

Fig. 12 Duct Layout for Example 6

The principal limitation of the *equal-friction* method is that it does not differentiate between runs having several transitions, elbows, etc., and runs having none. Only the *actual length* of duct is considered; this and the flow rate fix the duct size. Moreover, when computing the system resistance, the designer must be sure that the pressure losses of transitions, elbows, etc., are included and added to the straight pipe losses.

If the pressure available for the ductwork is known, as it is for packaged equipment, this pressure can be divided by the total equivalent length of the run apparently having the highest resistance, to obtain a design friction loss value per foot, for use with Fig. 2 or 3. Hence, for these applications, it is not necessary to select an initial velocity. However, the weakness of this method is that the resistances of fittings must be expressed in terms of *equivalent length*. Since transitions, elbows, etc., have predominantly dynamic losses, the equivalent length of a particular fitting varies considerably with its actual size. Note that, for example, the values for elbows in Fig. 7, Chapter 7 of the 1964 GUIDE AND DATA BOOK are related to duct size, and note also that the elbow losses in Fig. 9 of this chapter are given in terms of the number of *diameters*. Hence, when the available pressure is known, the method requires that the duct size be estimated in advance. The calculated duct size should therefore be compared with the initial estimate, and if there is a considerable difference, a recalculation should be made using the calculated size.

Less dampening is required if the method is modified so that only the main duct is sized by the equal-friction method. The fan is selected for this total duct resistance in the manner described for the *velocity-reduction* method. The pressure available at each branch is divided by its equivalent length in hundreds of feet, to obtain a design friction loss value for use with Fig. 2 or Fig. 3, in conjunction with the branch flow rate. The branch ducts are sized as nearly as possible to dissipate all of the available pressure.

When this method is used care should be exercised to prevent velocities in short branches from becoming excessive, to avoid noise problems. This is easily prevented during the design process, because the velocity can be read directly from the friction chart. If velocity is excessive, read horizontally to the left and select a diameter which yields a lower velocity. The damper for this run will have to dissipate the excess pressure. Since ductwork attenuates noise to some extent, the damper should be located as close to the main as possible. Sound treatment for this branch should also be considered. An alternative solution may be to revise the duct layout to increase the resistance of the run, e.g., by relocating the branch take-off so that the total duct length is increased.

Table 7 Tabulation of Results (Example 6)

Section	Flow Rate Cfm	Friction per 100 ft in. H ₂ O	Duct Dia. in.	Velocity fpm	Rectangular Duct in.
A	2500	0.2	17.0	1600	20 × 12
B	1750	0.2	14.8	1480	15 × 12
C	1000	0.2	12.0	1290	15 × 8
D	750	0.2	10.7	1190	12 × 8
E	750	0.2	10.7	1190	12 × 8

Example 6: (Equal-Friction Method). A duct layout is shown in Fig. 12. Outlets Nos. 1 and 2 deliver 750 cfm each and outlet No. 3 delivers 1000 cfm. Having selected a velocity of 1600 fpm in Section A, size the duct system and determine its static-pressure requirement.

Solution: The total cfm to be handled is 2500 cfm. From Fig. 3, with 2500 cfm and 1600 fpm velocity, read a diameter of 17 in. and a friction loss of 0.2 in. of water per 100 ft. By subtraction, the flow rate in Section B is 1750 cfm. Along the 0.2 friction line in Fig. 3, all of the ducts can be sized immediately because the flow rates are known. Results are presented in Table 7.

The rectangular equivalents were selected from Table 2 with the objective of having the same duct depth for all branch runs.

The duct run to outlet No. 3 has the highest apparent resistance. It is decided to fabricate the elbow in Section C with a radius ratio of 1.2; hence, from Fig. 8 with $H/W = 1.9$, $L/W = 8$. Since $W = 1.25$ ft (15 in.), the additional equivalent length due to the elbow L is 10 ft. The total equivalent length of the run is therefore $(20 + 10 + 15 + 10 + 15) = 70$ ft. Therefore, at 0.2 per 100 ft, the duct resistance is $0.2 \times 70 = 0.14$ in. of water. Including the outlet pressure of 0.12 in., the static-pressure requirement of the duct system is 0.26 in. of water. The pressure requirement of the duct system will be relied upon for design is now complete, and dampers will be relied upon for adjusting the outlets to the design flow rates.

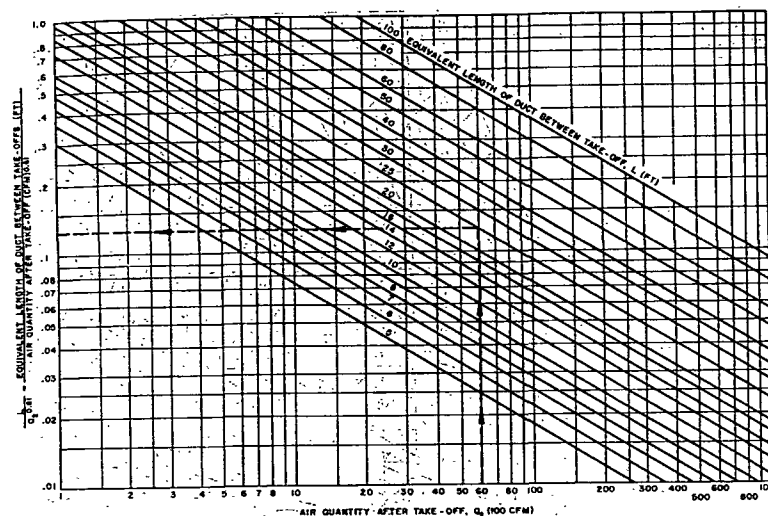
If refinement is necessary, the modified method can be applied to Sections D and E. First, the static pressures available at the junctions with the main of the Section D and E branch ducts are obtained. For Section D, it is the system pressure of 0.26 minus the friction pressure loss in Section A. The latter is $0.20 \times (20/100) = 0.04$; hence, the pressure at the entrance of Section B is 0.22 in. of water. The pressure available for the ductwork is $0.22 - 0.12$, or 0.10. Assume the equivalent length of the branch take-off and the elbow to be 10 ft each. The total equivalent length of Section D is then $(10 + 10 + 10 + 5) = 35$, and the friction loss per 100 ft required to dissipate 0.10 in. of water is $0.10 \times (100/35) = 0.29$. With this unit friction loss and a flow rate of 750 cfm, Fig. 2 yields a diameter of 10.0 in. and a velocity of 1380 fpm.

Section E is sized in a similar manner. The pressure available is 0.26 minus the friction loss in Sections A and B, or 0.20. With the outlet pressure loss of 0.12 deducted, the available ductwork pressure loss is 0.08 in. Assuming that the branch take-off loss is equivalent to 10 ft of duct, the total equivalent length is 20 ft. The required friction loss is $0.08 \times (100/20) = 0.40$. With this unit friction loss and a flow rate of 750 cfm, Fig. 2 yields a diameter of 9.4 in. and a velocity of 1680 fpm. An equivalent rectangular size is 9×8 in.

A comparison of these results with those in Table 7, shows that the modified method has reduced the size of Section D somewhat and that of Section E considerably. The reduced sizes accomplish more economically what would otherwise have to be done with dampers.

Static-Regain Method

Consider a straight run of duct with several branch take-offs attached. The flow rate of air along the run is progressively reduced by the amount diverted into each successive take-off. If, for example, the size of the run were the same throughout its length, the velocity would become progressively less in accordance with Equation 3. When velocities are reduced, a conversion of velocity pressure into static pressure occurs (as well as a loss in total pressure). The principle of the *static-regain* method is to size a duct run so



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Fig. 13 Chart for Determining Values of L/Q^2

that the increase in static pressure (regain) at each take-off junction just offsets the pressure loss of the succeeding section of the run.

The method provides a convenient means of designing a long run of duct having several take-offs so that essentially the same static pressure exists at the entrance to each branch, outlet, or terminal takeoff. As a consequence, outlet or terminal selection and system balancing is simplified. The method is particularly suited to large installations having several long runs of duct, with each run having many take-offs or supply outlets attached. For this type of application, little or no dampening is ordinarily required to balance the system.

If the distance between branch take-offs is either very small or very great, it may not be feasible or economically desirable to design for the same static pressure at each junction. In such cases, the method can be used to size the main for either a progressively lower static pressure (net static-pressure loss) or a progressively higher pressure (net static-pressure gain).

The duct length of any section should include the equivalent length of any elbows or transitions within the section. The charts apply to constructions where regain takes place unaccompanied by radical change in direction, namely, to *straight-through* sections of divided-flow fittings.

If no friction or dynamic losses occurred at the junction, there would be no loss in total pressure, and the change in velocity pressure would be completely converted into a regain (rise) in static pressure, which, for standard air, would be

$$P_1 = \left(\frac{V_1}{4005} \right)^2 - \left(\frac{V_2}{4005} \right)^2 \quad (12)$$

where

P_1 = theoretical static-pressure regain, inches of water.

V_1 = velocity in main upstream of branch, feet per minute.

V_2 = velocity in main downstream of branch, feet per minute.

4005 = conversion factor of velocity equivalent to 1 in. water pressure.

It has been found by test that the regain coefficient across a takeoff or an outlet will equal about 0.90 for well-designed and constructed ducts with no reducing section immediately after the outlet. However, for practical design, an average recovery of 0.75 is assumed. Hence the actual regain P_1 is:

$$P_1 = 0.75 \left[\left(\frac{V_1}{4005} \right)^2 - \left(\frac{V_2}{4005} \right)^2 \right] \quad (13)$$

In any duct section through which air is flowing there is a continuous loss of pressure due to friction. This pressure loss may be expressed as:

$$H_f = 0.0270 \left(\frac{L}{d^{1.33}} \right) \left(\frac{V_1}{1000} \right)^{1.83} \quad (14)$$

where

H_f = pressure loss, inches of water.

L = duct length, feet.

d = duct diameter, inches.