TABLE 3. PRESSURE LOSSES DUE TO ELBOWS
(Additional Equivalent Losses in Excess of Friction to Intersection of Center Lines)

TYPE	ILLUSTRATION	CONDITIONS	PRESSURE LOSS C^a	L/D	L/W
N-DEG.		RECTANGULAR OR ROUND; WITH OR WITHOUT VANES	$\frac{N}{90}$ TIMES VALUE FOR SIMILAR 90-DEG. ELBOW[9]		
90-DEG. ROUND SECTION		MITER	1.30[b]	65[9]	
		R/D=0.5	0.90		
		0.75	0.45	23	
		1.0	0.33	17	
		1.5	0.24	12	
		2.0	0.19	10	
90-DEG. RECTANGULAR SECTION		H/W R/W			
		0.25 MITER	1.25[b]		25[9]
		0.25 0.5	1.25		25
		0.25 0.75	0.60		12
		0.25 1.0	0.37		7
		0.25 1.5	0.19		4
		0.5 MITER	1.47		49
		0.5 0.5	1.10		40
		0.5 0.75	0.50		16
		0.5 1.0	0.28		9
		0.5 1.5	0.13		4
		1.0 MITER	1.50		75
		1.0 0.5	1.00		50
		1.0 0.75	0.41		21
		1.0 1.0	0.22		11
		1.0 1.5	0.09		4.5
		4.0 MITER	1.38		110
		4.0 0.5	0.96		85
		4.0 0.75	0.37		43
		4.0 1.0	0.19		17
		4.0 1.5	0.07		6
90-DEG. SQUARE SECTION WITH SPLITTER VANES		R/W R/W R_2/W			
		MITER 0.5	0.70[9]		28[10]
		0.5 0.4			19
		0.7 0.6			12
		1.0 1.0	0.13		7.2
		1.5	0.12		
		MITER 0.3 0.5			22[10]
		0.5 0.2 0.4	0.45		16
		0.75 0.4 0.7	0.12		
		1.0 0.7 1.0	0.10		
		1.5 1.3 1.8	0.15		
MITER WITH TURNING VANES	PLATE / FORMED	PLATE VANES	0.35[9]		
		FORMED VANES	0.10[9]		
MITER TEE WITH VANES		CONSIDER EQUAL TO A SIMILAR ELBOW. BASE LOSS ON ENTERING VELOCITY.			
RADIUS TEE					

[a] Values based on f values of approximately 0.02.
[b] Values calculated from L/D and L/W values of Reference 6 for $f = 0.02$.
Note: Superscript numbers refer to references at end of chapter.

for elbows in rectangular ducts; Fig. 9 gives the *equivalent length* of duct in terms 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.

Example 5: Use of Fig. 8 for the calculation of elbow losses.

Given the portion of a duct system shown in Fig. 10, 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

TABLE 4. PRESSURE LOSSES DUE TO AREA CHANGES

TYPE	ILLUSTRATION	CONDITIONS	LOSS COEFFICIENT	
ABRUPT EXPANSION		A_1/A_2	C_1	C_2
		0.1	0.81	81
		0.2	0.64	16
		0.3	0.49	5
		0.4	0.36	2.25
		0.5	0.25	1.00
		0.6	0.16	0.45
		0.7	0.09	0.18
		0.8	0.04	0.06
		0.9	0.01	0.01
GRADUAL EXPANSION		θ	C_1	
		5°	0.17[9]	
		7°	0.22	
		10°	0.28	
		20°	0.45	
		30°	0.59	
		40°	0.73	
ABRUPT EXIT	$(A_2=\infty)$	$A_1/A_2=0.0$	1.00	
SQUARE EDGE ORIFICE EXIT		A_2/A_1		C_o
		0.0		2.50[12]
		0.2		2.44
		0.4		2.26
		0.6		1.96
		0.8		1.54
		1.0		1.00
BAR ACROSS DUCT		E/D		C
		0.10		0.79
		0.25		1.4
		0.50		4.0
PIPE ACROSS DUCT		E/D		C
		0.10		0.209
		0.25		0.55
		0.50		2.0
STREAMLINED STRUT ACROSS DUCT		E/D		C
		0.10		0.079
		0.25		0.23
		0.50		0.90

TYPE	ILLUSTRATION	CONDITIONS	LOSS COEFFICIENT
ABRUPT CONTRACTION SQUARE EDGE		A_2/A_1	C_2
		0.0	0.34[12]
		0.2	0.32
		0.4	0.25
		0.6	0.18
		0.8	0.06
GRADUAL CONTRACTION		θ	
		30°	0.02[9]
		45°	0.04
		60°	0.07
EQUAL AREA TRANSFORMATION		A_1, A_2	C
	$\theta \leq 14°$		0.15[9]
FLANGED ENTRANCE		$A=\infty$	C
			0.34[12]
DUCT ENTRANCE		$A=\infty$	C
			0.85[9]
FORMED ENTRANCE		$A=\infty$	C
			0.03[9]
SQUARE EDGE ORIFICE ENTRANCE		A_o/A_2	C_o
		0.0	2.50[12]
		0.2	1.90
		0.4	1.39
		0.6	0.96
		0.8	0.61
		1.0	0.34
SQUARE EDGE ORIFICE IN DUCT	$A_1 = A_2$	A_o/A	C_o
		0.0	2.50[12]
		0.2	1.86
		0.4	1.21
		0.6	0.64
		0.8	0.20
		1.0	0.0

Note 1: Subscript on C indicates cross section at which velocity is calculated. (See, for example, Equation 10 in text.)
Note 2: Superscript numbers refer to references at end of chapter.

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. 8: $(L/W)_1 = 11.5$. 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. 8 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 ASHAE Friction Chart, Fig. 3, 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 elbow loss will be greater for a flat bend