

less, customary to express the dynamic and friction losses in duct sections or elements in equivalent length of duct in feet, or in diameters to facilitate their computation as friction losses. Formulas have been developed for expressing these relations.⁸

PRESSURE LOSSES IN ELBOWS

It is convenient to express the dynamic and friction losses in elbows as equal to a number of diameters of round pipe, or a number of widths of rectangular pipe, or equivalent length of duct.⁹ The curves in Fig. 5 give the number of diameters or widths of pipe which have a frictional resistance equivalent to the pressure drop in the elbows. Curves *B* and *C* are based on tests of round and square elbows¹⁰ of ordinary good sheet metal construction.

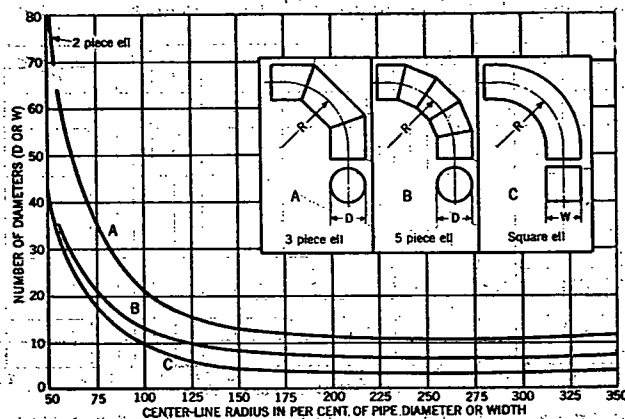


FIG. 5. LOSS OF PRESSURE IN ELBOWS

Values obtained from Curve *A* should be used when there is any doubt as to quality of duct construction. It is suggested that this curve be used for rectangular elbows and five-piece elbows, as it will thus allow an additional factor of safety without seriously affecting the design.

As indicated in Fig. 5, long radius elbows will offer much less resistance to the flow of air than short radius elbows. Experience has shown that good results may be expected when the radius to the center of the elbow is 1.5 times the pipe diameter or duct width parallel to the radius. Examination of Fig. 5 will indicate that little advantage is to be gained by selecting elbows having a centerline radius of more than two diameters.¹¹ Elbows having a radius of more than three diameters show a slightly increased resistance due to the increased length of pipe but, when used, they reduce the overall resistance of the system and therefore should not be avoided.

Where space conditions necessitate the use of short radius or miter elbows in square or rectangular duct work, turning vanes should be used to reduce the pressure losses. Rough or raw edges on the vanes should be avoided to prevent objectionable noise. Table 3 shows typical types of vanes and gives the resistance, expressed in equivalent length of straight pipe, for a 7-in. x 7-in. elbow of each type.

The pressure loss through elbows of less than 90 deg may be assumed to be directly proportional to the ratio of the angle through which the turn is made. The resistance will vary widely for the large degree turns depending upon the aspect ratio and the length of straight pipe between the elbows but, for practical purposes, it may be assumed that the ratio remains proportional to the angle through which the turn is made. Reverse 90 deg elbow turns should be avoided wherever possible but, where used, the friction indicated in Fig. 5 should be doubled for the second elbow. Additional tests are needed on the loss of pressure in elbows and other types of duct fittings in order to reconcile the difference between values shown in

TABLE 3. EFFECT OF VANES ON PRESSURE LOSS OF 7-INCH SQUARE VENTILATING Duct^a

Expressed in feet of total equivalent length of duct (ELD)

SQUARE MITER ELBOW								STANDARD ELBOWS WITH VARIOUS RADII							
	Radius Ratio R_1/W	0	2	4	6	8	1.0		Radius Ratio R_1/W	0	2	4	6	8	1.0
	ELD, ft	41.1	30.5	27.5	30.1	37.7	38.5		ELD, ft	39.7	23.3	22.0	25.7	28.9	39.7
	Radius Ratio R_1/W	0	2	3					Radius Ratio R_1/W	0	2	3	4	5	6
	Radius Ratio R_2/W	0	4	5					Radius Ratio R_2/W	0	4	5	6	7	8
	ELD, ft	41.1	23.5	23.3					ELD, ft	39.7	20.0	22.0	23.0	23.8	25.7
	Radius Ratio R_1/W	0	2	3					Radius Ratio R_1/W	0	4	6	8	1.0	1.1
	Radius Ratio R_2/W	0	4	5					Radius Ratio R_2/W	0	4	6	8	1.0	1.1
	Radius Ratio R_3/W	0	6	7					ELD, ft	25.3	17.7	16.5	18.7	23.5	25.7
	ELD, ft	41.1	20.7	22.2				1 1/2" L.R.							
	VANE	A	B	C	D				Radius Ratio R_1/W	0	7	8	9	1.0	1.1
	ELD, ft	21.8	17.0	17.9	17.8			4" L.R.		ELD, ft	14.2	13.3	13.0	12.7	12.5

^a For more complete data see A.S.H.V.E. Research Report No. 1216—Effect of Vanes in Reducing Pressure Loss in Elbows in 7-Inch Square Ventilating Duct, by M. C. Stuart, C. F. Warner and W. C. Roberts (A.S.H.V.E. TRANSACTIONS, Vol. 48, 1942, p. 409).

Note: *A*: Vane *A* made up of a large number of small splitters; *B* made up of a small number of large splitters bent on a large radius; *C* hollow vane having different outside and inside curvature; and *D* four splitters with $R/W = 0.4$. Elbow same as *D* except 2 in. trailing edge on the end of each splitter, ELD in feet = 17.0.

Fig. 5 and results of more recent tests shown in Table 3. A study of this subject is in progress at the A.S.H.V.E. Research Laboratory for the purpose of obtaining such data.

LOSSES DUE TO AREA CHANGES

Area changes in ducts, generally unavoidable, are necessitated frequently by the building construction or changes in the volume of air carried. Experimental investigations^{12,13} of pressure changes, and pressure losses at changes of the area of duct cross-sections, indicate that the excess pressure loss over the normal friction loss is a shock loss due to a faster stream expanding into a slower stream, as determined by the actual areas occupied by the flow rather than the areas of the duct. No perceptible