

# There's **Gold** in the

## How to Reduce Energy Costs for Ventilation and Emission Control Systems with Careful Attention to Four Factors

by **Gerry Lanham**

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The mathematics for properly designing ventilation and emission control systems have been around for quite a while, but studies of hundreds of systems suggest that many waste energy, while still lacking capacity to meet applicable codes and process objectives.

More than 40% 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. This represents a large part of the plant's operating costs in a given year and can have a significant impact on profits.

### The Air Power Equation

Opportunities for improvement reside in the air power equation, a simple mathematical representation of flow-through ventilation systems (measured in cubic feet per minute, or CFM), and the resistance

that these systems must overcome due to the lengths of duct, number of elbows, and installed air control devices such as scrubbers and baghouses.

The power required for an air handling system is computed using the following factors:

1. Volumetric flow rate  $Q$ , stated in ft<sup>3</sup>/min (CFM);
2. Total pressure  $TP$  (i.e., resistance due to friction in ducts, hoods, and control devices), stated in inches of water (H<sub>2</sub>O);
3. Density factor of the gas being collected  $df$  (dimensionless); and
4. Efficiency of the fan,  $\eta$  (dimensionless).

These are combined to form the air power equation:

$$\text{Power (hp)} = \frac{(Q)(TP)(df)}{(\eta)(6356)} \quad (1)$$

# Air Power Equation

Even small reductions in the numerator can have a significant impact on costs. For example, a typical 20,000 CFM baghouse requires 60 hp or more for operation. A reduction of 1000 CFM with improved hood design, or a reduction of 1-in static pressure with an improved duct or baghouse system, can save as much as US\$4000 per year.

There are always limits on what can be done, however. The process may require certain airflow or hooding arrangements that will dictate air volume. Adjustments to system pressure and fan efficiency may offer better reductions.

System pressure is typically affected by two factors: hood and duct resistance, as a function of velocities in the system and the inefficiencies of airflow (e.g., poorly designed hoods, short radius elbows, branch entry angles greater than 45°, abrupt contractions, and elbows and other interferences at fan inlets and outlets—called fan system effects); and resistance across the emission control device.

For example, a baghouse that operates at a pressure drop of 8-in H<sub>2</sub>O will require twice the power of a collector operating at 4-in H<sub>2</sub>O (see Table 1). 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 a filter area, but this requires 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.

**Table 1.** Electrical costs for ventilation systems (\$/hp).

Utility Rate	.02/kWh	.04/kWh	.06/kWh	.08/kWh	.10/kWh	.12/kWh	.14/kWh	.16/kWh	.18/kWh
1 hr	.017	.035	.053	.07	.088	.105	.123	.141	.158
24 hr	.42	.84	1.26	1.68	2.10	2.52	2.94	3.36	3.78
1 yr	154	308	464	613	770	920	1078	1235	1385

## Energy Saving Tips

Below are four 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, whereas 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. For example, 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 emissions (e.g., from grinding and sawing) must be located so the opening is in the direct path of the dust, fume, or mist. The American Conference of Governmental Industrial Hygienists publication *Industrial Ventilation—A Manual of Recommended Practice* provides guidelines for good design of hoods, duct, and similar exhaust equipment (see [www.acgih.org](http://www.acgih.org)).

Other factors such as explosive limits for the gas being collected, moisture content (i.e., dew point), and heat content may influence the air volumetric flow rate requirements, so there may be limits to the optimization.



Excess static pressure just wastes power.

## In Addition to Energy...

Before thinking about the air power equation, here are a few design goals for any team studying new projects or system alterations.

1. Protect worker and public health by meeting local/national standards for in-plant air and exhaust.
2. 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.
3. Minimize auxiliary costs (e.g., compressed air, natural gas, water).
4. Minimize replacement costs (e.g., filter bags, neutralizing chemicals).
5. Provide an easily maintained and accessible system.
6. Make the system simple to operate and train personnel to ensure ongoing performance.
7. Look for opportunities to recycle tempered air back to the plant or process by filtering exhaust through redundant systems.

The design of the fan and its blade type can greatly affect energy efficiency and power requirements.

### 2. Minimize Pressure

Pressure offers greater opportunities to reduce energy costs. A system with good airflow characteristics (i.e., 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. Baghouses are generally more efficient at higher pressure drop, but 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 each year on the operation of even medium-size systems. As variable frequency drives become less expensive, they are now being found on many installations, especially systems of over 10,000 CFM.



**Figure 1.** Example, ducts, short-radius elbows, and fan system effects that add to energy costs.

Be mindful of duct inefficiencies and fan system effects. These shortcuts increase static pressure and operating costs for the life of the system. Figure 1 shows an example of short-radius elbows and fan system effects that could add up to US\$6500 per year in wasted power.

### 3. Control Density

Temperature, moisture, molecular weight, elevation, and the 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. For example, evaporative cooling 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 air power 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 energy 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 even small changes in system pressure. The designer must consider both curves when selecting the best fan and operating point to optimize reliability and power

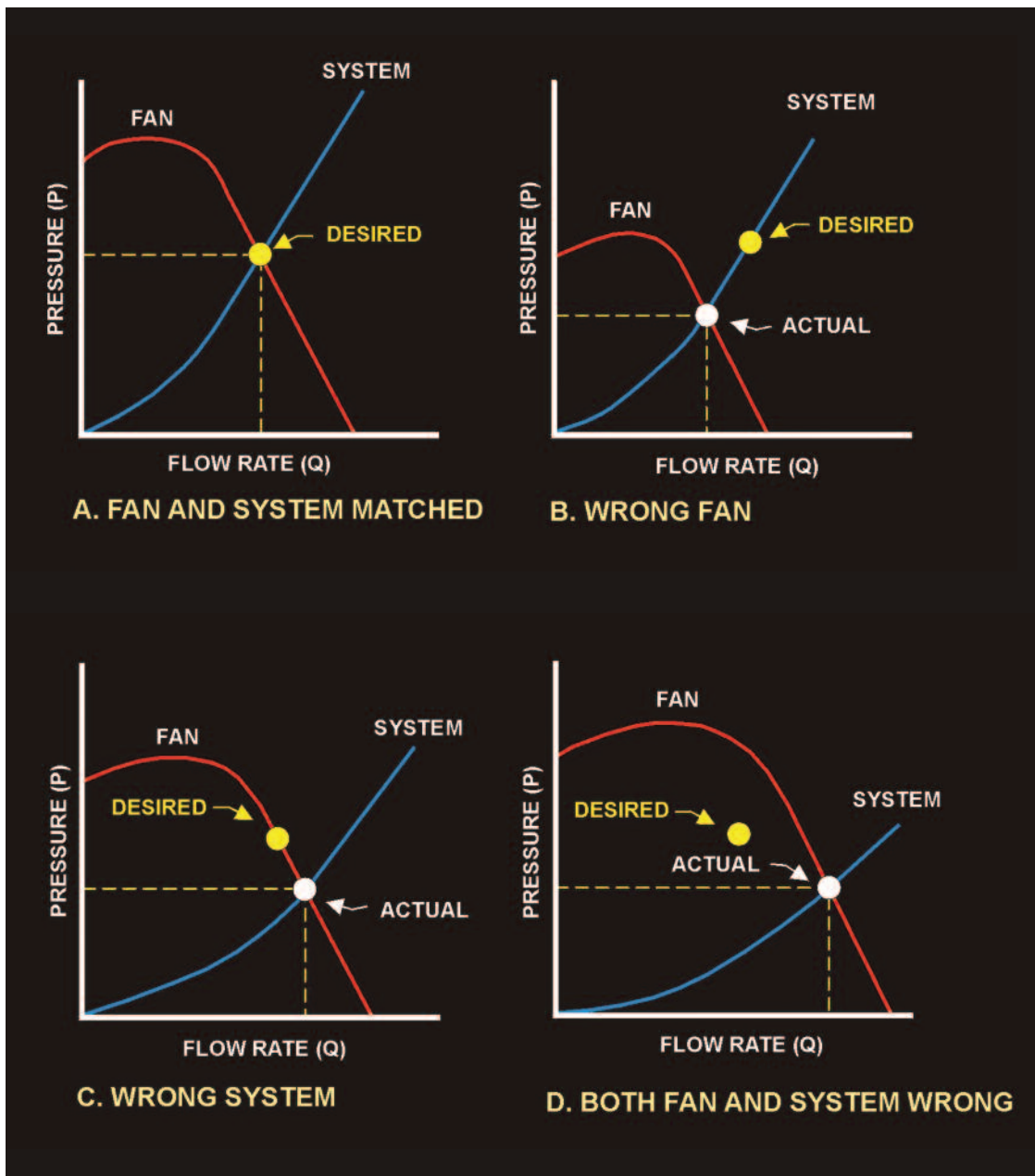


Figure 2. The importance of matching the fan to the air handling system for optimum efficiency.

usage. And fan type may dictate proper selection. For example, airfoil wheels, while more energy efficient, may not be a good choice when handling particulate-laden air.

The key to any design is proper fan selection. Figure 2 illustrates the importance of matching the fan to the air handling system to avoid wasting power and producing unsatisfactory system performance.

### Summary

The air power equation identifies four main areas—volumetric flow rate, pressure, density, and fan efficiency—that affect energy consumption. The challenge for industry is to operate in the narrow functional range that guarantees system effectiveness with minimum energy consumption. Attention to the air power equation can help meet those goals. **em**