King Abdulaziz University

College of Engineering

Mechanical Engineering

MEP 451 Refrigeration & Air Conditioning

Duct Design

June 2009

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Duct design

- Air flow in ducts
- Major and Minor Losses in Ducts
- Loss coefficient for some fittings
- Equivalent length for a fittings
- Duct accessories
- Pressure diagram
- Duct design
  - Equal friction method
  - Balanced Capacity method

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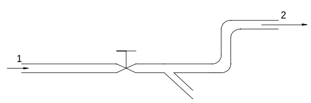
Air Flow in Ducts

Modified Bernoulli equation



$$\left(p_1+\frac{1}{2}\frac{\rho V_1^2}{g_c}\right)=\left(p_2+\frac{1}{2}\frac{\rho V_2^2}{g_c}+\frac{\rho g l_f}{g_c}\right)$$

Major and minor losses

$$\left(\frac{g_c p_1}{\rho g}+\frac{1}{2}\frac{\rho V_1^2}{g}\right)=\left(\frac{p_2}{\rho g}+\frac{1}{2}\frac{\rho V_2^2}{g}+l_f\right)$$

$$P_{s1}+P_{v1}=P_{s2}+P_{v2}+\Delta P_f$$

$$P_{01}=P_{02}+\Delta P_f$$

$$\Delta P_f=\frac{\rho g l_f}{g_c}$$

Pressure loss between 1 and 2

3

Velocity air pressure, P_v

$$P_v=\rho\left(\frac{V^2}{1097}\right)=\left(\frac{V}{4005}\right)^2$$

P_v in in water and V in ft/min

$$P_v=\rho\left(\frac{V^2}{1.414}\right)=\left(\frac{V}{1.29}\right)^2$$

P_v in Pa and V in m/s

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Major losses in duct

$$\Delta P_f=f\frac{L}{D}\rho\frac{V^2}{2g}$$

f friction factor = f(Re, e/D)

$$\frac{1}{\sqrt{f}}=-2\log_{10}\left[\frac{12e}{3.7D}+\frac{2.51}{\mathrm{Re}_D\sqrt{f}}\right]$$

F = friction factor=f(Re, roughness)

e is the pipe roughness

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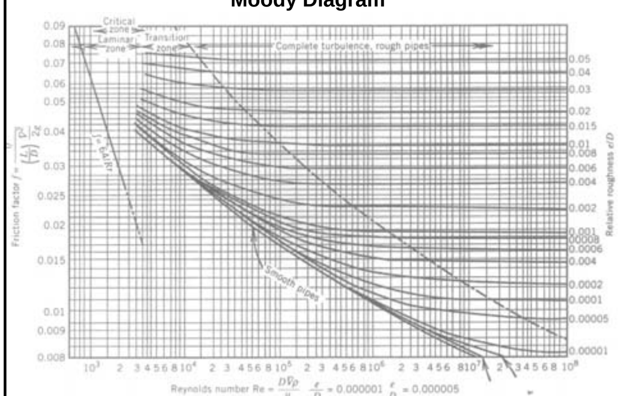
Moody Diagram



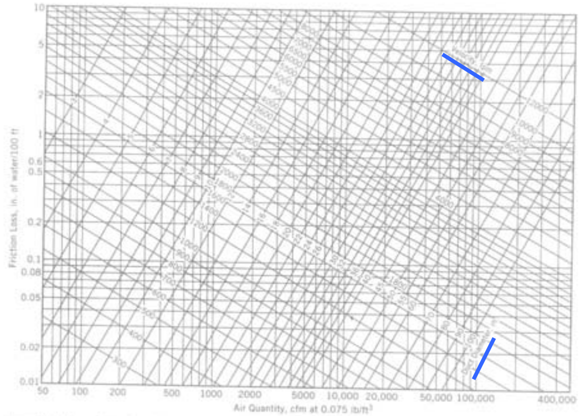


Figure 12-21 Pressure loss due to friction for galvanized steel ducts, IP units. (Reprinted by permission from *ASHRAE Handbook, Fundamentals Volume IP*, 1997.)

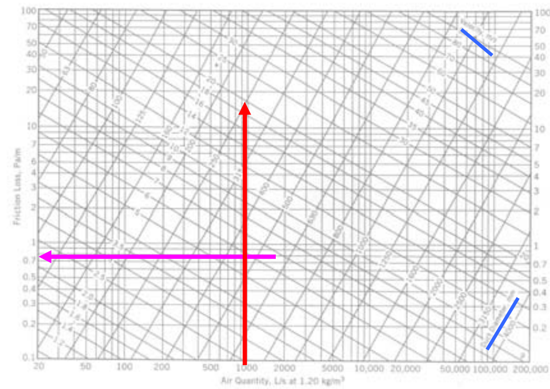


Figure 12-22 Pressure loss due to friction for galvanized steel ducts, SI units. (Reprinted by permission from *ASHRAE Handbook, Fundamentals Volume SI*, 1997.)

Uses of pressure loss charts

1-In English unit chart (Fig. 12.21), the y-axis is the pressure drop per 100 ft length of the duct

2-The chart has 4 parameters: pressure drop, air flow rate, air velocity, and duct diameter

3-Knowing two of these parameters, one can get the other two parameters

4-The given duct size is for circular pipe. Use the equivalent table or equation to find the size of the rectangular duct

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Equivalent of a circular duct

$$D_e = 1.3\frac{(ab)^{5/8}}{(a+b)^{1/4}}$$

D_e equivalent diameter

a and b are the dimension of a rectangular duct

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Table 12-7 Circular Equivalents of Rectangular Ducts for Equal Friction and Capacity—Dimensions in Inches, Feet, or Meters

Side a of Rectangular Duct	Diameter D_e of Circular Duct																
	b = 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24
6	6.6																
7	7.1	7.7															
8	7.5	8.2	8.8														
9	8.0	8.6	9.3	9.9													
10	8.4	9.1	9.8	10.4	10.9												
11	8.8	9.5	10.2	10.8	11.4	12.0											
12	9.1	9.9	10.7	11.3	11.9	12.5	13.1										
13	9.5	10.3	11.1	11.8	12.4	13.0	13.6	14.2									
14	9.8	10.7	11.5	12.2	12.9	13.5	14.2	14.7	15.3								
15	10.1	11.0	11.8	12.6	13.3	14.0	14.6	15.3	15.8	16.4							
16	10.4	11.4	12.2	13.0	13.7	14.4	15.1	15.7	16.3	16.9	17.5						
17	10.7	11.7	12.5	13.4	14.1	14.9	15.5	16.1	16.8	17.4	18.0	18.6					
18	11.0	11.9	12.9	13.7	14.5	15.3	16.0	16.6	17.3	17.9	18.5	19.1	19.7				
19	11.2	12.2	13.2	14.1	14.9	15.6	16.4	17.1	17.8	18.4	19.0	19.6	20.2	20.8			
20	11.5	12.5	13.5	14.4	15.2	15.9	16.8	17.5	18.2	18.8	19.5	20.1	20.7	21.3	21.9		
22	12.0	13.1	14.1	15.0	15.9	16.7	17.6	18.3	19.1	19.7	20.4	21.0	21.7	22.3	22.9	24.1	
24	12.4	13.6	14.6	15.6	16.6	17.5	18.3	19.1	19.8	20.6	21.3	21.9	22.6	23.2	23.9	25.1	26.2
26	12.8	14.1	15.2	16.2	17.2	18.1	19.0	19.8	20.6	21.4	22.1	22.8	23.5	24.1	24.8	26.1	27.2
28	13.2	14.5	15.6	16.7	17.7	18.7	19.6	20.5	21.3	22.1	22.9	23.6	24.4	25.0	25.7	27.1	28.2
30	13.6	14.9	16.1	17.2	18.3	19.3	20.2	21.1	22.0	22.9	23.7	24.4	25.2	25.9	26.7	28.0	29.3
32	14.0	15.3	16.5	17.7	18.8	19.8	20.8	21.8	22.7	23.6	24.4	25.2	26.0	26.7	27.5	28.9	30.1
34	14.4	15.7	17.0	18.2	19.3	20.4	21.4	22.4	23.3	24.2	25.1	25.9	26.7	27.5	28.3	20.7	31.0
36	14.7	16.1	17.4	18.6	19.8	20.9	21.9	23.0	23.9	24.8	25.8	26.6	27.4	28.3	29.0	30.5	32.0
38	15.0	16.4	17.8	19.0	20.3	21.4	22.5	23.5	24.5	25.4	26.4	27.3	28.1	29.0	29.8	31.4	32.8
40	15.3	16.8	18.2	19.4	20.7	21.9	23.0	24.0	25.1	26.0	27.0	27.9	28.8	29.7	30.5	32.1	33.6

Source: Reprinted by permission from *ASHRAE Handbook, Fundamentals Volume*, 1989.

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Figs. 12.21 and 12.22 correction factors

A) Correction factor for density and viscosity when T >100°F (38 C)

$$C = \left(\frac{\rho_a}{\rho_s}\right)^{0.9}\left(\frac{\mu_a}{\mu_s}\right)^{0.1}$$

subscript a refers to actual and s refers to standard condition

$$\Delta P_{0a} = C\Delta P_{0s}$$

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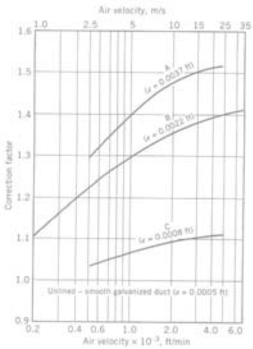
B-Correction due to duct liners

f for typical galvanized duct is 0.02

f for liners is between 0.03 and 0.06



Roughness correction factor for commercial duct liners

Non-circular duct

$$D_h = \frac{4(Cross\ section\ area)}{Wetted\ \text{Perimeter}}$$

$$\text{Re}_D = \frac{\rho V D}{\mu} = \frac{VD}{\nu}$$

$$\text{Re}_{D_h} = \frac{\rho V D_h}{\mu} = \frac{VD_h}{\nu}$$

Notes on using pressure loss chart

You can enter the chart knowing the CFM and pressure loss to get duct size in diameters and air velocity

If you know the flow rate and rectangular cross section velocity, then calculate V and enter the chart using V and D_h

Minor losses (losses in fittings)

$$\Delta P = C_0 \frac{\rho V^2}{2g} = C_0 P_v$$

Tables to finds C_o for different fittings

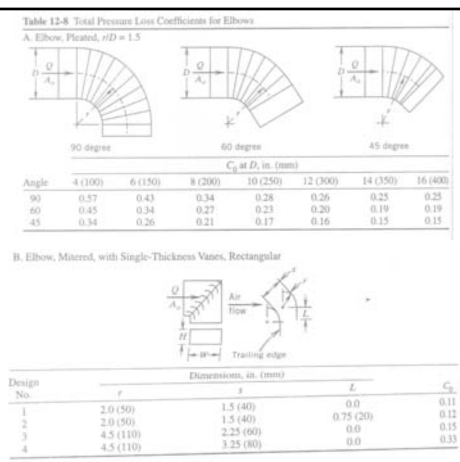


Table 12-8 Total Pressure Loss Coefficients for Elbows

A. Elbow, Pleated, r/D = 1.5

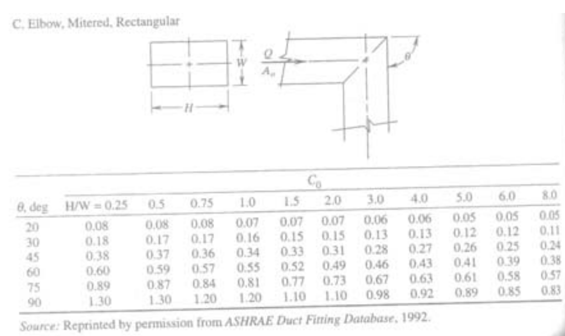
90 degree 60 degree 45 degree

Angle	C_0 at D, in. (mm) 4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	14 (350)	16 (400)
90	0.57	0.43	0.34	0.28	0.26	0.25	0.25
60	0.45	0.34	0.27	0.23	0.20	0.19	0.19
45	0.34	0.26	0.21	0.17	0.16	0.15	0.15

B. Elbow, Mitered, with Single-Thickness Vanes, Rectangular

Design No.	Dimensions, in. (mm) r	s	L	C_0
1	2.0 (50)	1.5 (40)	0.0	0.11
2	2.0 (50)	1.5 (40)	0.75 (20)	0.12
3	4.5 (110)	2.25 (60)	0.0	0.15
4	4.5 (110)	3.25 (80)	0.0	0.33

Table 12.8 C



C. Elbow, Mitered, Rectangular

θ, deg	C_0 H/W = 0.25	0.5	0.75	1.0	1.5	2.0	3.0	4.0	5.0	6.0	8.0
20	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
30	0.18	0.17	0.17	0.16	0.15	0.15	0.13	0.13	0.12	0.12	0.11
45	0.38	0.37	0.36	0.34	0.33	0.31	0.28	0.27	0.26	0.25	0.24
60	0.60	0.59	0.57	0.55	0.52	0.49	0.46	0.43	0.41	0.39	0.38
75	0.89	0.87	0.84	0.81	0.77	0.73	0.67	0.63	0.61	0.58	0.57
90	1.30	1.30	1.20	1.20	1.10	1.10	0.98	0.92	0.89	0.85	0.83

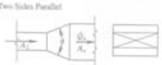
Source: Reprinted by permission from *ASHRAE Duct Fitting Database*, 1992.

Table 12-9 Total Pressure Loss Coefficients for Transitions

A. Transition, Round to Round

A_o/A_1	C_o: $\theta = 10°$	20°	45°	90°	120°	150°	180°
0.10	0.05	0.05	0.07	0.19	0.29	0.37	0.43
0.17	0.05	0.04	0.06	0.18	0.28	0.36	0.42
0.25	0.05	0.04	0.06	0.17	0.27	0.35	0.41
0.50	0.05	0.05	0.06	0.12	0.18	0.24	0.26
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.44	0.76	1.32	1.28	1.24	1.20	1.20
4.00	2.56	4.80	9.76	10.24	10.08	9.92	9.92
10.00	21.00	38.00	76.00	83.00	84.00	83.00	83.00
16.00	53.76	97.28	215.04	225.28	225.28	225.28	225.28

B. Transition, Rectangular, Two Sides Parallel



A_o/A_1	C_o: $\theta = 10°$	20°	45°	90°	120°	150°	180°
0.10	0.05	0.05	0.07	0.19	0.29	0.37	0.43
0.17	0.05	0.04	0.05	0.18	0.28	0.36	0.42
0.25	0.05	0.04	0.06	0.17	0.27	0.35	0.41
0.50	0.06	0.05	0.06	0.14	0.20	0.26	0.27
1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
2.00	0.56	0.60	1.40	1.52	1.48	1.44	1.40
4.00	2.72	3.52	9.60	11.20	11.04	10.72	10.56
10.00	24.00	36.00	69.00	93.00	93.00	92.00	91.00
16.00	66.56	102.40	181.76	256.00	255.44	250.88	258.88

Source: Reprinted by permission from *ASHRAE Duct Fitting Database*, 1992.

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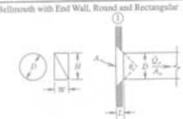
Table 12-10 Total Pressure Loss Coefficients for Duct Entrances

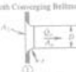
A. Conical Converging Bellmouth with End Wall, Round and Rectangular



Rectangular: $D = 2HW/(H + W)$

L/D	C_o: $\theta = 0$	10°	20°	30°	40°	60°	100°	140°	180°
0.025	0.50	0.47	0.45	0.43	0.41	0.40	0.42	0.45	0.50
0.05	0.50	0.45	0.41	0.36	0.33	0.30	0.35	0.42	0.50
0.075	0.50	0.42	0.35	0.30	0.26	0.23	0.30	0.40	0.50
0.10	0.50	0.39	0.32	0.25	0.22	0.18	0.27	0.38	0.50
0.15	0.50	0.37	0.27	0.20	0.16	0.15	0.25	0.37	0.50
0.60	0.50	0.27	0.18	0.13	0.11	0.12	0.23	0.36	0.50

B. Smooth Converging Bellmouth with End Wall



r/D	C_o	r/D	C_o
0	0.50	0.06	0.20
0.01	0.43	0.08	0.15
0.02	0.36	0.10	0.12
0.03	0.31	0.12	0.09
0.04	0.26	0.16	0.06
0.05	0.22	≥ 0.20	0.03

Source: Reprinted by permission from *ASHRAE Duct Fitting Database*, 1992.

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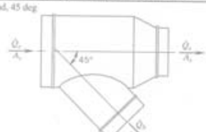
Table 12-11 Total Pressure Loss Coefficients for Diverging Flow Fittings

A. Diverging Wye, Round, 45 deg



Branch, C_b

A_b/A_c	$Q_b/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.1	0.38	0.39	0.48					
0.2	2.25	0.38	0.31	0.39	0.46	0.48	0.45	
0.3	6.29	1.02	0.38	0.30	0.33	0.39	0.44	0.48
0.4	12.41	2.25	0.74	0.38	0.30	0.31	0.35	0.39
0.5	20.58	4.01	1.37	0.62	0.38	0.30	0.30	0.32
0.6	30.78	6.29	2.25	1.02	0.56	0.38	0.31	0.30
0.7	43.02	9.10	3.36	1.57	0.85	0.52	0.38	0.31
0.8	57.29	12.41	4.71	2.25	1.22	0.74	0.50	0.38
0.9	73.59	16.24	6.29	3.06	1.69	1.02	0.67	0.48

Main, C_s

A_s/A_c	$Q_s/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.1	0.13	0.16						
0.2	0.20	0.13	0.15	0.16	0.28			
0.3	0.90	0.13	0.13	0.14	0.15	0.16	0.20	
0.4	2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16
0.5	6.25	0.37	0.17	0.14	0.13	0.14	0.14	0.15
0.6	11.88	0.90	0.20	0.13	0.14	0.13	0.14	0.14
0.7	18.62	1.71	0.33	0.18	0.16	0.14	0.13	0.15
0.8	26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13
0.9	36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14

continues

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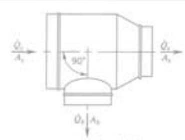
Table 12-11 Total Pressure Loss Coefficients for Diverging Flow Fittings *(continued)*

B. Diverging Tee, Round



Branch, C_b

A_b/A_c	$Q_b/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	1.20	0.62	0.80	1.28	1.99	2.92	4.07	5.44	7.02
0.2	4.10	1.20	0.72	0.62	0.66	0.80	1.01	1.28	1.60
0.3	8.99	2.40	1.20	0.81	0.66	0.62	0.64	0.70	0.80
0.4	15.89	4.10	1.94	1.20	0.88	0.72	0.64	0.62	0.63
0.5	24.80	6.29	2.91	1.74	1.20	0.92	0.77	0.68	0.63
0.6	35.73	8.99	4.10	2.40	1.62	1.20	0.96	0.81	0.72
0.7	48.67	12.19	5.51	3.19	2.12	1.55	1.20	0.99	0.85
0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.49	1.20	1.01
0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.46	1.20

Main, C_s

A_s/A_c	$Q_s/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.13	0.16							
0.2	0.20	0.13	0.15	0.16	0.28				
0.3	0.90	0.13	0.13	0.14	0.15	0.16	0.20		
0.4	2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5	6.25	0.37	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6	11.88	0.90	0.20	0.13	0.14	0.13	0.14	0.14	0.15
0.7	18.62	1.71	0.33	0.18	0.16	0.14	0.13	0.15	0.14
0.8	26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13	0.14
0.9	36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14	0.13

Source: Reprinted by permission from *ASHRAE Duct Fitting Database*, 1992.

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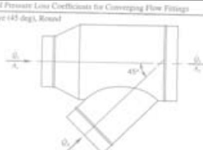
Table 12-12 Total Pressure Loss Coefficients for Converging Flow Fittings

A. Converging Wye (45 deg), Round



Branch, C_b

A_b/A_c	A_s/A_c	$Q_b/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.4	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.5	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Main, C_s

A_b/A_c	A_s/A_c	$Q_s/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.4	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.5	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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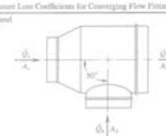
Table 12-12 Total Pressure Loss Coefficients for Converging Flow Fittings *(continued)*

B. Converging Tee, Round



Branch, C_b

A_b/A_c	A_s/A_c	$Q_b/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.4	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.5	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Main, C_s

A_b/A_c	A_s/A_c	$Q_s/Q_c = 0.1$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.4	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.5	0.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: Reprinted by permission from *ASHRAE Duct Fitting Database*, 1992.

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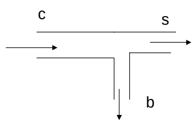
Example 12.8

Compute the pressure loss due to a round 90° diverging section. The common section is 12", and the straight through section is 10 ". The flow rate in the common section is 1100 cfm, the flow rate in the branch is 250 cfm.



Straight section

$$V_s = \frac{Q_s}{A_s} = 1558\ \text{ft/min}$$

$$\frac{Q_s}{Q_c} = \frac{850}{1100} = 0.77$$

$$\frac{A_s}{A_c} = 0.69$$

Branch section

$$V_b = \frac{Q_b}{A_b} = 1273\ \text{ft/min}$$

$$\frac{Q_b}{Q_c} = \frac{250}{1100} = 0.23$$

$$\frac{A_b}{A_c} = 0.25$$

From fig. 12.11B

C_s=0.14

C_b =1.55

$$\Delta P_{0s} = C_s \left[\frac{V_s}{4005}\right]^2 = 0.021\ \text{in}\ H_2O \qquad \Delta P_{0b} = C_b \left[\frac{V_b}{4005}\right]^2 = 0.16"\ H_2O$$

Equivalent of a minor loss in terms of straight pipe length

Major loss

$$\Delta P_L = f \frac{L}{D} \rho \frac{V^2}{2g}$$

Minor losses (losses in fittings)

$$\Delta P_0 = C \rho \frac{V^2}{2g}$$

$$\frac{L}{D} = \frac{C}{f}$$

Table 12-13 Friction Factors for Various Galvanized Steel Ducts

Diameter in.	Diameter mm	Darcy Friction Factor
4	10	0.035
6	15	0.028
8	20	0.023
10	25	0.022
12	30	0.019
14	36	0.017
16	40	0.016
20	50	0.015
24	60	0.014

Table 12-14 Approximate Equivalent Lengths for Selected Fittings in Circular Ducts[a]

Fitting	L/D	Equivalent Length, ft (m) at Diameter, in. (cm): 6 (15)	8 (20)	10 (25)	12 (30)
Elbows					
Pleated, 90 deg	15	8 (2.4)	10 (3.1)	13 (4.0)	15 (4.6)
Pleated, 45 deg	9	5 (1.5)	6 (1.8)	8 (2.4)	9 (2.7)
Mitered, 90 deg	60	30 (9.1)	40 (12.2)	50 (15.2)	60 (18.3)
Mitered with vanes	10	5 (1.5)	7 (2.1)	8 (2.4)	10 (3.1)
Transitions					
Converging, 20 deg	4	2 (0.6)	3 (0.9)	3 (0.9)	4 (1.2)
Diverging, 120 deg	40	20 (6.1)	27 (8.2)	33 (10.1)	40 (12.2)
Abrupt expansion	60	30 (9.1)	40 (12.2)	50 (15.2)	60 (18.3)
Round to rectangular boot, 90 deg	*50*	*25 (7.6)*	*33 (10.1)*	*40 (12.2)*	*50 (15.2)*
Round to rectangular boot, straight	10	5 (1.5)	7 (2.1)	8 (2.4)	10 (3.1)
Entrances					
Abrupt, 90 deg	30	15 (4.6)	20 (6.1)	25 (7.6)	30 (9.1)
Bellmouth	12	6 (1.8)	8 (2.4)	10 (3.1)	12 (3.7)
Branch Fittings, Diverging					
Wye, 45 deg, branch	20	10 (3.1)	13 (4.0)	17 (5.2)	20 (6.1)
Wye, 45 deg, through	8	4 (1.2)	5 (1.5)	7 (2.1)	8 (2.4)
Tee, branch	40	20 (6.1)	27 (8.2)	33 (10.1)	40 (12.2)
Tee, through	8	4 (1.2)	5 (1.5)	7 (2.1)	8 (2.4)
Branch Fittings, Converging[b]					
Wye, 45 deg, branch	20	10 (3.1)	13 (4.0)	17 (5.2)	20 (6.1)
Wye, 45 deg, through	10	5 (1.5)	7 (2.1)	8 (2.4)	10 (3.1)
Tee, branch	40	20 (6.1)	27 (8.2)	33 (10.1)	40 (12.2)
Tee, through	12	6 (1.8)	8 (2.4)	10 (3.1)	12 (3.7)

[a] Equivalent lengths are approximate and based on Tables 12-7 through 12-12 using typical operating conditions with velocity less than about 1200 ft/min or 6 m/s.

[b] It is difficult to assign one value of L/D to this type fitting. Consult Table 12-12.

Example 12.9

Compute L_e for duct system shown in figure

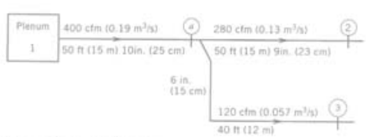


Figure 12-24 A simple duct system.

Fittings	**Description**	**Loss coefficient C_o**	**L_e (ft)**	**L_e (m)**
Entrance	Conical θ=0° Table 12.10A f=0.022 for D=10''	0.5	19	5.8
45 Diverging branch	C_b=0.6, Table 12.11A, D=6"	0.6	11	3.4
Straight 45 diverging	C_s=0.13, Table 12.11A, f=0.0225 for D=9''	0.13	4	1.22
90 elbow	C=0.43, Table 12.8A, f=0.028, D=9"	0.43	7.7	2.35

Duct accessories

1- Dampers (Parallel blades and opposed blades)

2-Fire dampers

3-Turnning vanes (linear and aerofoil)

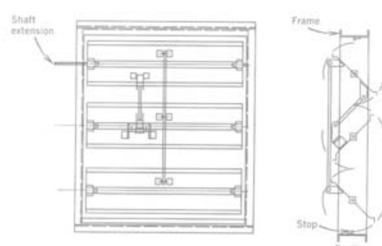


Figure 12-25 Typical opposed blade damper assembly.

Pressure diagram

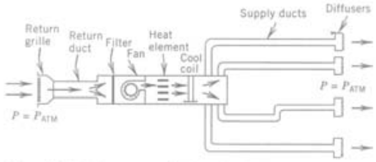


Figure 12-26 Total pressure profile for a simple unitary system.

Element	Total pressure loss, in. wg
Return grille	0.04
Return duct	0.08
Filter	0.08
Heat and cool coils	0.23
Supply ducts	0.14
Diffusers	0.03
Fan total	0.60

Pressure diagrams

Energy grade line EGL=Total pressure=P_o

Hydraulic grade line EGL=static pressure, P_s

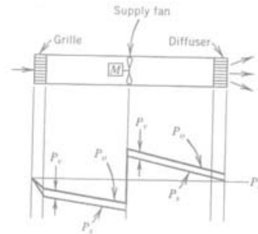


Figure 12-27 A simple fan system.

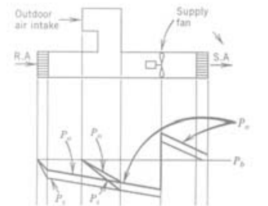


Figure 12-28 A simple duct system with outdoor air intake.

Pressure diagrams

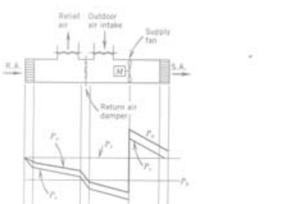


Figure 12-29 A simple duct system with outdoor air intake and exhaust (relief).

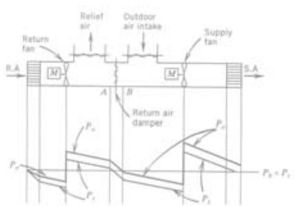


Figure 12-30 A two-fan duct system with outdoor air intake and exhaust.

Duct design methods

1-Equal friction method

2-Balanced capacity method

3-Static regain method

Equal friction method

1-Select the run with the anticipated max. flow resistance

2-Calculate the duct equivalent length (L_e)

3-From the known pressure available for the supply duct, calculate the pressure loss in inches of water per 100 feet ($\Delta P/L$)

4-Size each duct section using the pressure drop and the flow rate in that section

5-Calculate the total pressure drop for each run. Use dampers when necessary

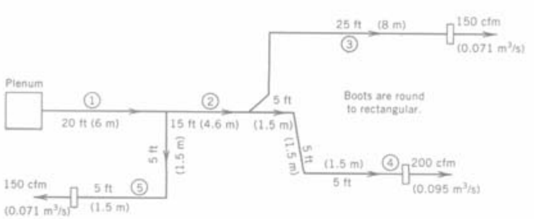


Figure 12-32 A simple duct layout.

Example 12.11

Size the duct system shown using equal friction method. Total pressure available fro duct is 0.12 " water. The pressure drop for each diffuser is 0.02 " water

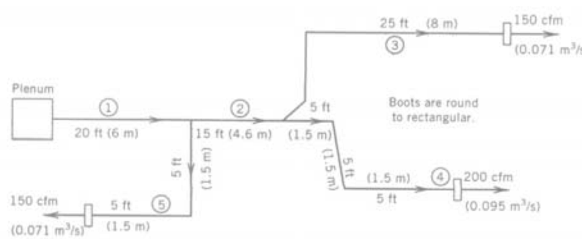
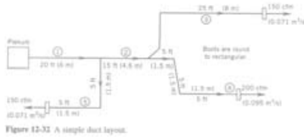


Figure 12-32 A simple duct layout.

Example 12.11

Available pressure is 0.12 in H_2O (30 Pa). Loss in diffuser is 0.02 in H_2O (5 Pa).



$$L_{123} = (L_1 + L_{ent}) + (L_2 + L_{st}) + (L_3 + L_{wye} + L_{45} + L_{90} + L_{boot})$$

$$L_{123} = (20+30)+(15+8)+(25+13+6+10+33) = 160\text{ ft}$$

$$\Delta P_0 / L = 0.1*(100/160) = 0.063\text{ in H}_2\text{O per }100\text{ ft}$$

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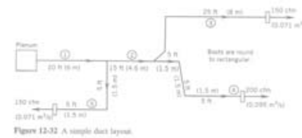
Summary of results for Example 12.11

Section	Q (cfm)	D (in)	V (ft/min)	$\Delta P_0 / L$	L_e	ΔP
1	500	12	650	0.058	50	0.029
2	350	10	650	0.07	23	0.016
3	150	8	440	0.045	87	0.039
4	200	8	590	0.075	73	0.055
5	150	8	440	0.045	80	0.036

Pressure losses in each run

Run	ΔP_0 (inches water)
123	0.029+0.016+0.039=0.084
124	0.029+0.016+.055=0.010
15	0.029+0.036=0.065



Balanced Capacity method

Example 12. 12

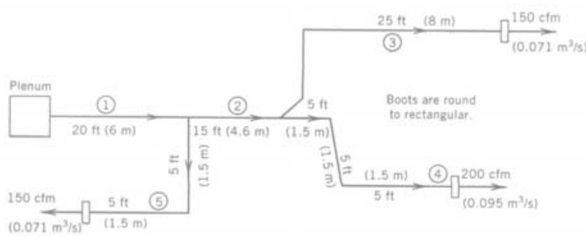


Figure 12-32 A simple duct layout.

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Example 12.12

For section 4

$$\Delta P_{04} = \Delta P_{03} = 0.039\text{ inches of water}$$

$$\Delta P_{04} / L = 0.039(100/74) = 0.053$$

From Fig. 12.21 D_4=8.7 or 9 inches V_4=469 ft/min

For section 5

$$\Delta P_{05} = 0.084 - 0.029 = 0.055$$

From Fig. 12.21 D_5=7.4 or 8 inches V_5 =440 ft/min

The difference between the two solution is minor

section	Equal friction method	Balanced Capacity method
4	D_4=8''	D_4=9''
5	D_5=8''	D_5=8''

40

Recommended air velocities (f/m)

	Recommended velocity		
	Residence	Schools, public areas	Industrial areas
Outside air inlet	500	500	500
Fan outlet	700	800	1000
Main ducts	700-900	1000-1300	1200-1800
Branch duct	500-600	500-600	800-1000

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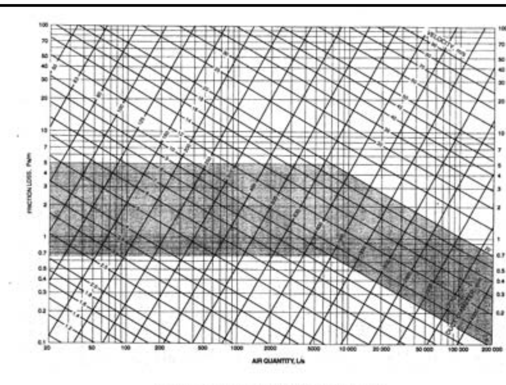

Recommended velocities regions

1 m/s ≅200 ft/min

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