is required for symmetrical layouts in which all runs have about the same resistance. For layouts having both short and long runs, the shortest run will require considerable dampering.

Usual practice is to select the velocity in the main duct near the fan from the standpoint of noise for the particular application. Since the flow rate (cfm) is known, this establishes a value of friction loss per 100 ft of duct in Figs. 2 or 3. This same friction loss value is maintained throughout the design. For example, the flow rate in the main after the first branch take-off is reduced by that handled by the branch. Therefore, proceed vertically downward in Figs. 2 or 3 to the new flow rate value, and read the velocity and diameter. Note that the velocity is reduced by this procedure; a merit of this method is that it *automatically* reduces the duct velocities in

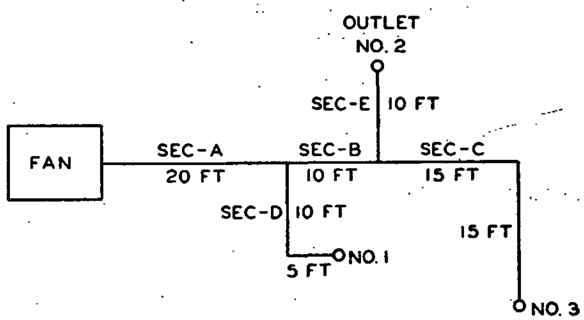

FIG. 12. DUCT LAYOUT FOR EXAMPLE 6

the direction of flow, thereby insuring that noise will not be a problem. The equivalent rectangular size of any diameter is obtained from Table 2. By continuing the procedure, all sections, including branch ducts, are sized from Figs. 2 and 3 at the same friction loss per foot of actual length.

After sizing the system the pressure loss of the run having apparently the highest resistance is calculated. In so doing, the pressure losses of all elbows and transitions are included, and are expressed in terms of *equivalent length* of straight pipe.

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, care must be exercised that the pressure losses of transitions, elbows, etc., are included and added to the straight pipe losses.

If the pressure available for the duct work 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 Fig. 3. Hence, for these applications, it is not necessary to select an initial velocity. However, the method then has the weakness 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, for example, the values for elbows in Fig. 7 of Chapter 19 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 considerably different, a recalculation should be made using the calculated size.

Less dampering 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 and the pressure available at each branch take-off is found 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 therefore sized as nearly as possible to dissipate all of the available pressure.

When using this modified method, care should be exercised that the velocities in short branches do not become excessive from a noise standpoint. This is easily guarded against during the design process, because the velocity can be read directly from the friction chart. If it is excessive, move horizontally to the left on the chart and select a diameter which yields a reasonable velocity. The damper for this run will have to dissipate the excess pressure. Since duct work 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, for example, by relocating the branch take-off so that the total duct length is increased.

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. Selecting a velocity of 1600 cfm 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 three 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 $0.2 \times 0.70 = 0.14$ in. of water. Adding to this the outlet pressure of 0.12 in., the static pressure requirement of the duct system is 0.26 in. of water. The design is now complete, and dampers will be relied upon for adjusting the outlets to the design flow rates.

If refinement is deemed 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. Deducting the outlet pressure loss of 0.12, that available for the duct work is 0.10. Assume the equivalent lengths 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; hence, 0.20. With the outlet pressure loss of 0.12