Smart Energy: Finding Gold in the Air Power Equation

You can reduce energy costs for ventilation and emission control systems with careful attention to volumetric flow rate, pressure, density, and fan efficiency. Here's how to meet the challenge...

QUOTE:'More than 40 percent of the energy consumed in most manufacturing plants is used to power fans, pumps, and ventilators'Well-designed air handling systems can have a significant impact on electrical operating costs.WITH IMAGE ci71trend02b***These inefficient short-radius elbows and fan system effects can mean $6,500 in wasted power.***WITH IMAGE ci71trend02c***Proper fan selection is key. The three improper matches above show wasted power and unsatisfactory performance.***
By Gerry Lanham, P.E.

The mathematics for properly designing ventilation and emission control systems have been around for quite a while, but studies of hundreds of systems show that many are wasting energy while still lacking the capacity to meet applicable codes and process objectives.
There is a lot of money on the table in operating costs for these systems. More than 40 percent of the energy consumed in most manufacturing plants is used to power fans, pumps, and ventilators. In some cases, the annual operating costs of a system may actually exceed the initial capital cost within two years of installation.
Opportunities for improvement reside in the air power equation.
Power required for an air handling system is computed with the following factors:
1. Volumetric Flow Rate "Q", stated in ft^3/min (cubic feet per minute)
2. Total Pressure (resistance due to friction in ducts, hoods, and ΔP of control device, etc.) "TP" stated in inches of water (in. H_20)
3. Density factor of the gas being collected "df" (dimensionless)
4. Efficiency of the fan, "η" (dimensionless)
These are combined into the air power equation:
Power (horsepower) = (Q) (TP) (df)(η)(6356) Small reductions in the numerator can have a significant cost impact. For example, a typical 20,000 CFM with a baghouse requires 60 or more horsepower for operation. A reduction of 1,000 CFM with improved hood design, or reduction of 1 inch static pressure with an improved duct or baghouse system, can save as much as $4,000 per year.
There are always limits on what can be done, however. The process may require a certain airflow or hooding arrangement, and that will dictate air volume. Adjustments to system pressure and fan efficiency may be better places to effect reductions.
System pressure is usually affected by two factors:
One is hood and duct resistance as a function of velocities in the system and the inefficiencies of flow (poorly designed hoods, short radius elbows, branch entry

angles greater than 45 degrees, abrupt contractions, and elbows and other interferences at fan inlets and outlets &#151 called fan system effects, etc.)
The other is resistance across the emissions control device. A baghouse that operates at a pressure drop of 8 in. H_2O will require twice the power of a collector operating at 4 in. H_2O. However, the lower pressure drop collector may not provide the capture efficiency of the baghouse with higher pressure drop. Of course, you can lower the pressure drop in a baghouse by adding filter area, but this means a larger housing. More important, baghouses often perform best at high pressure drops. The key is to minimize pressure drop while still meeting emission requirements. Excess static pressure just wastes power.
Here are some tips to help find that narrow range of safe and efficient operation.

1. Minimize Flow

Systems directly connected to a process source are inherently volume-limited while systems that capture emissions with enclosures or hoods need to be optimized during the design process. Total enclosure of an emission source minimizes airflow and worker exposure. However, such enclosures can restrict visual observation of the process and hinder maintenance access. Hoods that cannot be designed for total enclosure should be located as close to the source as possible. A side draft hood located twice the distance from the source can require as much as four times the exhaust volumetric flow rate as a total enclosure. Capture hoods for high-velocity emission (from grinding, sawing, etc.) must be located so that the opening is in the direct path of the dust, fume, or mist. ACGIH's "Industrial Ventilation &#151 A Manual of Recommended Practice" provides guidelines for good design of hoods, duct, and similar equipment. Because other factors, such as explosive limits for the gas being collected, moisture content (dew point), and heat content, may influence the air volumetric flow rate requirements, there may be limits to the optimization.

2. Minimize Pressure

Pressure offers greater opportunities to reduce energy costs. A system with good airflow characteristics (duct velocities and sizes optimized), matched with the proper control device, pressure monitors, and variable frequency drives, can help manage system pressure. Most baghouses or other collection devices will have varying pressure drops over the life of the system. Bags are generally more efficient at higher pressure drop but then use more energy. Scrubbers, oxidizers, and electrostatic precipitators tend to operate at more constant resistance. A good pressure monitoring system that controls system volumetric flow rate can save thousands of dollars every year on the operation of even medium sized systems. Since variable frequency drives are becoming less expensive, they are found on many installations, especially systems of more than 10,000 CFM. Be mindful of duct inefficiencies and fan system effects (elbows at inlets and outlets, etc.) because these shortcuts increase static pressure and operating costs for the life of the system.

3. Control Density Temperature, moisture, molecular weight, elevation, and absolute pressure in the duct or vessel affect the density of the transporting gas. A density change may affect the hardware requirements for the system. Evaporative cooling, for example, reduces volume, but the higher density air requires more power. This may be more than offset by reduced costs for smaller ducts, control devices, and fans (as well as lower the value for volumetric flow rate in the equation). Cooler temperatures may also allow use of less expensive collectors,

fans, and peripheral devices.
4. Fan Efficiency The design of the fan and its blade type can greatly affect efficiency and power requirements. Laboratory-measured peak fan efficiency may not be the most stable point of operation. If peak efficiency coincides with the peak of the pressure curve, then there may be operational problems as volumetric flow rates vary with small changes in system pressure. The designer must consider both curves when selecting the best fan and operating point to optimize reliability and power usage. And, fan type may dictate proper selection. Airfoil wheels, though more efficient, may not be a good choice when handling particulate-laden air. The key to any design is proper fan selection.

Gerry Lanham, P.E., is the president of KBD/Technic Inc., 3131 Disney St., Cincinnati, OH 45209. He has more than 40 years of experience with dust control and industrial ventilation systems. More information is available by calling 513-351-6200.
SIDEBAR:

Additional Advice

In addition to exploring the air power equation, here are areas to focus on when studying new projects or system alterations.
&#149 Protect worker and public health by meeting local/national standards for in-plant air and exhaust.
&#149 Provide an efficient connection to the process through proper hood design or direct connection to the process while considering safety for fire, explosion, and process reactions as well as the ergonomics of process access.
&#149 Minimize auxiliary costs (compressed air, natural gas, water, etc.)
&#149 Minimize replacement costs (filter bags, neutralizing chemicals, etc.)
&#149 Provide an easily maintained and accessible system.
&#149 Make the system simple to operate and train personnel to ensure ongoing performance.
&#149 Look for opportunities to recycle tempered air back to the plant or process by filtering exhaust through redundant systems.