appreciable, as in elbows of good design, it is customary to include the dynamic loss with the friction loss, thereby facilitating design calculations.

PRESSURE LOSSES IN ELBOWS

It is convenient to express the combined dynamic and friction losses due to an elbow as equivalent to the loss in a length L of similar straight duct. A recent A.S.H.V.E. survey[9] of available data has indicated that this method of expressing the loss is justified for design purposes, owing to the relation of the loss to the corresponding friction factor, f.

Fig. 5 gives the *additional equivalent length* of duct in terms of widths W for elbows in rectangular ducts; Fig. 6 gives the equivalent length in terms

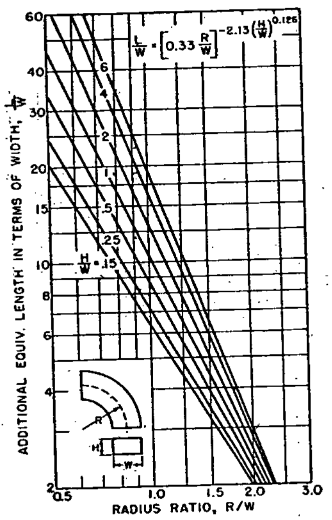

FIG. 5. LOSS IN 90-DEG ELBOWS OF RECTANGULAR CROSS-SECTION

of diameters D for round ducts. When these curves for *additional* equivalent length are used, the straight lengths of duct between elbows should be measured to the intersection of their center lines. The data of Figs. 5 and 6 may be readily converted[9] to the loss as a percentage of the velocity head.

Example 3: (Use of Fig. 5 for the calculation of elbow losses.)

Given the portion of a duct system shown in Fig. 7, it is required to determine the pressure loss between points A and D. Air at standard conditions is being supplied at the rate of 2000 cfm in a 6 by 24 in. galvanized duct of average construction. Elbows No. 1 and 2 have centerline radii of 18 and 9 in., respectively.

Solution: For elbow No. 1 the radius ratio is $\frac{R_1}{W_1} = \frac{18}{24} = 0.75$ and the aspect ratio is $\frac{H_1}{W_1} = \frac{6}{24} = 0.25$. The additional equivalent length for elbow No. 1 in terms of W is obtained from Fig. 5: $(L/W)_1 = 11.5$. Thus $L_1 = 11.5 \times 24/12 = 23$ additional equivalent feet. Similarly for elbow No. 2, the ratio radius is $\frac{R_2}{W_2} = \frac{9}{6} = 1.5$ and

the aspect ratio is $\frac{H_2}{W_2} = \frac{24}{6} = 4.0$; Fig. 5 gives $(L/W)_2 = 6$, so $L_2 = 6 \times 6/12 = 3$ additional equivalent feet.

The total length of the straight runs from A to D is $l = l_{A-B} + l_{B-C} + l_{C-D} = 7 + 20 + 5 = 32$ ft and the additional equivalent length due to the elbows is $L = L_1 + L_2 = 23 + 3 = 26$ ft. Thus the equivalent length of the system from A to D is $l + L = 32 + 26 = 58$ ft of 6 by 24 in. duct.

The diameter of a circular duct, equivalent in friction and capacity to this rectangular duct, is 12.4 in. as given by the table of circular equivalents, Table 2. At a delivery rate of 2000 cfm, the A.S.H.V.E. Friction Chart, Fig. 2, gives a loss of 0.6 in. of water per 100 ft of 12.4 in. diameter duct. Thus the loss from A to D is $0.6 \times 58/100 = 0.348$ in. of water.

The use of elbows of radius ratio, $R/W = 1.5$, is considered good practice with respect to both installation and operation. In a given rectangular duct 6 by 24 in., for example, the additional equivalent length L necessary to represent the elbow loss will generally be greater for a flat bend where the

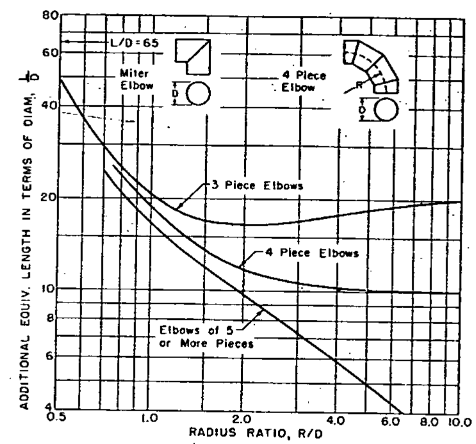

FIG. 6. LOSS IN 90-DEG ELBOWS OF ROUND CROSS-SECTION

aspect ratio, $H/W = 1/4$, than if the bend of the same radius ratio had been made in the plane of the narrow dimension giving an aspect ratio, $H/W = 4$.

Data presently available for losses in compound bends,[10, 11] where two or more elbows are close together, do not warrant refinement of design calculations beyond use of the sum of the additional equivalent lengths L for the individual elbows. Where angles of other than 90-deg bend are encountered, the loss may be considered as directly proportional to the angle of bend. Losses[11] for elbows discharging air directly into a large space are higher than those indicated in Figs. 5 and 6 for elbows within duct systems. Data[12] for losses at branch take-offs are at present quite meager. An A.S.H.V.E. cooperative investigation is underway for the purpose of obtaining more data on losses in typical take-off fittings.

Turning vanes may be advantageously employed in elbows, both to reduce the pressure loss and to provide a more uniform velocity distribution downstream from the bend. Vanes and concentric splitters are particularly recommended where miter elbows are used, because even the simplest vane