon start-up, measurements can be taken and compared against the available performance curve.

Let's assume that a tachometer reading indicates the fan is running at 1200 RPM instead of 1750 RPM, because of mistakes in motor speed or drive selection, and an airflow check indicates only 6000 CFM. These readings confirm that the system was calculated correctly and that the fan speed must be corrected to 1750 RPM as originally specified to achieve the desired 8750 CFM. If the tachometer reading indicates the proper speed but the airflow reading is down, additional system resistance beyond that originally calculated is indicated. This additional resistance could be caused by partially closed louvers/dampers, changes in duct sizing from the original design, system effect losses, or just an error in the system-resistance calculations. The deficiency can usually be corrected by either altering the system or increasing the fan speed.

Often, performance curves for one speed must be used to determine the performance of a fan for use on systems requiring more air or higher pressures. A performance curve such as Figure 4 can be used to determine fan performance beyond the SP scale shown by using the fan laws to obtain a reference point of operation on the system line. This can be accomplished by applying some suitable factor to the required CFM and the square of that factor to the required SP.

For example, the performance curve shown in Figure 4 can be used to determine fan performance requirements for a system calculated at 15,000 CFM and 23.5" SP, even though that point is beyond the curve. By determining a suitable reference capacity using the fan laws, that falls within the curve data, fan performance requirements can be obtained at the curve speed and then projected up to the system requirements using the fan laws once again.

The required 15,000 CFM and 23.5" SP is on the same system line as 10,000 CFM at 10.4" SP which intersects the fan's SP curve drawn for 1750 RPM and has a corresponding BHP of 33.0 at 1750 RPM. Therefore:

$$\text{RPM (new)} = \frac{15000}{10000} (1750) = 2625 \text{ RPM}$$

$$\text{BHP (new)} = \left( \frac{15000}{10000} \right)^3 (33.0) = 111 \text{ BHP}$$

## FAN PERFORMANCE CHARACTERISTICS

The performance characteristics of a fan can be determined from the performance curve at a glance. These characteristics include such things as stability, increasing or non-overloading BHP, and acceptable points of operation.

Fan performance is based on certain flow characteristics as the air passes over the fan wheel blades. These flow characteristics are different for each generic fan or wheel type, (i.e. radial, forward-curved, backwardly-inclined, radial-tip, and axial). Thus, the performance characteristics will be different for each of these general fan types. Further, these performance characteristics may vary from one manufacturer to the next depending upon the particular design. The characteristics described in this letter are based on **nyb** fan equipment.

The performance curves presented in Figures 1 through 4 are typical of fans with radial-blade wheels. The SP curve is smooth and stable from wide open to closed off. The BHP curve clearly indicates that the BHP increases steadily with the volume of air being handled as shown in Figure 4.

Fans with forward-curved wheels, such as shown in Figure 5, also have a BHP curve that increases with the volume of air being handled. The SP curve differs significantly from the radial since it exhibits a sharp “dip” to the left of the static pressure peak. This sharp dip (shaded area) indicates unpredictable flow characteristics. Though not technically accurate, this region is often referred to as the “stall” region. It indicates that at these combinations of pressure and relatively low volumes, the airflow characteristics across the wheel blades change or break away so that the fan performance point is no longer stable. Any fan with this characteristic SP curve should not be selected for operation in the unstable area.

As shown in Figure 6, the SP curve for a backwardly-inclined fan has a sharp dip to the left of the static pressure peak. This indicates an area of instability. However, the backwardly-inclined SP curve is generally steeper than that of the forward-curved wheel indicating its desirability for use in higher pressure systems. Therefore, variations in system resistance will result in smaller changes in volume for the BI Fan when compared to the FC Fan.

Even though New York Blower centrifugal fans with AcoustaFoil® wheels are stable in the area left of the peak, the majority of fans with backwardly-inclined wheels exhibit an SP curve similar in appearance to that of the forward-curved fan. The SP curve shown (in Figure 7) for fans using AcoustaFoil (air-foil, backwardly-inclined) wheels exhibits a much smoother depression to the left of the static pressure peak. This indicates that the overall fan design is such that internal flow characteristics remain desirable or predictable even in the region left of peak and that performance in this region is stable.

AcoustaFoil® is a trademark of The New York Blower Company.

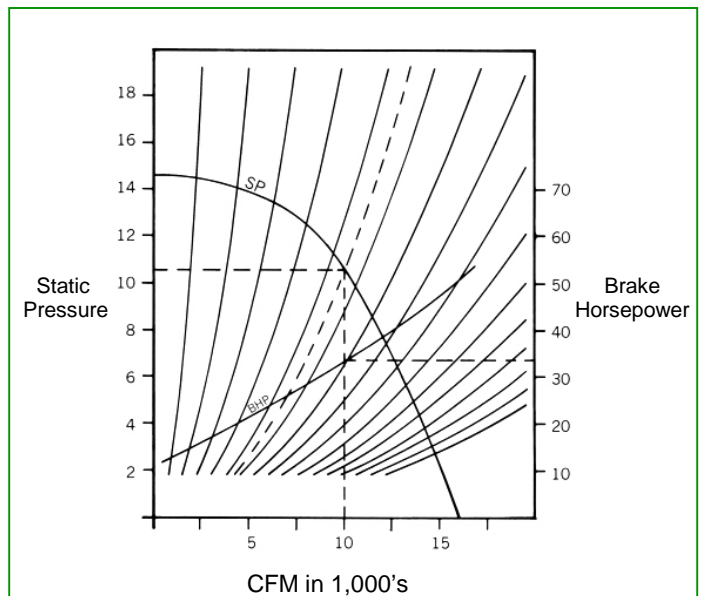


Figure 4 – Typical Radial-Blade Fan Performance Curve

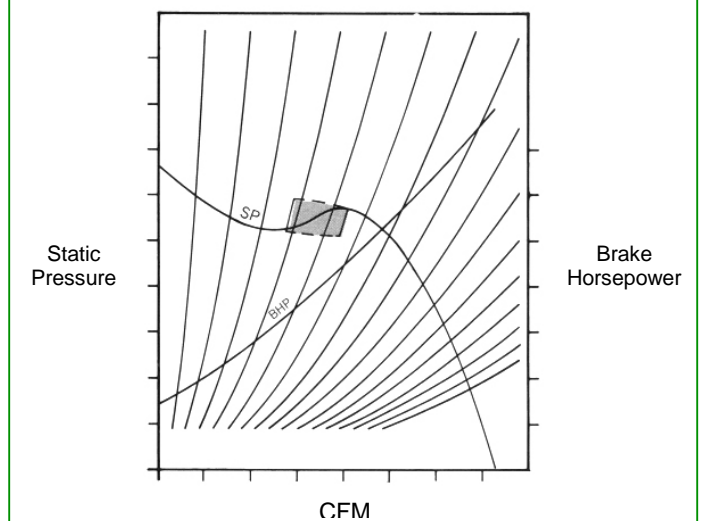


Figure 5 – Typical FC Fan Performance Curve

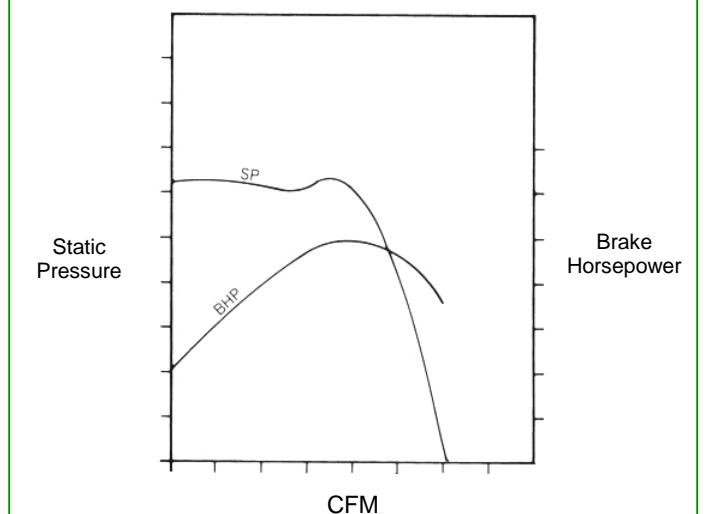


Figure 6 – Typical BI Fan Performance Curve

The BHP curve for all backwardly-inclined fans is the major difference between them and all other fan types. As shown in Figures 6 and 7, the BHP curve for backwardly-inclined fans reaches a peak and then drops off as the fan's volume increases. With this "non-overloading" BHP characteristic, it is possible to establish a maximum BHP for a given fan speed and select a motor that can not be overloaded despite any changes or errors in system design. Because BHP varies as  $(\text{RPM})^3$ , this non-overloading characteristic does not apply to increases in fan speed, but it is very useful for motor protection against errors or changes in system calculations and installation.

Figures 5 and 6 indicate certain unacceptable selection areas on the SP curve. Although stability or performance may not be a problem, a point of operation down to the far right on the SP curve should be avoided. Selecting a fan that operates far down to the right, eliminates the flexibility to compensate for future system changes. Also, the fan is less efficient in this area as compared to a larger fan operating at a slower speed. Figure 7 shows the best selection area on the SP curve and the area in which the majority of capacity tables are published.

As is evident in Figure 8, the radial-tip fan design combines the backwardly-inclined SP curve characteristics with the radial fan's BHP curve. The radial tip is often more efficient than radial fans and typically best applied in high-pressure applications. As a result of its efficiency and dust-handling capabilities, the radial-tip fan can also be applied to lower pressure material conveying systems.

The term axial fan is used to describe various propeller, vaneaxial, tubeaxial, and duct fans. The performance curves of these fans are characterized by the ability to deliver large volumes of air in relatively low pressure applications. As can be seen in Figure 9, the axial flow fan is distinguished by a drooping BHP curve that has maximum horsepower at no flow or closed-off conditions. The axial fan SP curve exhibits an area of extreme instability to the left of the "hump" in the middle of the curve. Depending upon the severity, axial fans are normally only selected to the right of this area.

## CONCLUSION

A good working knowledge of performance curves is necessary to understand the performance characteristics and capabilities of different fan equipment. Use of performance curves in the selection of fan types and sizing will assure stable and efficient operation as well as future flexibility.

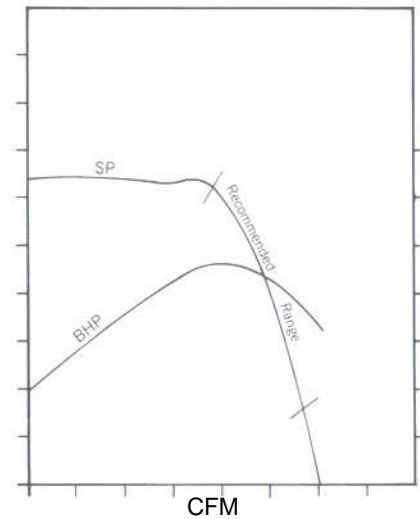


Figure 7 – Typical AcoustaFoil Fan Performance Curve

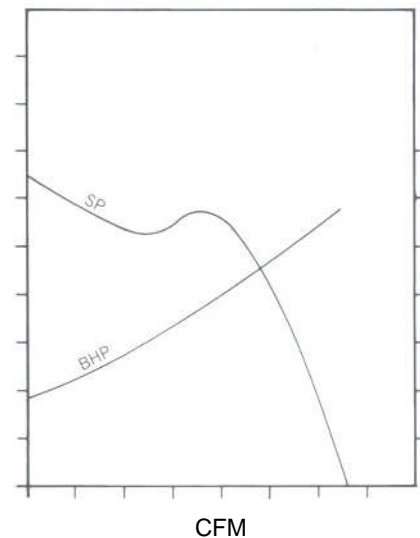


Figure 8 – Typical Radial-Tip Fan Performance Curve

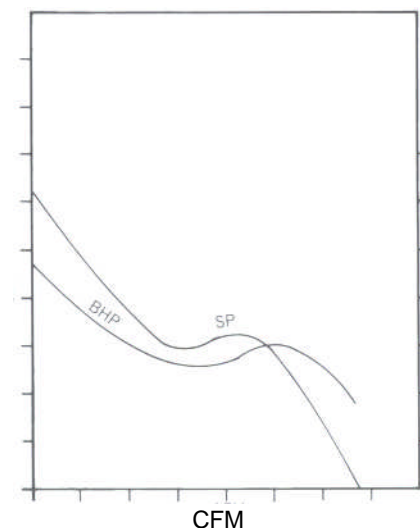


Figure 9 – Typical Axial Fan Performance Curve