be used to straighten the flow of air from the outlet. Sometimes it is desirable to mount the outlet flush with the side of the duct, in which case the duct velocity should be kept below twice that of the outlet velocity, and even then an outlet larger than normally required should be used, as the entire outlet area will not be effective. Manufacturers' selection tables base sizing of outlets on required volume of air, temperature differential, and distance of throw or radius of diffusion. In following their recommendations, maxima should be avoided. See Chapter 30 for a discussion of air outlets.

DESIGN METHODS

The design of the air transmission system is generally the last step in the design of the heating, ventilating or air conditioning system, but it should always be kept in mind that the type of air transmission used will, to some extent, depend on the type of equipment used, as well as on the purpose of the system. Various factors such as zoning and zone control, and their influence on the transmission and air distribution system, are briefly discussed in Chapter 29 (Central Systems for Air Conditioning).

The methods used for the design of duct systems reflect, to some degree, certain developments in the arts of heating, ventilating and air conditioning, and it took a long time before empirical methods gave way to more refined and scientific calculations. Some engineers prefer speed and simplicity to scientific exactness, but experience is then needed and proper judgment must be exerted to prevent mistakes. Both the *Velocity Reduction Method* and the *Equal Friction Method* take no account of the static regain resulting from the difference between the velocity of fan discharge and velocities of pipe discharge, and are therefore, to some degree, approximate methods. However, they are more easily applied than the static regain method which is based on proper theory, *but is subject to an assumption (based on tests) regarding the efficiency of conversion from kinetic energy to static regain.*

1. Velocity Reduction Method

When this method is used, arbitrary velocities for the various sections of the ducts are selected, with the highest velocity at the fan outlet, and lower velocities down the run as various branch ducts are taken off the main duct. As the quantities of air that are to be delivered through each section of the duct are known, the area of each duct section can be easily determined by using the formula:

$$A = \frac{Q_a}{V_m} \tag{17}$$

where

A = duct area in square feet.

Q_a = air quantity in cubic feet per minute.

V_m = air velocity in feet per minute.

To find the total static pressure against which the fan must operate, the static pressure loss of each section is calculated separately, and the total loss found by adding the individual losses of the sections of the duct which has the highest resistance. This may be the duct with the longest run, but not necessarily so.

The velocity method has the advantage that the duct area can be determined very easily. It should be used only for simple layouts. The air velocities given earlier in this chapter are helpful in choosing proper velocities. Balancing is obtained by use of dampers. The method is illustrated in *Example* 3.

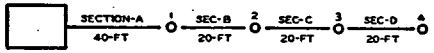


FIG. 8. DUCT LAYOUT FOR EXAMPLE 3

Example 3. (Velocity Reduction Method). A duct layout is shown in Fig. 8. The fan delivers 8000 cfm. Four outlets deliver 2000 cfm each. Find duct dimensions and total pressure loss.

Solution. Select velocity for Section A (2200 fpm) and reduce velocity arbitrarily along run. Find duct areas by using Equation 17. For selection of circular equivalents of rectangular ducts refer to Table 2, and for determination of friction loss in duct refer to Fig. 2 (See *Example 1*). Results are tabulated in Table 5.

TABLE 5. TABULATION OF RESULTS (EXAMPLE 3)

Section	Air Volume cfm	Velocity fpm	Area sq. ft.	Area sq. in.	Duct Size in.	Diam. in.	Fricт. per 100 ft. in. H_2O	Fricт. Loss in. H_2O
A	8000	2200	3.64	524	26 x 20	24.8	0.25	0.10
B	6000	2000	3.00	432	22 x 20	22.9	0.23	0.05
C	4000	1800	2.22	320	20 x 16	19.5	0.24	0.05
D	2000	1600	1.25	180	12 x 16	15.1	0.24	0.05
							Total resistance,	0.25

2. Equal Friction Method

When the equal friction method of design is used, the duct system is designed for equal friction per foot of length. This prevents one section of the duct from having an excessive resistance compared with another. The usual procedure in this method is to select the main duct velocity to be consistent with good practice from a standpoint of noise for a particular type of building. This velocity should be less than the fan outlet velocity. All ducts are then sized for equal friction per unit length by the use of Figs. 1 or 2 and Table 2. The equal friction method has the advantage of automatically reducing the velocities in the various sections of the system, and also of allowing a quick check of the total duct resistance.

In cases where the fan or factory assembled air conditioning unit can operate against only a limited external resistance, it is necessary to divide the permissible total resistance by the total *equivalent* length of the longest or most complicated run of duct to determine the design resistance per 100 ft, and then to size all ducts at this resistance value. This will automatically determine the duct velocities and give the desired total duct resistance. A further refinement, which is sometimes used in large systems, is to size each branch duct so that it has a resistance equal to the resistance of the main system at the point of juncture. Even when this refinement is added, regulating dampers are recommended in each branch.

Example 4. (Equal Friction Method). A duct layout is shown in Fig. 9. The fan delivers 2500 cfm. Outlets No. 1 and 2 deliver 750 cfm each and outlet No. 3 delivers 1000 cfm. Trunk velocity is assumed as 1500 fpm; the area will be 1.67 sq ft (240 sq in.); and the size will be 20 x 12 in. Determine sizes of ducts for sections B, C, D and E and find the total pressure loss.