

SYSTEM CALCULATION

INTRODUCTION

A fan system is any combination of ductwork, hoods, filters, louvers, collectors, etc., that relies upon a fan to produce airflow. When the air moves past each of these components, resistance is created which must be considered in system calculations. It is also important to remember that fans are rated independently of a system and that fan performance will vary depending upon the accuracy of the system calculations. This Engineering Letter will explain some of the basic fundamentals of system design and calculation.

SYSTEM DESIGN

The purpose of the system will dictate the design criteria to be used. Generally they will fall into one of the following two categories:

Velocity is typically the primary consideration in dust collection, dilute pneumatic conveying, fume removal, and contaminant applications. In these applications, a capture velocity is required to redirect the flow of airborne materials into the duct system. In addition, a minimum conveying velocity is necessary to maintain the flow of the materials within the system.

Given these velocity requirements, system components can be selected to maintain the appropriate air volume and required velocity through the system.

Air Mass is the primary consideration in many drying, combustion process, and ventilating applications. These applications generally require a certain amount of air mass, usually measured in pounds of air, to support the application. Because fan manufacturers publish fan capacities in actual cubic feet per minute (ACFM), the mass of air required must be converted from standard cubic feet per minute (SCFM) to ACFM.

The velocity through a system can be determined once the ACFM is known. The relationship between velocity and airflow is defined by the equation:

$$Q = VA$$

where: $Q = \text{ACFM}$

$V = \text{velocity in lineal feet per minute}$

$A = \text{cross-sectional area in square feet}$

To determine the airflow requirement, the cross-sectional area is multiplied by the required velocity.

System design is really a matter of defining the required work in terms of volume or velocity and then sizing and selecting the necessary system components to accomplish that work. Of course, this must be done within the economic and space constraints of the installation.

DETERMINING SYSTEM RESISTANCE

System resistance is the sum of the resistance through each component within the system. The system depicted in Figure 1 may appear complex, but dealing with each component separately provides an orderly process for determining the overall resistance.

HOOD LOSS

To determine hood or entrance losses, resistance calculations must be made for both the acceleration loss and the entry loss.

Since the air or atmosphere surrounding the hood must be accelerated from a state of rest, energy will be required to set the air in motion. This energy is equal to the velocity pressure at the entrance to the duct. Assuming the hood in this example empties into a 7" diameter duct, the required 1165 ACFM results in a velocity of 4363 FPM:

$$V = Q \div A$$

where: $Q = 1165 \text{ CFM}$

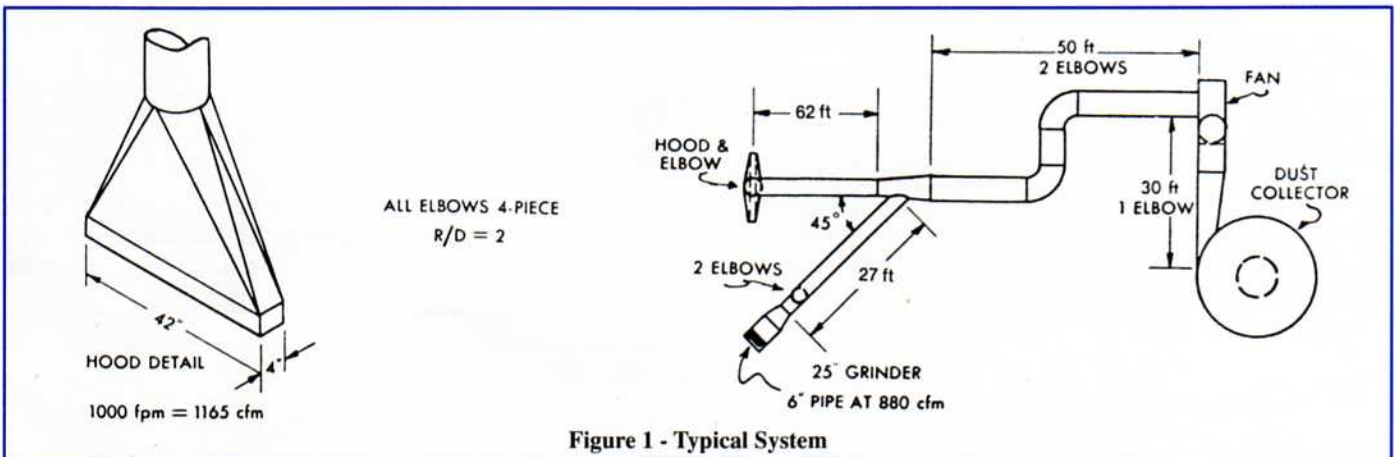


Figure 1 - Typical System

$$A = \frac{(3.5 \text{ in. radius})^2 \times 3.1416}{144 \text{ in.}^2 / \text{ft.}^2} = .267 \text{ ft.}^2$$

therefore: $V = 1165 \text{ CFM} \div .267 \text{ ft.}^2 = 4363 \text{ FPM}$

The velocity pressure (VP) at 4363 FPM is calculated by:

$$VP = \left(\frac{\text{Velocity}}{4005} \right)^2$$

therefore: Acceleration Loss = $\left(\frac{4363}{4005} \right)^2 = 1.19'' \text{ W.G.}$

The same result can be obtained by interpolating from the data in Figure 2.

The entry loss of a hood is a function of its efficiency. The efficiencies of several common entry conditions are shown in Figure 3. The relative efficiencies are expressed as losses in percentage of the duct velocity pressure. Consequently, the lowest percentage is actually the most efficient.

Outlet Velocity	Velocity Pressure	Outlet Velocity	Velocity Pressure	Outlet Velocity	Velocity Pressure
800	.040	2800	.489	4600	1.32
1000	.063	3000	.560	4800	1.44
1200	.090	3200	.638	5000	1.56
1400	.122	3400	.721	5200	1.69
1600	.160	3600	.808	5400	1.82
1800	.202	3800	.900	5600	1.95
2000	.250	4000	.998	5800	2.10
2200	.302	4200	1.10	6000	2.24
2400	.360	4400	1.21	6200	2.40
2600	.422				

Figure 2 - Entrance Loss Percentage


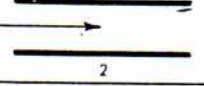
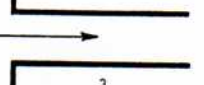
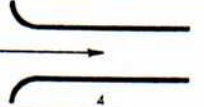
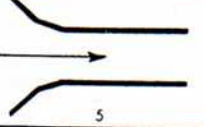
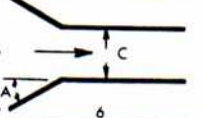
ILLUSTRATION 3 — PIPE ENTRANCE LOSSES	
ENTRY	LOSS IN % OF PIPE V. P.
	GRINDER HOOD 60%
	UNFLANGED PIPE 90%
	FLANGED PIPE 50%
	SMOOTH WELL-ROUNDED 3%
	FABRICATED WELL-SHAPED 5%
	"A" LESS THAN 45° % LOSS = 100% "B" V P 25% "C" V. P.

Figure 3 - Entrance Losses

The hood in this example is most similar to item 2 in Figure 3. Therefore, the entry loss from atmosphere into the hood is .90 x the entering air velocity pressure at 1000 feet per minute or:

$$\text{Entry Loss} = .90 \times \left(\frac{1000}{4005} \right)^2 = .06'' \text{ W.G.}$$

This loss could have been reduced to .5 VP by simply adding a flange to the bottom edge of the hood as indicated by item 3 in Figure 3.

The total hood loss in the example is the acceleration loss added to the entry loss:

$$\text{Hood loss} = .06'' + 1.19'' = 1.25'' \text{ W.G.}$$

PRIMARY BRANCH

The duct loss from the hood to the branch junction can be determined by using the equivalent length method. This run of duct includes 62' of 7" diameter duct and one 4 piece 90° elbow of R/D = 2. According to Figure 4, the elbow has a loss equal to 12 diameters of 7" duct, or 7'. Thus, the total equivalent length of straight duct is 69'.

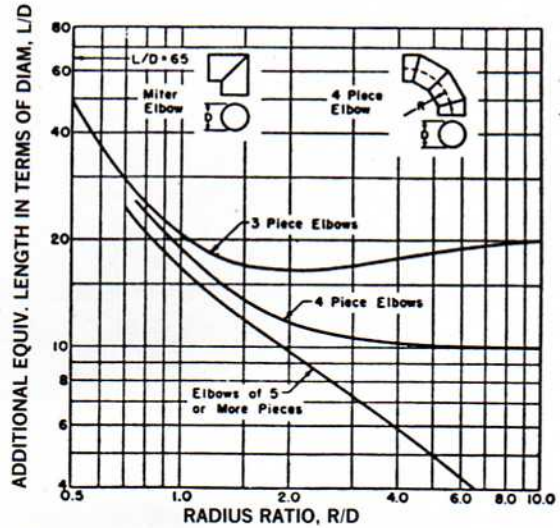


Figure 4 - Loss in 90° elbows of round cross-section

Chart I on page 4 indicates a 4.0" loss for every 100' of 7" diameter duct handling 1165 CFM. The loss for this run can be determined as:

$$\text{Duct Loss} = \left(\frac{69}{100} \right) \times 4.0 = 2.76'' \text{ W.G.}$$

Therefore, the total resistance of the hood branch to the junction is:

$$\text{Branch Loss} = 1.25'' + 2.76'' = 4.01'' \text{ W.G.}$$

SECONDARY BRANCH

A secondary branch is calculated in the same manner as the main branch. For example, a grinder hood handling 880 CFM through a 6" pipe results in a velocity of 4500 FPM, which has a 1.26" VP.

According to item 1 in Figure 3, a grinder hood has a .6 VP loss, so the total hood loss will be:

$$\text{Hood Loss} = 1.26'' + (.60 \times 1.26'') = 2.02'' \text{ W.G.}$$

