Pressure Losses from Fan Accessories

For a fan in a system to perform as rated in a catalog, it is necessary for the system to be constructed in such a way that the airflow pathways into and out of the fan are similar to the conditions present during the tests performed to develop the fan's ratings. Usually, this means that the fan's inlet and outlet are free from immediate obstructions and there are no bends in the ductwork close to the fan. Due to accessory requirements or space limitations, this may not be possible. In such cases, the effect of accessories and/or ducting conditions must be taken into account during fan selection to get the airflow desired. This newsletter will cover the effect of accessories/appurtenances added to a fan system.

Performance losses are usually represented in units of pressure. Performance loss values indicate how much a fan's static pressure needs to increase in order to achieve the same flow at the system's point of rating with the addition of the appurtenance. Typically, the magnitude of the performance loss is calculated as a function of the velocity pressure at the appurtenance.

Velocity pressure is proportional to the air stream density and the square of the air stream velocity. Consider a system with two locations A & B. If the velocity of the air stream at point B is double the velocity at point A, any appurtenance placed into the air stream at point B will have four times the loss than if the appurtenance is placed at point A. Appurtenances placed in the throat of a fan's inlet (where the velocities are usually much greater than the ductwork) can have a considerable impact on the fan's performance.

Formulae for calculating performance losses may be available from the fan/accessory manufacturer or the loss can be estimated using one of many available references (e.g. *AMCA Publication 201 — Fans and Systems*).

Screens, Dampers, Stack Caps and Hoods

These appurtenances place a system resistance on the airflow. The function for the magnitude of the performance loss is typically:

Loss = k x Pv = k x (flow rate / flow area)^2 x density – converted to units of pressure.

Pv is the velocity pressure of the air stream at the appurtenance and k is a constant value for the given appurtenance. A screen with a fine mesh will have a higher value for k than a screen with a loose mesh. The value of k for a fan exhaust or supply hood is typically much greater than k for a stack cap, which has straight through flow. The value for k for a filtered hood would be even higher.

Evasé or Outlet Transitions

These appurtenances change the velocity of the air stream by changing the cross sectional area of the ductwork. When air stream velocity changes, velocity pressure is converted to static pressure (or vice-versa). The formula for the losses for changes in area is:

Loss = -1 x k x dPv

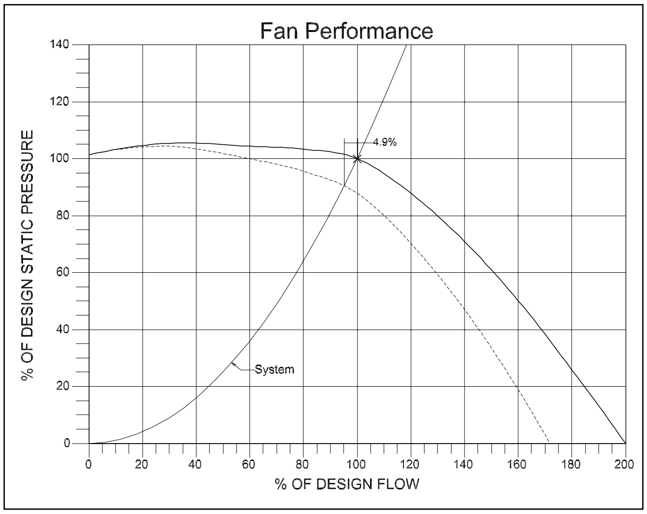
dPv is the change in the air stream velocity pressure and k is the efficiency of the transition. The value for dPv is positive when the air stream is slowed down (i.e. the cross sectional area of the ductwork is increased) and negative when the velocity is increased. When the loss is negative (slowing down the air stream), the static pressure generated by the fan with the transition will be greater than the static pressure generated without the transition. The efficiency of the transition is dependent on its design. Long gradual transitions can have efficiencies around 85% while short abrupt transitions can have efficiencies less than 25%. Since the flow at the outlet is not uniform, regions of flow velocities well in excess of the averages exist. Converting this extra velocity pressure to static pressure can effectively raise the apparent efficiency to 100%.

Variable Inlet Vanes

When 100% open, variable inlet vanes cause a pressure loss proportional to the velocity pressure. When they are not 100% open, the effect of variable inlet vanes on performance is not so simple to predict. Inlet vanes produce a pre-spin in the air stream at the fan's inlet. The spin produced is in the same direction as the fan's impeller rotation. This has the effect of lowering the fan's static pressure (and thus the airflow through the system) as well as the power consumed by the fan. Typically, the effect of variable inlet vanes on fan performance is interpolated from a series of tests done at various vane settings. Variable inlet vanes are generally more efficient than dampers for regulating airflow because they decrease the power consumed by the fan as well as the flow.

Example of an Accessory Loss

In the graph below, the solid line represents the fan's catalog performance. The dotted line represents the fan's performance with some appurtenance added.



The addition of the appurtenance lowered the airflow produced by the fan by about 5% along the system curve. If the effect of the appurtenance was ignored during the fan's selection process, it would be necessary to increase the running speed of the fan, get a new impeller for the fan, or get a new fan to achieve 100% of the desired flow.

Notice that the intersection of the system curve with the corrected (dotted) fan curve occurs at about 91% of the design static pressure. If the fan selection software used to make the selection could not automatically correct for the appurtenance, the selection could be made at the required flow and at a static pressure 9% higher than desired. When the resulting performance is corrected for the appurtenance, the fan curve would pass through the desired flow and pressure.

For example, if the desired fan performance is 10,000 CFM and 10.0 in. w.g., we would have calculated a loss of 0.9 in. w.g. for the appurtenance. To select the correct fan, we would enter 10,000 CFM and 10.9 in. w.g. into the selection program. When the results of the selection are corrected for the appurtenance, the fan's corrected performance curve will pass through 10,000 CFM at 10.0 in. w.g. The uncorrected fan curve will show 10.9 in. w.g. at the design flow even though only 10.0 in. w.g. will be measured in the installed system.

Reminders

1) Fan performance is usually published with disclaimers indicating any appurtenances in the air stream present when the ratings were developed. If the ratings were developed with a stack cap present, do not correct the performance for the stack cap. If the ratings were developed with an evase', correct the performance if the evase' is not used.

2) Losses must be calculated at the same density as the point of rating.

3) Expanding transitions in the ductwork have a negative loss (which is a gain). The corrected fan curve after adding an expanding transition will be above the uncorrected fan curve. If the selection program does not allow for correction to an expanding area, the static pressure entered into the program will be lower than the desired static pressure. Once corrected, the result for the addition of the transition (subtracting a negative loss value) will pass through the desired point of operation.

4) Failure to account for the effects of appurtenances in the air stream could require significant changes to achieve the desired airflow.

   - Belt driven fans may be able to achieve the desired performance by increasing the speed of the fan. Before selecting/adjusting sheaves, it will be necessary to check that the impeller, shaft, bearings and motor can handle the new speed and power requirements.
   - Direct drive fans may be able to achieve the desired performance by using a higher pitch impeller (axial fans) or an over width/diameter impeller design (centrifugal fans). If the direct drive fan is attached to an inverter, speeding up the fan may be possible. Again, it will be necessary to check that the impeller and motor can handle the requirements.
   - It may become necessary to select an entirely new fan to meet the requirements.

Conclusion

AMCA Publication 201 — Fans and Systems is an excellent reference for fan performance in a system. This publication covers such topics as fan ratings, fan laws, fan/system interaction and system effects (the accessories covered in this newsletter are considered a system effect). Formula and charts are included for estimating values for losses due to accessories. This publication also covers losses due to ducting conditions, which are not covered in this newsletter.

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