The Static Pressure Paradox

An important consideration during fan selection

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Usually, facility managers don't get much "static" about static pressure—that is, until an air handler fails to meet design airflow. Whenever these problematic situations occur, both the "static" and "pressure" begin to rise. This article will briefly discuss static pressure issues that commonly surface during the design, selection and operation of air handlers.

THE DEBATE

Anyone who has ever designed an air handler knows that static pressure is required to select a fan and, ultimately, size the air tunnel. Often, common knowledge stops at this point, and a debate over the practice of specifying total static pressure (TSP) or external static pressure (ESP) arises. TSP is the pressure difference the fan must overcome, both negative pressure on the inlet and positive pressure on the outlet. It is the summation of both internal component pressure losses and external losses in the air-distribution system. ESP includes all dynamic pressure losses exterior to the air handling unit cabinet. The line between internal losses and ESP is occasionally blurred as some schedules and specifications include filter losses and other internal static pressure drops in the ESP.

Since air-handling-unit manufacturers regularly deal with some of the same internal components across many different air-unit designs and applications, HVAC system designers might be able to simplify their workload and focus on accurate calculation or estimation of ESP. A

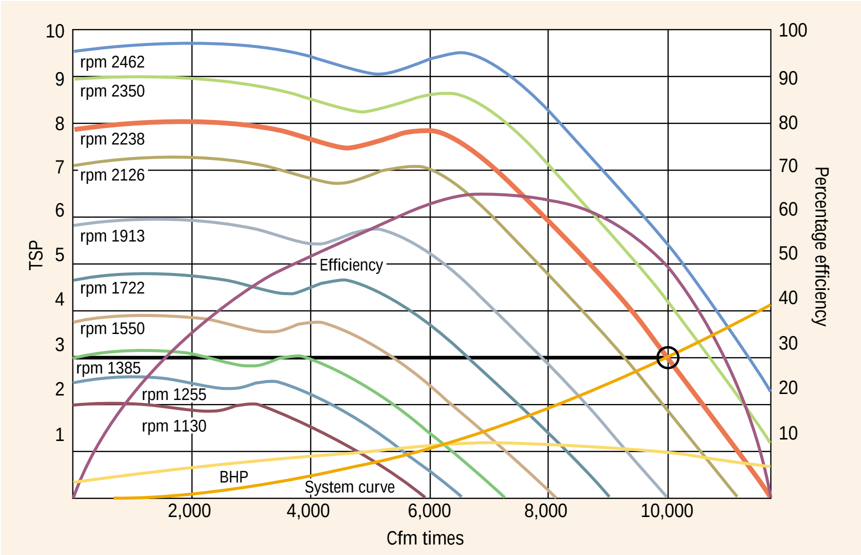

FIGURE 1. Fan point of operation. When the actual TSP is lower than the design TSP, the air-unit fan may be too small and too loud for the system. As shown, the fan will be operating too far down its rpm curve.

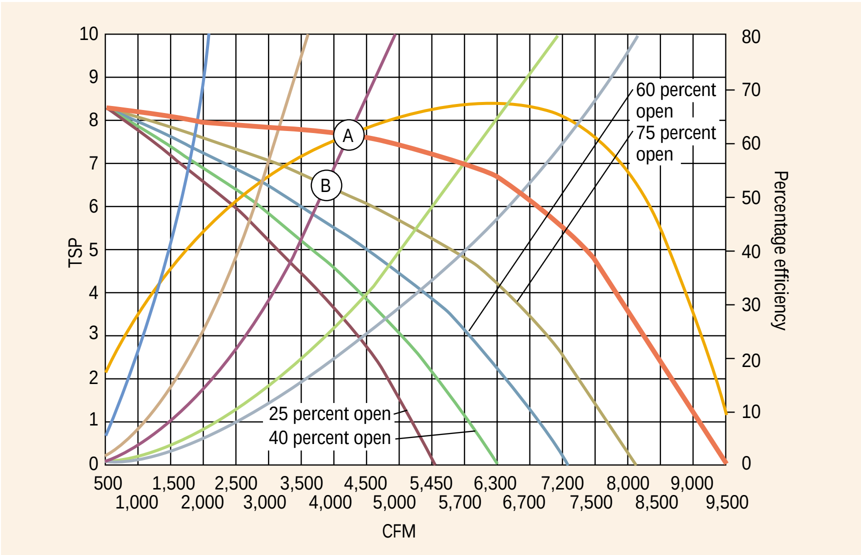

FIGURE 2. By using a cone, the fan characteristic curve slope increased and allowed the system curve to shift from Point A to a more stable operating Point B.

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common practice in our industry is adding a "safety factor" to the pressure-loss estimates. If designing mechanical systems subject to static and dynamic loading, this may be a good practice, but it can prove disastrous when selecting fans for an air handler.

However, if the estimate for ESP is too low, the selected fan may be too large and because the actual TSP seen by the fan is higher than anticipated, it may become unstable and begin operating in a "rotating stall." When this happens, the fan, air unit and building will likely vibrate and generate unwanted noise (Figure 1).

SLOWING THE FAN

The price of variable-frequency drives (VFDs) have drastically been reduced over the last few years and are becoming commonly specified items. Some believe that by applying VFDs to the supply and/or return fans in a system, they will be able to overcome the operating problems discussed above. Nothing could be more inaccurate. Just like changing the speed or power setting of an airplane does not avoid a stall, changing the speed of a fan does not change an unstable operating point or system characteristic. In Figure 3, if the fan was found to be operating left of the peak mechanical efficiency curve (Point A), changing the speed with the VFD (Point B) would not change this relationship. On System 2, the fan would be unstable at both operating points; slowing it down would not help.

CHANGING THE FAN CHARACTERISTICS

If changing the speed of the fan will not theoretically correct unstable operation, how can a proper fan be selected for buildings with VAV systems that change their system curve? Or, if my initial fan pick is either unstable or too loud (inefficient), how can I find a selection that works? These situations can be addressed by changing the shape of the fan's operating (rpm) curve using inlet guide vanes, partial-width wheels, or variable-cone devices. Remember, however, that inlet devices can affect the inlet-flow conditions and add static-pressure loss to the system. Therefore, the best way to avoid unstable fan operation is to pay particular attention when calculating ESP, avoid the liberal use of "safety factors," and select the proper fan to begin with.

Inlet vanes have been available for many years and appear not only on centrifugal fans, but also on centrifugal pumps. Inlet vanes are capable of changing the shape of a fan's constant-rpm performance curve by changing the flow of air into the fan, introducing a swirl rotating in the same direction as the fan impeller. While inlet vanes do provide a means of correcting an unstable operating point, they are not without a cost. Vanes remove energy from the system in the form of static pressure drop. AMCA publication 201-90, *Fans and Systems*, provides the ability to estimate this system effect on a generic wide-open inlet vane using Figure 7-1 and a calculated inlet velocity. Since vanes introduce turbulence at the inlet of the fan, they additionally have an unwanted side effect on some applications: noise.

If your application requires a direct-drive fan or a fan specifically tuned to the HVAC system, partial-width wheels may be the answer to potential instability. Partial-width wheels, compared to full-width, have steeper cfm-vs.-TSP curves. With this shape, the unstable operating point may land to the right of peak mechanical efficiency.

Finally, cones or disks mounted inside the fan wheel offer another means of changing the fan characteristic cfm-vs.-TSP curve. By effectively changing the wheel width on the fly, a new cfm-vs.-TSP performance characteristic can be developed.

Variable-cone devices, while used in some VAV applications, are very well-suited for redundant fan applications where the backup fan must be shut off to avoid short-circuiting of air through its inlet. The cone can simply be closed on the non-operating fan. The operation of both variable cone and inlet vanes is best seen in Figure 2. By moving the cone to a 75-percent open position, the fan characteristic curve slope increased and allowed the system curve to shift from Point A to a more stable operating Point B.

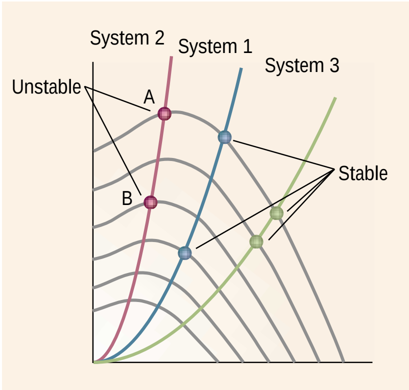

FIGURE 3. Changing the speed of a fan does not change an unstable operating point or system characteristic.

SUMMARY

Total static pressure is a critical design parameter for properly selecting fans and air handlers. Because air-handling-unit manufacturers deal with some of the same internal components, they are well-suited to estimate internal static-pressure losses. Accurate estimation of ESP, combined with these internal static losses, will assure fans are selected near their peak efficiency in a stable operating range. VFDs are an excellent choice for most VAV applications, but simply reducing the fan speed with a VFD does not guarantee the elimination of instability, vibration and noise.

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