SMACNA

SMACNA Technical Service

Presented By:

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Duct Design Fundamentals

Learning Objectives

- **Basic Air Flow**
- **Pressure**
- **Pressure Losses - Friction**
- **Pressure Losses – Dynamic**
  - Fitting Efficiencies
- **Duct Design Overview**
- **Duct Design – Equal Friction**
- **Duct Design – Static Regain**
- **Acoustics**
- **Commissioning**

Duct Design Fundamentals

Basics of AirFlow

Mass Flow and Continuity Equations

Mass flow into a section = mass flow out of a section

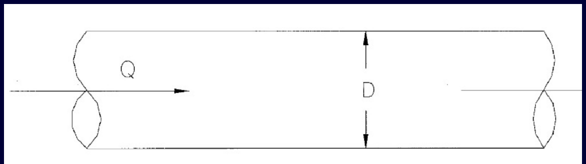
$$\dot{m} = \rho A_d V = constant$$

If air density is constant, we get the Continuity Equation

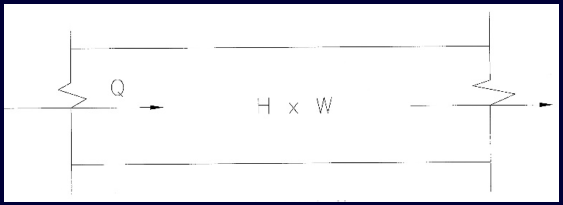
$$\frac{\dot{m}}{\rho} = Q = A_d V = constant$$

Duct Areas

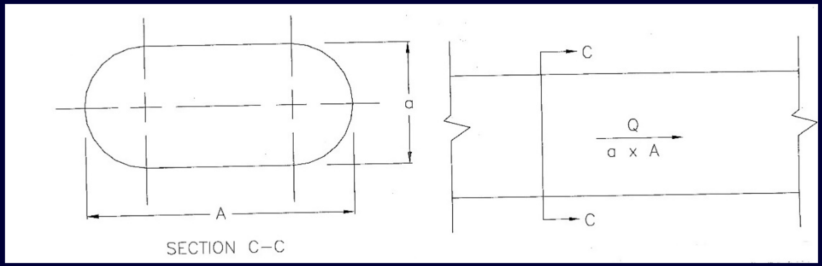
Round: $A_d = \frac{\pi D^2}{4}$



Rectangular : $A_d = WH$



Flat Oval: $A_d = \left(\frac{\pi a^2}{4}\right) + a\,(A - a)$



Velocity

If Q and A are known, the duct velocity, V can be calculated.

$$V = \frac{Q}{A_d}$$

Example 1: If the volume flow rate in a 22 in. duct is, Q = 5000 cfm, what is the average velocity of air in the duct.

D = 22 inch (1.83 ft)

$$A_d = \frac{\pi(1.83)^2}{4} = 2.64 \text{ ft}^2$$

V = 5000 / 2.64 = 1894 fpm

Calculate Duct Size for a Given Velocity

$$V = \frac{Q}{A_d} \rightarrow A_d = \frac{Q}{V}$$

Example 2: If the design volume flow rate and velocity is 13,000 cfm and 4000 fpm respectively, what is the H dimension in a rectangular duct if the W dimension is 14 inches

A_d = Q / V = 13,000 / 4000 = 3.25 ft^2 (Multiply by 144 to get in^2)
= *468* in^2

$A_d = WH \rightarrow H = A_d / W$

H = 468 / 14 = 33.4 inches

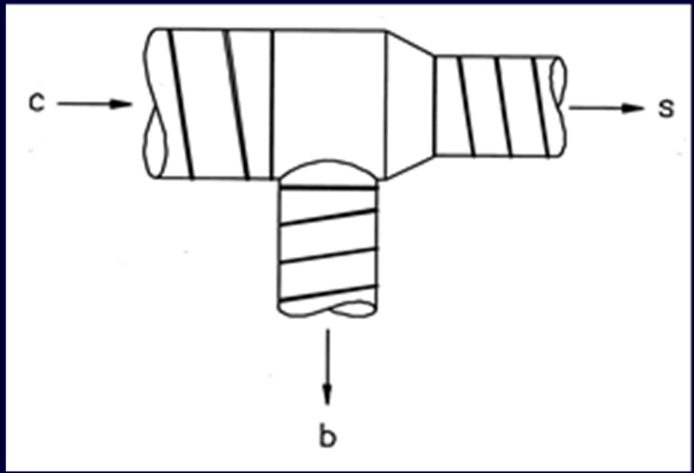
Diverging Flow

According to the law of conservation of mass, the volume flow rate before flow divergence is equal to the sum of the flows after divergence.

$$Q_c = Q_b + Q_s$$

Where:

Q_c = common (upstream) volume flow rate, cfm
Q_b = branch volume flow rate, cfm
Q_s = straight-through volume flow rate, cfm



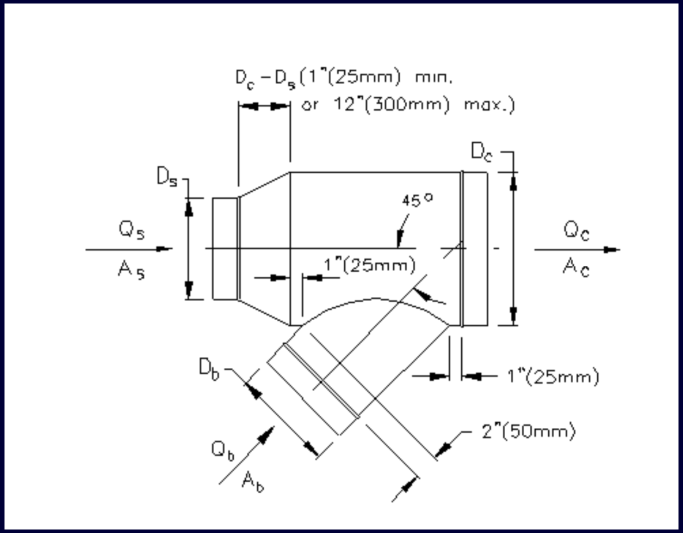
Converging Flow

According to the law of conservation of mass, the volume flow rate after flow convergence is equal to the sum of the flows before convergence

$$Q_c = Q_b + Q_s$$

Where:

Q_c = common (downstream) volume flow rate, cfm
Q_b = branch volume flow rate, cfm
Q_s = straight-through volume flow rate, cfm



Duct Design Fundamentals

Pressure

CONSERVATION OF ENERGY

$$p_t = p_s + p_v$$

Where:

p_t = total pressure, in. of water
p_s = static pressure, in. of water
p_v = velocity pressure, in. of water

Duct Design Fundamentals
Pressure

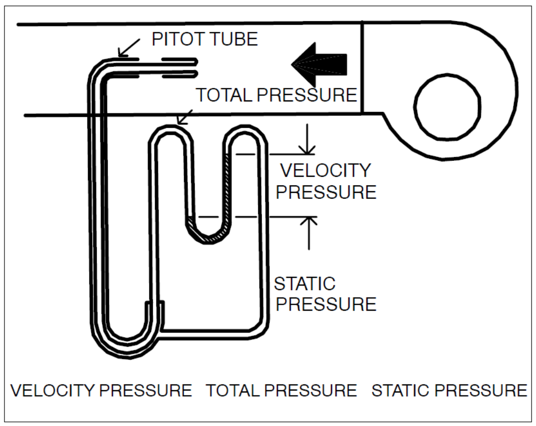


FIGURE 5–25 FAN VELOCITY PRESSURE (V_P)

The **inch** of **water** is defined as the **pressure** exerted at the base of a column of fluid exactly 1 **inch** (in) high

27.7 inch of water per 1 psi (lb_f/in^2)

1 inch of water is 5.2 psf (lb_f/ft^2)

1 inch of water is 0.036 psi

Duct Design Fundamentals
Static Pressure (p_s)

- Measure of the static energy of air flowing
- Air which fills a balloon is a good example of static pressure
- Equally exerted in all directions
- The atmospheric pressure of air is a static pressure = 14.696 psi at sea level. One psi ~ 27.7 in. of water, so 1 atm ~ 407 in. of water.
- Air always flows from an area of higher pressure to an area of lower pressure.
- Because the static pressure is above atmospheric pressure at a fan outlet, air will flow from the fan through any connecting ductwork until it reaches atmospheric pressure at the discharge
- Because the static pressure is below atmospheric at a fan inlet, air will flow from the higher atmospheric pressure through an intake and any connecting ductwork until it reaches the area of lowest static pressure at the fan inlet.

Duct Design Fundamentals
Velocity Pressure (p_v)

- Measure of the kinetic energy of the air flowing in a duct system
- Proportional to the square of the velocity

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

Where:

p_v = velocity pressure, in. of water
V = velocity, ft/min
ρ = density, lb_m/ft^3

$$p_v = \left(\frac{V}{4005}\right)^2$$

Duct Design Fundamentals
Velocity Pressure (p_v)

- Velocity pressure (p_v) is always a positive number in the direction of flow.
- Will increase if duct cross-section area decreases.
- Will decrease if duct cross-sectional area increases.
- When velocity pressure increases, static pressure must decrease.
- When velocity pressure decreases, there can be a gain in static pressure, commonly called STATIC REGAIN.

CONSERVATION OF ENERGY

Change in total pressure between any two points of a system is equal to the sum of the change in static pressure and the change in velocity pressure

$$\Delta p_t = \Delta p_s + \Delta p_v$$

Derived from the Bernoulli Equation:

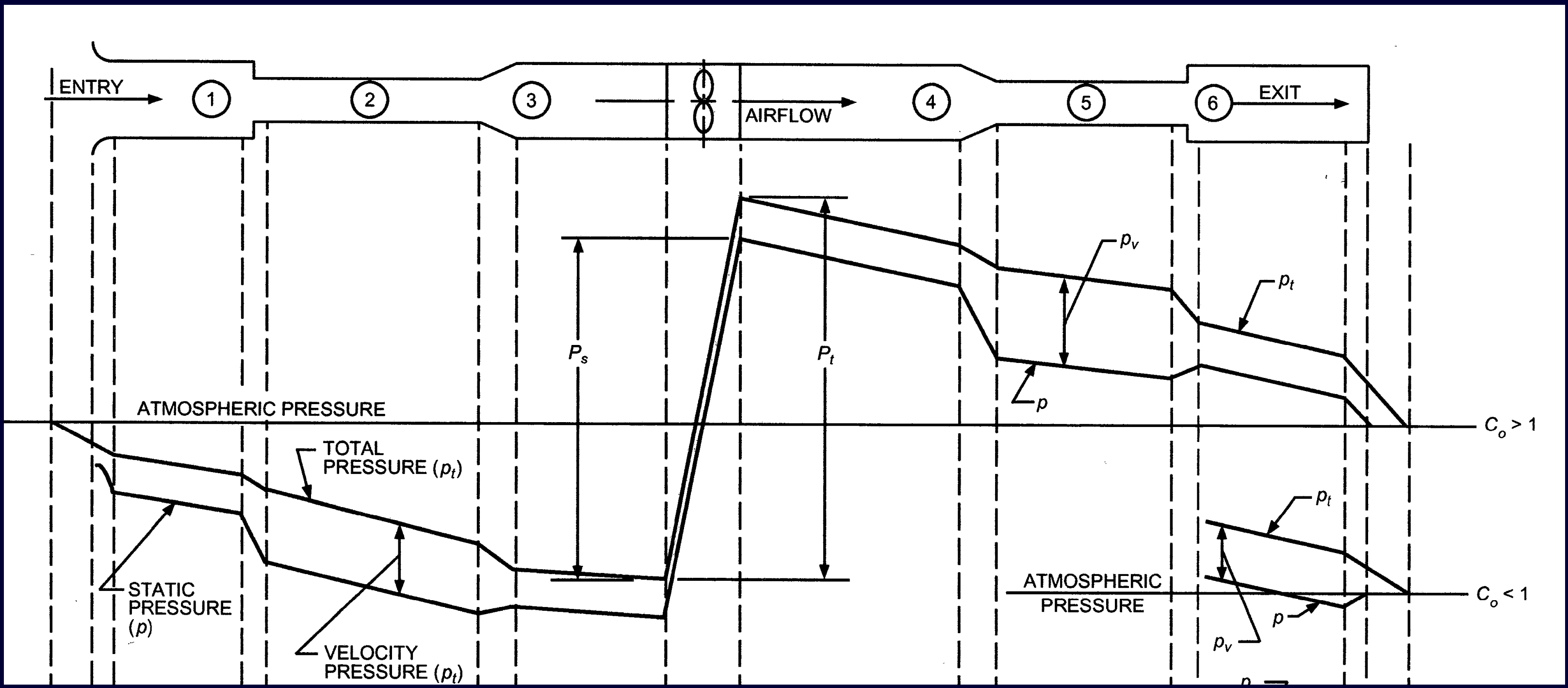
$$p_{s1} + \frac{\rho_1 V_1^2}{2g_c} + \frac{g}{g_c}\rho_1 z_1 = p_{s2} + \frac{\rho_2 V_2^2}{2g_c} + \frac{g}{g_c}\rho_2 z_2 + \Delta p_{t,1-2}$$

Duct Design Fundamentals
Pressure Changes During Flow in Ducts

- Total pressure (p_t) represents the energy of the air flowing in a duct system.
- Energy cannot be created or increased except by adding work or heat
- Energy and thus total pressure must always decrease in the direction of flow once the fan is turned on except at the fan .
- Total pressure losses represent the irreversible conversion of static and kinetic energy to internal energy in the form of heat.
- These losses are classified as either friction losses or dynamic losses.

Duct Design Fundamentals

Pressure Changes During Flow in Ducts – Graphically



Duct Design Fundamentals

Pressure Losses in Duct Systems

Two Types of Losses

Friction Losses

Produced whenever moving air flows in contact with a fixed boundary

Dynamic Losses

Result of turbulence or changes in size, shape, direction, or volume flow rate

Duct Design Fundamentals

Pressure Losses

Darcy-Weisbach Equation

Darcy-Weisbach Equation

$$\Delta p_t = \left(\frac{f\ L}{D_h} p_v\right) + \sum(C) * p_v$$

Duct Design Fundamentals
Darcy-Weisbach Equation

$$D_h = \frac{4A_d}{P}$$ which is known as **Hydraulic Diameter**.

$$A_d = \frac{\pi D^2}{4}, P = \pi D$$ Round

$$A_d = WH, P = 2(W + H)$$ Rectangular

$$A_d = \frac{\pi a^2}{4} + a(A - a), P = \pi a + 2(A - a)$$ Flat Oval

Duct Design Fundamentals

Pressure Losses – Friction

The left-hand side of the Darcy-Weisbach Equation, which is the Darcy Equation, calculates the friction loss.

$$\Delta p_f = \left(\frac{f\ L}{D_h} p_v\right)$$

Duct Design Fundamentals

Pressure Losses – Friction

Colebrook Equation

$$\frac{1}{\sqrt{f}} = -2\,log\left(\frac{\varepsilon}{3.7\,Dh} + \frac{2.51}{Re\sqrt{f}}\right)$$

The Colebrook equation was developed to calculate the friction factor, *f*, requires you to also know the Reynolds Number, Re and the absolute roughness, ε, which is determined experimentally. Values of ε are available in the SMACNA HVAC SYSTEMS DUCT DESIGN MANUAL, FOURTH EDITION – DECEMBER 2006, Table A-1, pg A.4. A common value to remember is 0.0003 ft for standard galvanized material which is what the friction chart is based on. The Colebrook equation value of *f* must be solved for iteratively

Duct Design Fundamentals

Pressure Losses – Friction

Duct Material	Roughness Category	Absolute Roughness ε_1 (ft)	Absolute Roughness ε_1 (mm)
Uncoated carbon steel, clean (Moody 1944) (0.00015 ft) (0.05 mm) PVC plastic pipe (Swim 1982) (0.0003 to 0.00015 ft) (0.01 to 0.05 mm) Aluminum (Hutchinson 1953) (0.00015 to 0.0002 ft) (0.04 to 0.06 mm)	Smooth	0.0001	0.03
Galvanized steel, longitudinal seams, 4 ft (1200 mm) joints (Griggs 1987) (0.00016 to 0.00032 ft) (0.05 to 0.1 mm)	Medium Smooth	0.0003	0.09
Galvanized steel, spiral seam with 1, 2, and 3ribs, 12 ft (3600 mm) joints (Jones 1979, Griggs 1987) (0.00018 to 0.00038 ft) (0.05 to 0.12 mm)	(New Duct Friction Loss Chart)		
Hot-dipped galvanized steel, longitudinal seams, 2.5ft (760 mm) joints (Wright 1945) (0.0005 ft) (0.15 mm)	Old Average	0.0005	0.15
Fibrous glass duct, rigid Fibrous glass duct liner, air side with facing material (Swim 1978) (0.005 ft) (1.5 mm)	Medium Rough	0.003	0.9
Fibrous glass duct liner, air side spray coated (Swim 1978) (0.015 ft) (4.5 mm) Flexible duct, metallic, (0.004 to 0.007 ft (1.2 to 2.1 mm) when fully extended) Flexible duct, all types of fabric and wire (0.0035 to 0.015 ft (1.0 to 4.6 mm) when fully extended) Concrete (Moody 1944) (0.001 to 0.01 ft) (0.3 to 3.0 mm)	Rough	0.01	3.0

Table A–1 Duct Material Roughness Factors

$$\frac{\varepsilon}{3.7\,D_h} + \frac{2.51}{Re\sqrt{f}}$$

Duct Design Fundamentals

Pressure Losses – Friction

Reynolds Number

The Reynolds Number, Re is the ratio of the inertia force to the viscous force caused by changes in velocity.

The Reynolds Number is calculated from: $$Re = \frac{\rho D_h V}{\mu}$$

Air density (ρ) and dynamic viscosity (μ) are obtained from a Handbook or by using a calculator with psychometric routines.

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon}{3.7\,D_h} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

At standard air Conditions: $$Re = 8.56 D_h V$$

Duct Design Fundamentals

Pressure Losses – Friction

Comparison of Different Velocities and Materials

Example: Calculate the Friction Loss in 100 ft of rectangular duct 24" x 32" at 1000 fpm, 2000 fpm, 3000 fpm and 4000 fpm for standard galvanized metal (ε = 0.0003 ft) and lined duct (ε = 0.003 ft)

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon}{3.7\,D_h} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

Duct Design Fundamentals

Pressure Losses – Friction

Duct Material	Roughness Category	Absolute Roughness ε_1	
		ft	mm
Uncoated carbon steel, clean (Moody 1944) (0.00015 ft) (0.05 mm) PVC plastic pipe (Swim 1982) (0.0003 to 0.00015 ft) (0.01 to 0.05 mm) Aluminum (Hutchinson 1953) (0.00015 to 0.0002 ft) (0.04 to 0.06 mm)	Smooth	0.0001	0.03
Galvanized steel, longitudinal seams, 4 ft (1200 mm) joints (Griggs 1987) (0.00016 to 0.00032 ft) (0.05 to 0.1 mm)	Medium Smooth	0.0003	0.09
Galvanized steel, spiral seam with 1, 2, and 3ribs, 12 ft (3600 mm) joints (Jones 1979, Griggs 1987) (0.00018 to 0.00038 ft) (0.05 to 0.12 mm)	(New Duct Friction Loss Chart)		
Hot-dipped galvanized steel, longitudinal seams, 2.5ft (760 mm) joints (Wright 1945) (0.0005 ft) (0.15 mm)	Old Average	0.0005	0.15
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Fibrous glass duct liner, air side spray coated (Swim 1978) (0.015 ft) (4.5 mm) Flexible duct, metallic, (0.004 to 0.007 ft (1.2 to 2.1 mm) when fully extended) Flexible duct, all types of fabric and wire (0.0035 to 0.015 ft (1.0 to 4.6 mm) when fully extended) Concrete (Moody 1944) (0.001 to 0.01 ft) (0.3 to 3.0 mm)	Rough	0.01	3.0

Table A–1 Duct Material Roughness Factors

$$\frac{\varepsilon}{3.7\,D_h} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\Bigg)$$

Duct Design Fundamentals

Pressure Losses – Friction

Comparison of Different Velocities and Materials

Solution		
L =	100	ft
Area =	5.33	ft^2
P =	9.33	ft
D_h =	2.29	ft
$\rho = 0.075\ lb_m/ft^3$		Standard Conditions

			Standard Galvanized (ε = 0.0003 ft)		Lined Duct (ε = 0.003 ft)	
Velocity (fpm)	Velocity Pressure p_v (inch water)	Q = AV Flow Rate (cfm)	Friction Factor, *f*	Δp_f Friction Loss (inch water)	Friction Factor, *f*	Δp_f Friction Loss (inch water)
1000	0.06	5333	0.0163	0.04	0.0220	0.06
2000	0.25	10667	0.0148	0.16	0.0215	0.23
3000	0.56	16000	0.0142	0.35	0.0213	0.52
4000	0.99	21333	0.0139	0.60	0.0212	0.92

$$\Delta p_f = \left(\frac{f\ L}{D_h} p_v\right)$$

Duct Design Fundamentals

Pressure Losses – Friction

Comparison of Different Velocities and Roughness

Observations:

- Factor of ~15 increasing pressure loss from 1000 – 4000 fpm
  - 0.04 to 0.60 inch water

- Factor of ~ 1.5 increasing ε by a factor of 10
  - 0.02 to 0.32 inch of water increase

Duct Design Fundamentals

Using a Friction Loss Chart

Example: 1000 cfm in 10” Dia

Result: 0.40 in wg/100 ft

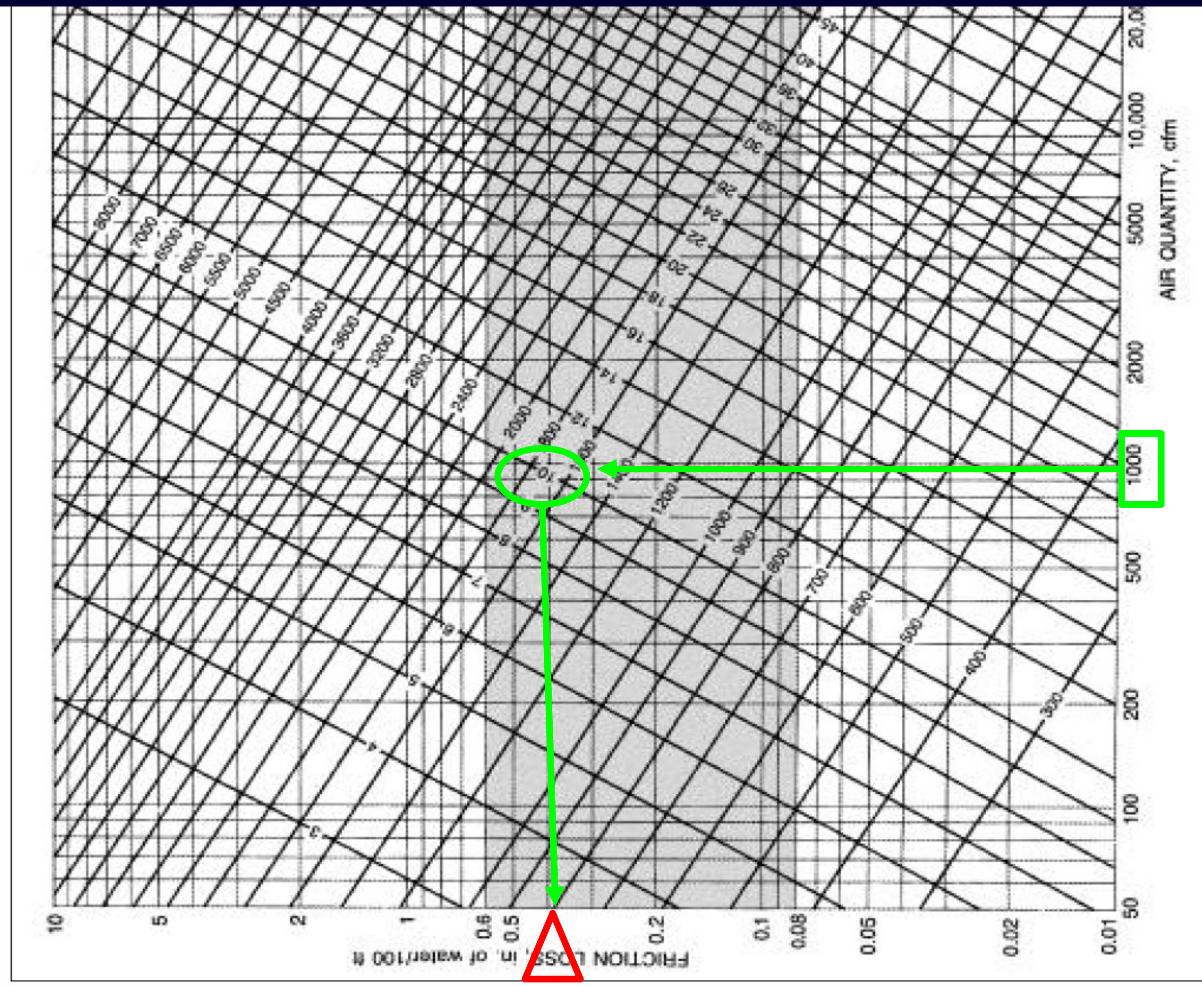


FIGURE A–1 DUCT FRICTION LOSS CHART

Duct Design Fundamentals

Pressure Losses – Friction

Equivalent Duct Sizes for Same Friction Loss Shape Options

- Most duct systems are originally sized with round ducts. For many reasons (head room, available equipment), the designer or engineer may want to use an equivalent rectangular or flat oval size.
- The following equations calculate the round duct diameter that will give the same friction loss as the rectangular or flat oval duct, at the same volume flow rate (cfm).
- Most of the time however, the round size is known, and the designer wants to determine one of the dimensions of the rectangular or flat oval section. (For example, the ceiling area may only allow a 12-inch minor axis).

Duct Design Fundamentals

Pressure Losses – Friction

Equivalent Duct Sizes for Same Friction Loss

Rectangular:

$$D_e = 1.55\,\frac{A^{0.625}}{P^{0.25}} = 1.30\,\frac{(WH)^{0.625}}{(W+H)^{0.25}}$$

Flat Oval:

$$D_e = 1.55\,\frac{A^{0.625}}{P^{0.25}} = 1.55\,\frac{[\frac{\pi a}{4}+a(A-a)\ ^{0.625}]}{[\pi a+2(A-a)]^{0.25}}$$

Because of the power relationships these must also be solved iteratively to get the original equivalent round size. Fortunately tables, ductulators, spreadsheets and other programs have been created to calculate the equations. See Appendix A, Tables A-2 and A-3 of the SMACNA HVAC SYSTEMS DUCT DESIGN manual – FOURTH EDITION – DECEMBER 2006

Duct Design Fundamentals

Pressure Losses – Friction

Equivalent Duct Sizes for Same Friction Loss

Side Rectangular Duct	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	Side Rectangular Duct
6	6.6																				6
7	7.1	7.7																			7
8	7.6	8.2	8.7																		8
9	8.0	8.7	9.3	9.8																	9
10	8.4	9.1	9.8	10.4	10.9																10
11	8.8	9.5	10.2	10.9	11.5	12.0															11
12	9.1	9.9	10.7	11.3	12.0	12.6	13.1														12
13	9.5	10.3	11.1	11.8	12.4	13.1	13.7	14.2													13
14	9.8	10.7	11.5	12.2	12.9	13.5	14.2	14.7	15.3												14
15	10.1	11.0	11.8	12.6	13.3	14.0	14.6	15.3	15.8	16.4											15

From:

Table A–2 Circulation Equivalents of Rectangular Ducts for Equal Friction and Capacity Dimensions (I–P)

Typo, "Circulation" should be "Circular"

Example: 12 x 7 Rectangular, 1000 cfm

Solution: From Table A-2 , the Equivalent Round Size is 9.9 inches. Use the friction chart at 1000 cfm in 9.9 inch Diameter to, friction loss is 0.4 in water/100 ft

Duct Design Fundamentals

Using a Friction Loss Chart

Example: 1000 cfm in 10” Dia

Result: 0.40 in wg/100 ft

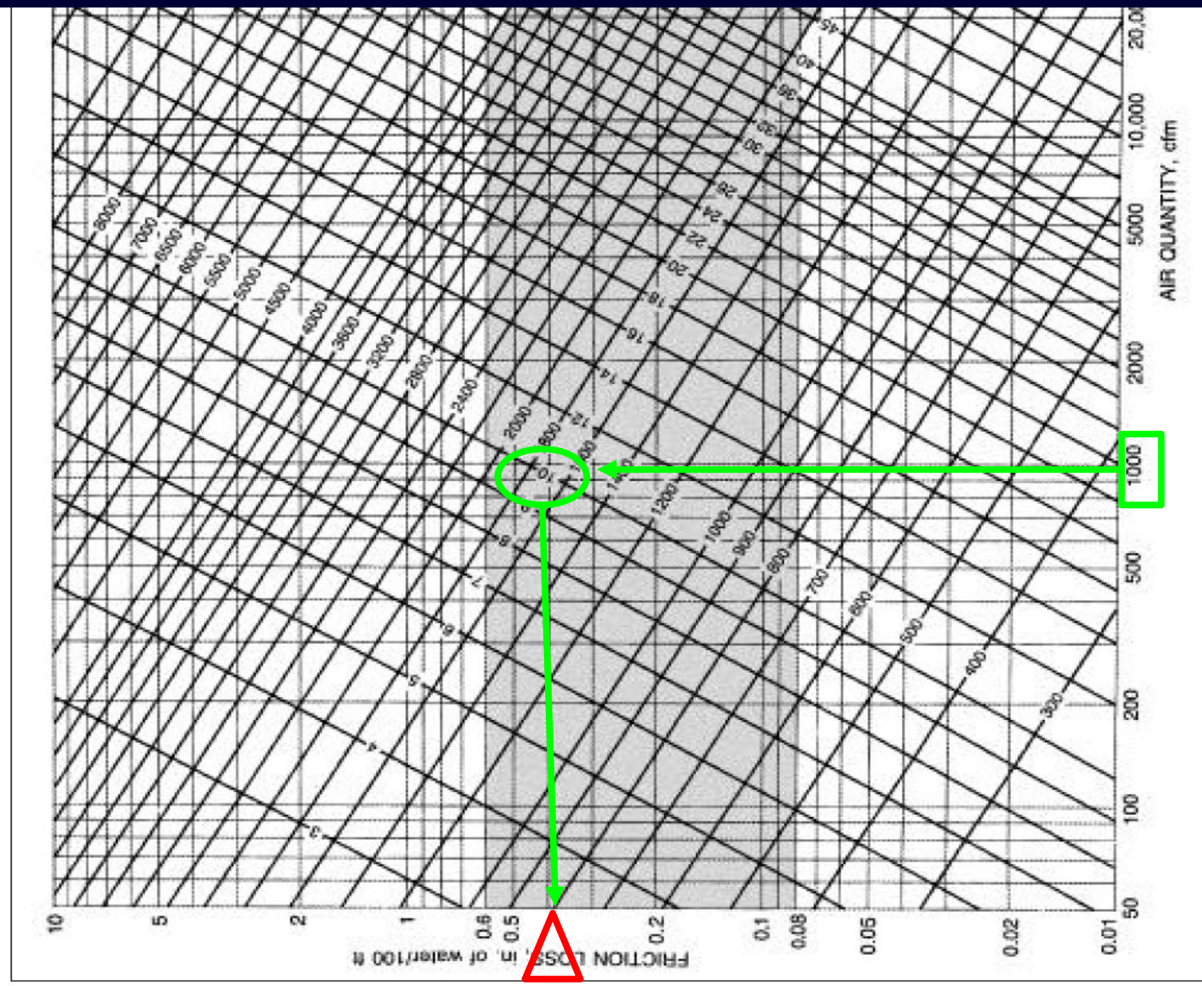


FIGURE A–1 DUCT FRICTION LOSS CHART

Duct Design Fundamentals

Pressure Losses – Friction

Equivalent Duct Sizes for Same Friction Loss

	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	26	28	30
7		5.7																	
8	5.1		6.6	6.9															
9	5.6	6.2		7.7															
10		6.7	7.3		8.	9.0													
11	6.0		7.9	8.4		9.8													
12	6.4	7.2		8.9	9.4		10.8	11.0											
13		7.6	8.4		10.1	10.6		11.9											
14	6.7		8.8	9.6		11.2	11.5												
15	7.0	8.0		10.1	10.7					13.8									
16			9.3					13.4	13.6										
17	7.3	8.4					12.9												
18					11.7	12.4				15.3									
19																			
20																			
21																			
22																			
23																			

Table A–3 Spiral Flat–Oval Duct (Nominal Sizes)
(Diameter of the round duct which will have the capacity and friction equivalent to the actual duct size)

Example: 12 x 7 Flat Oval 1000 cfm
Solution: From Table A-3 , the Equivalent Round Size is 9.4 inches. Use the friction chart at 1000 cfm in 9.4-inch Diameter to, friction loss is 0.5 in water/100 ft

Duct Design Fundamentals

Using a Friction Loss Chart

Example: 1000 cfm in 10” Dia

Result: 0.50 in wg/100 ft

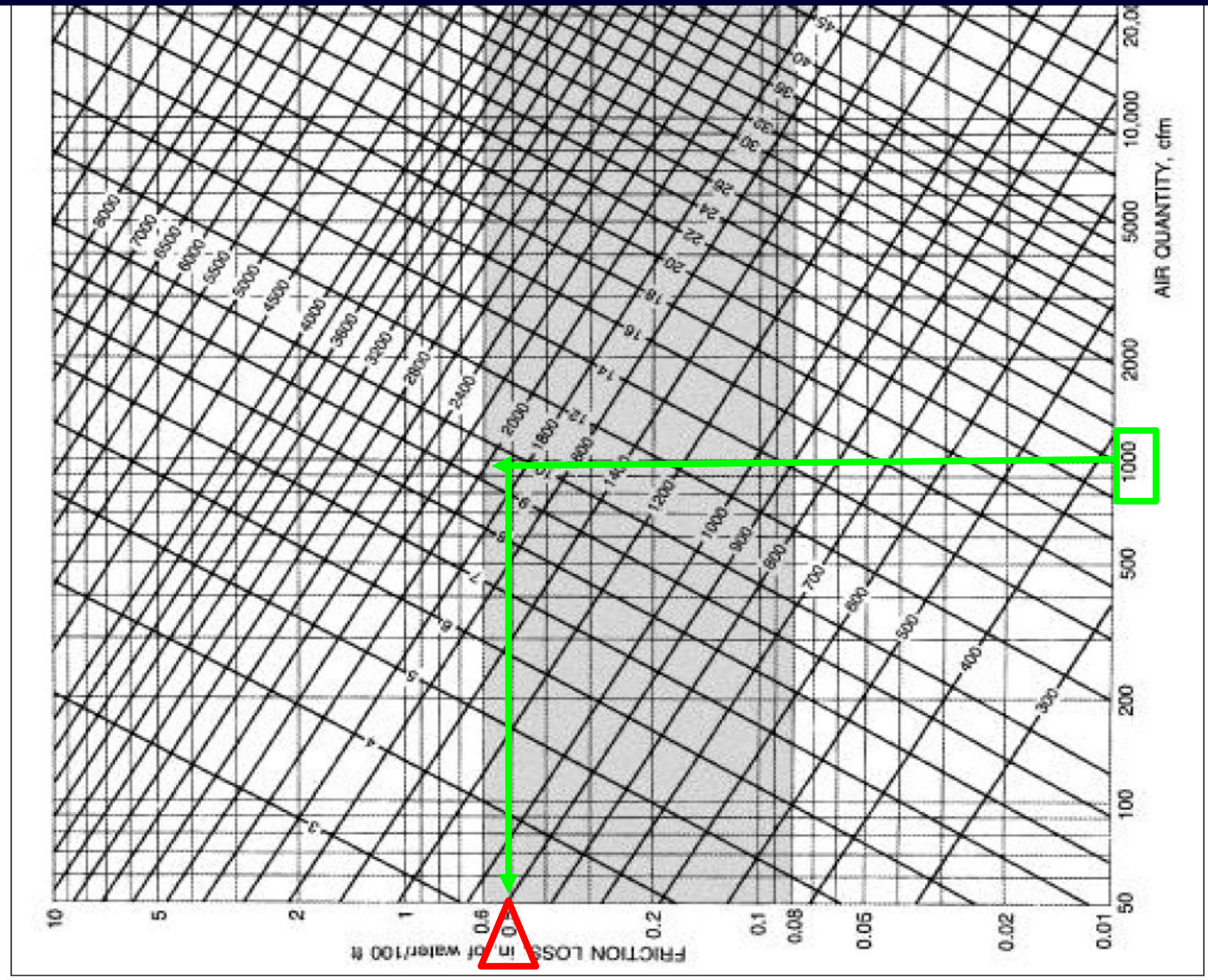


FIGURE A–1 DUCT FRICTION LOSS CHART

Duct Design Fundamentals

Pressure Losses in Duct Systems

Two Types of Losses

Friction Losses

Produced whenever moving air flows in contact with a fixed boundary

Dynamic Losses

Result of turbulence or changes in size, shape, direction, or volume flow rate

Duct Design Fundamentals

Pressure Losses

Darcy-Weisbach Equation

Darcy-Weisbach Equation

$$\Delta p_t = \left(\frac{f\ L}{D_h} p_v\right) + \sum(C) * p_v$$

Duct Design Fundamentals

Pressure Losses – Dynamic

The right-hand side of the Darcey-Weisbach Equation, which is the Weisbach Equation, calculates the dynamic loss.

$$\Delta p_{t,fittings} = \sum (C) * p_v$$

Duct Design Fundamentals

Pressure Losses – Dynamic

- Experimentally determined loss coefficients are generally used to calculate total pressure dynamic losses for fittings or components.
- Loss coefficients are a function of velocity pressure, p_v
- If the section velocity pressure is used, all loss coeffients can be added and multiplied by the sections velocity pressure to determine the dynamic losses for the section

$$\Delta p_{t,fittings} = \sum(C) * p_v$$

- If the common velocity pressure is used , then the individual losses must be totaled.

$$\Delta p_{t,fittings} = \sum[C * p_v]$$

Duct Design Fundamentals

Pressure Losses – How Loss Coefficients are Determined

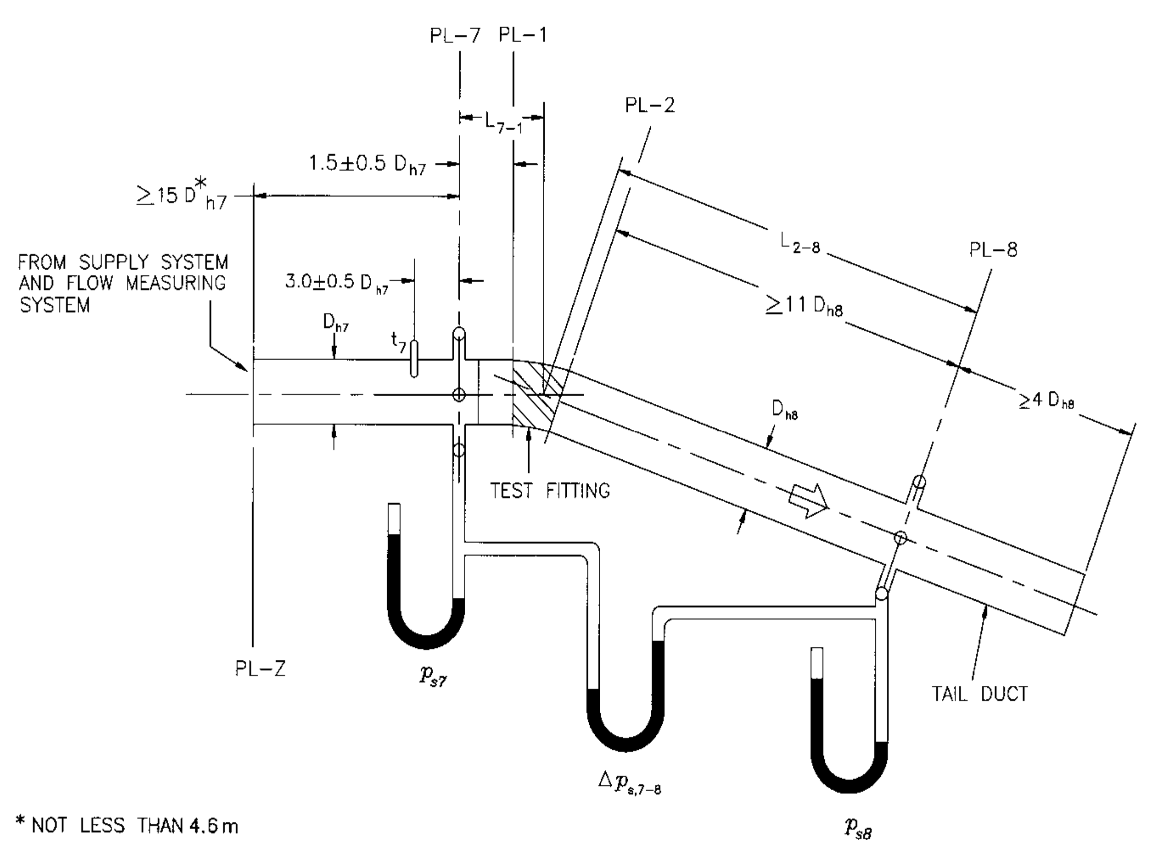
$$\Delta p_{t,fitting} = C * pv$$

$$C = \frac{\Delta p_{t,fitting}}{p_v}$$

Every fitting has associated loss coefficients, which can be determined experimentally by measuring the total pressure loss through the fitting for varying flow conditions. Often the pressure loss is regressed vs the velocity pressure and the slope of the regression is the loss coefficient.

Duct Design Fundamentals

Pressure Losses – How Loss Coefficients are Determined



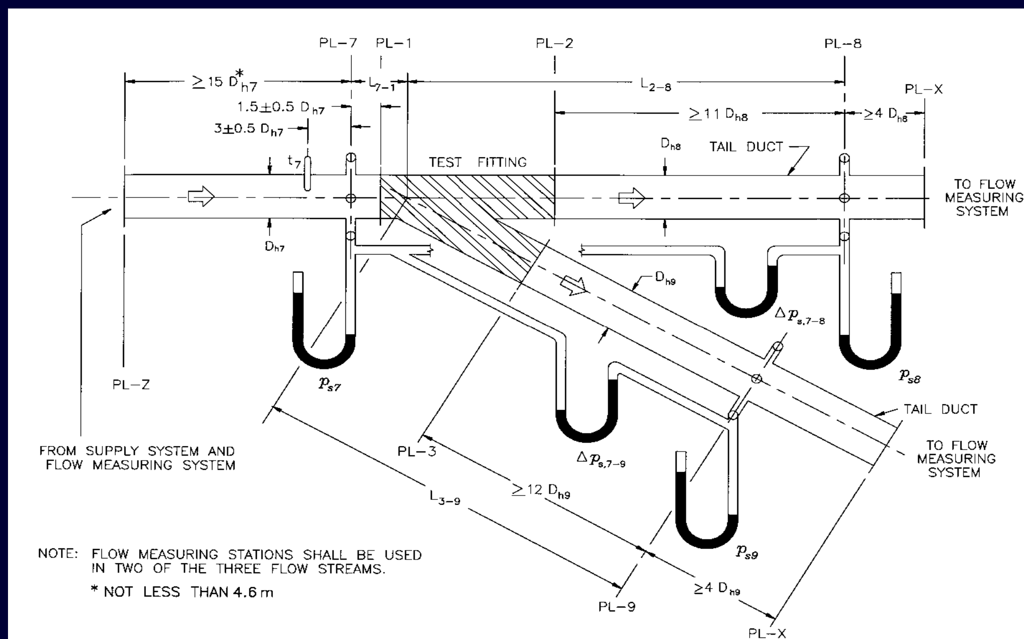
$$\Delta p_{t,1\text{-}2} = \Delta p_{s,7\text{-}8} + (p_{v7} - p_{v8}) - (L_{7\text{-}1}\Delta p_{f,7\text{-}1} + L_{2\text{-}8}\Delta p_{f,2\text{-}8})$$

$$C = \frac{\Delta p_{t,1-2}}{p_{v8}}$$

$L_{7\text{-}1}$ is the measured length from the upstream static pressure measurement plane to the center point of the fitting, and $L_{2\text{-}8}$ is the measured length from the center point of the fitting to the downstream static pressure measurement plane

Duct Design Fundamentals

Pressure Losses – How Loss Coefficients are Determined, Diverging Flow



$L_{7\text{-}1}$, $L_{2\text{-}8}$ and $L_{3\text{-}9}$ are measured to the centerline of the fitting

$$C_s = \frac{\Delta p_{t,1-2}}{p_{v8}}$$

$$\text{Main: } \Delta p_{t,1\text{-}2} = \Delta p_{s,7\text{-}8} + (p_{v7} - p_{v8}) - (L_{7\text{-}1}\Delta p_{f,7\text{-}1} + L_{2\text{-}8}\Delta p_{f,2\text{-}8})$$

$$\text{Branch: } \Delta p_{t,1\text{-}3} = \Delta p_{s,7\text{-}9} + (p_{v7} - p_{v9}) - (L_{7\text{-}1}\Delta p_{f,7\text{-}1} + L_{3\text{-}9}\Delta p_{f,3\text{-}9})$$

$$C_b = \frac{\Delta p_{t,1-3}}{p_{v7}}$$

Duct Design Fundamentals

Pressure Losses – How Loss Coefficients Branch Fittings are Determined when Referenced to the Common Section

For diverging flow , if the loss coefficient is referenced to the upstream velocity pressure

$$\Delta p_{t,u-d} = C_{u\_d} * p_{vu}$$

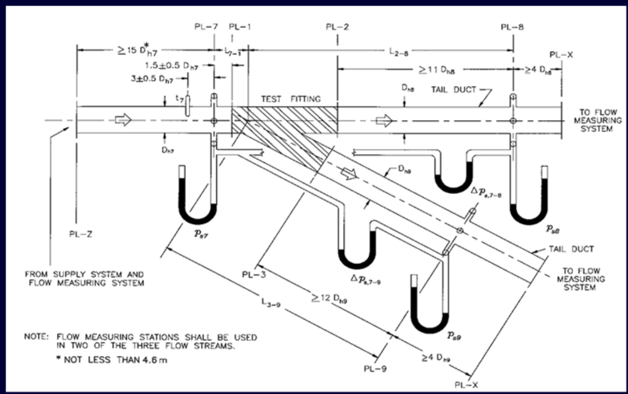
Since the total pressure loss has to be the same, then:

$$\Delta p_{t,1-2} = C_{section} * p_{v,section}$$

$$C_{section} * p_{v,section} = C_{u\_d} * p_{vu}$$

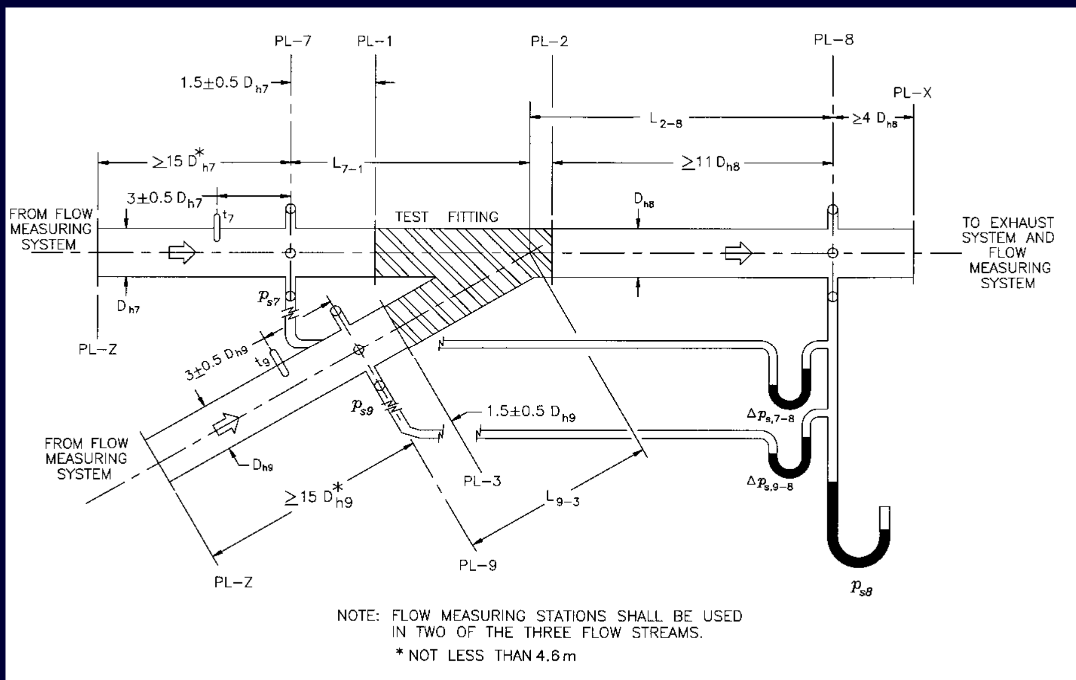
or

$$C_{section} = C_{u\_d} \frac{p_{vu}}{p_{v,section}}$$



Duct Design Fundamentals

Pressure Losses – How Loss Coefficients are Determined, Converging Flow



$L_{7\text{-}1}$, $L_{2\text{-}8}$ and $L_{9\text{-}3}$ are measured to the centerline of the fitting

Main: $\Delta p_{t,1\text{-}2} = \Delta p_{s,7\text{-}8} + (p_{v7} - p_{v8}) - (L_{7\text{-}1}\Delta p_{f,7\text{-}1} + L_{2\text{-}8}\Delta p_{f,2\text{-}8})$

$$C_s = \frac{\Delta p_{t,1-2}}{p_{v7}}$$

Branch: $\Delta p_{t,3\text{-}2} = \Delta p_{s,9\text{-}8} + (p_{v9} - p_{v8}) - (L_{9\text{-}3}\Delta p_{f,9\text{-}3} + L_{2\text{-}8}\Delta p_{f,2\text{-}8})$

$$C_b = \frac{\Delta p_{t,3-2}}{p_{v9}}$$

Duct Design Fundamentals

Pressure Losses – How Loss Coefficients Branch Fittings are Determined when Referenced to the Common Section

For converging flow , if the loss coefficient is referenced to the downstream velocity pressure

$$\Delta p_{t,u-d} = C_{u\_d} * p_{vd}$$

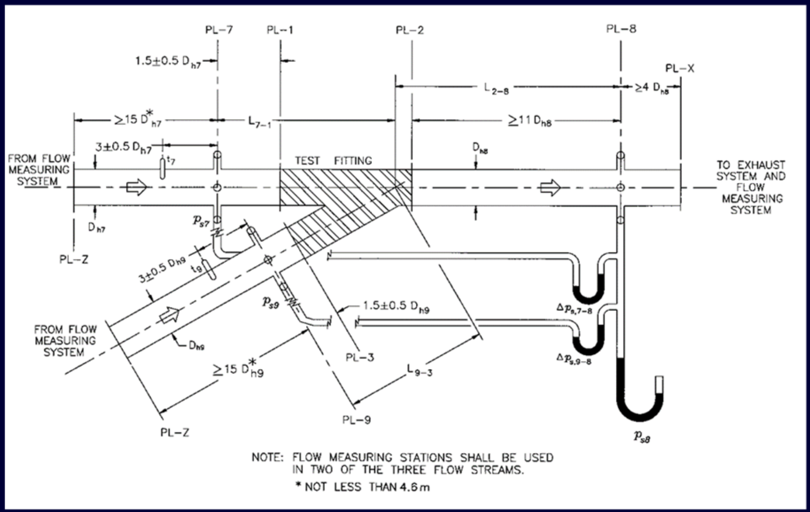
Since the total pressure loss has to be the same, then:

$$\Delta p_{t,1-2} = C_{section} * p_{v,section}$$

$$C_{section} * p_{v,section} = C_{u\_d} * p_{vd}$$

or

$$C_{section} = C_{u\_d} \frac{p_{vd}}{p_{v,section}}$$



Duct Design Fundamentals

Loss Coefficient Tables

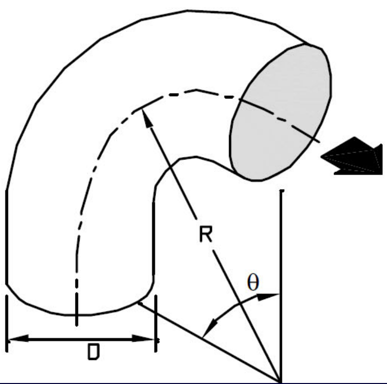
- Loss coefficients are often published in table form or equations. See tables A-7 to A-15 in the HVAC SYSTEMS DUCT DESIGN manual.
- If a branched fitting, check to see what referenced velocity pressure is used.
- If non-standard conditions are encountered, use the density correction factors from Figure A-4

Example: 10" Dia, 90° Smooth Radius Elbow, R/D = 1.5. Airflow is 1000 acfm. Elevation is 5000 ft.

Duct Design Fundamentals

Loss Coefficient Tables

A. ELBOW, SMOOTH RADIUS (DIE STAMPED), ROUND



Coefficients for 90° Elbows (*See* Note 1)						
R/D	0.5	0.75	1.0	1.5	2.0	2.5
C	0.71	0.33	0.22	0.15	0.13	0.12

Note 1: For angles other than 90° multiply by the following factors:											
θ	0°	20°	30°	45°	60°	75°	90°	110°	130°	150°	180°
K	0	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

Table A-7A, page A.15

Solution: Area = $(\pi \times 10^2/4)/144 = 0.55$ ft^2

Velocity = 1000/0.55 = 1833 fpm

Velocity pressure at standard conditions, $p_v = (1833/4005)^2 = 0.21$ inch of water

C = 0.15 from Table A-7A, Ke from Figure A-4, A.14 (elevation correction factor for density) = 0.83

Duct Design Fundamentals

Loss Coefficient Tables

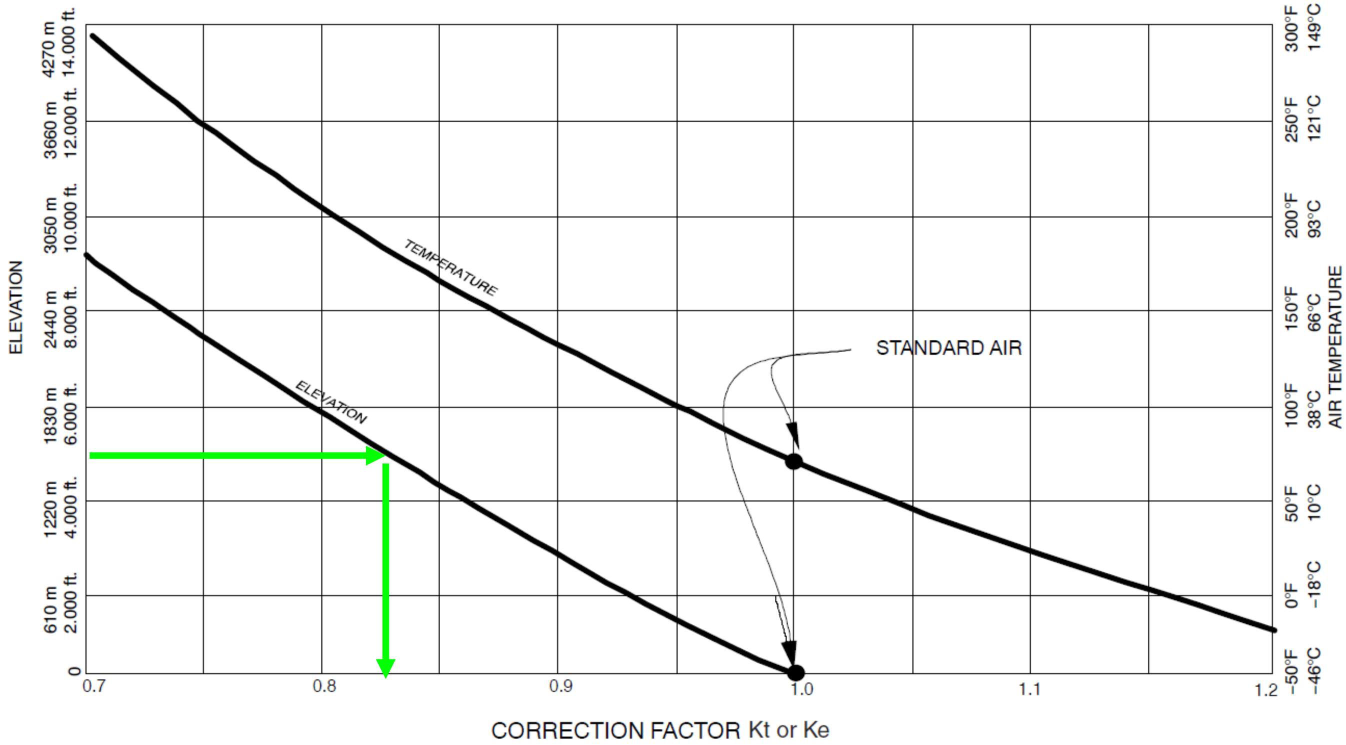


FIGURE A–4 AIR DENSITY FRICTION CHART CORRECTION FACTORS

Duct Design Fundamentals

Loss Coefficient Tables

$\Delta p_t = 0.15 \times 0.21 \times 0.83 = 0.03$ inch of water

Duct Design Fundamentals

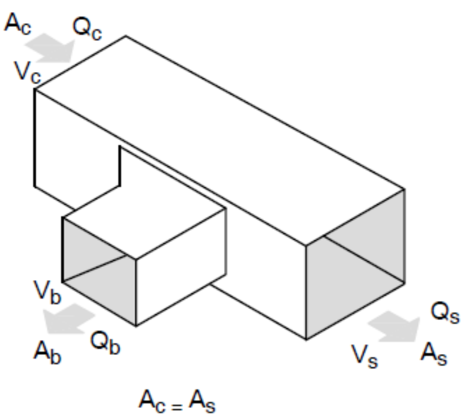
Loss Coefficient Tables

Example: Diverging Tee 45° Rectangular Main and Branch. Main is 10" x 10", Branch is 7" x 7". Airflow Main is 1000 cfm. AirFlow Branch is 500 cfm. Standard air.

Duct Design Fundamentals

Loss Coefficient Tables

N. TEE, 45° RECTANGULAR MAIN AND BRANCH



Branch, Coefficient C (*See* Note 8)									
V_b/V_c	Q_b/Q_c								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.2	0.91								
0.4	0.81	0.79							
0.6	0.77	0.72	0.70						
0.8	0.78	0.73	0.69	0.66					
1.0	0.78	0.98	0.85	0.79	0.74				
1.2	0.90	1.11	1.16	1.23	1.03	0.86			
1.4	1.19	1.22	1.26	1.29	1.54	1.25	0.92		
1.6	1.35	1.42	1.55	1.59	1.63	1.50	1.31	1.09	
1.8	1.44	1.50	1.75	1.74	1.72	2.24	1.63	1.40	1.17

Page A.33

Note 8: A = Area (sq. in.). Q= airflow (cfm). V= Velocity (fpm)
Use the velocity pressure (V_p) of the upstream section. Fitting loss TP = C × V_p

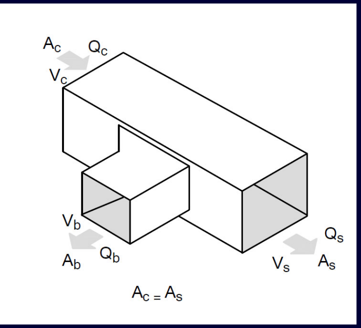
$V_p = p_{vc}$

Table A–11 Loss Coefficients, Diverging Junctions (Tees, Wyes) (Continued)

Duct Design Fundamentals

Loss Coefficient Tables

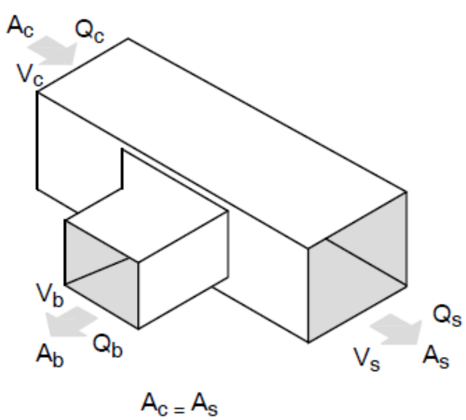
Solution: Area Main, A_c = (10 x 10) /144 = 0.69 ft^2
Area Branch, A_b = (7 x 7) /144 = 0.34 ft^2
Velocity, V_c = 1000/0.69 = 1440 fpm
Velocity, V_b = 500/0.34 = 1469 fpm
Velocity pressure p_{vc} = $(1440/4005)^2$ = 0.13 in H_20
Velocity pressure p_{vb} = $(1469/4005)^2$ = 0.13 in H_20
Velocity Ratio, V_b / V_c = 1469/1440 = 1.02
Flow Rate Ratio, Q_b / Q_c = 500/1000 = 0.50



Duct Design Fundamentals

Loss Coefficient Tables

N. TEE, 45° RECTANGULAR MAIN AND BRANCH



Branch, Coefficient C (*See* Note 8)									
V_b/V_c	Q_b/Q_c								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.2	0.91								
0.4	0.81	0.79							
0.6	0.77	0.72	0.70						
0.8	0.78	0.73	0.69	0.66					
1.0	0.78	0.98	0.85	0.79	0.74				
1.2	0.90	1.11	1.16	1.23	1.03	0.86			
1.4	1.19	1.22	1.26	1.29	1.54	1.25	0.92		
1.6	1.35	1.42	1.55	1.59	1.63	1.50	1.31	1.09	
1.8	1.44	1.50	1.75	1.74	1.72	2.24	1.63	1.40	1.17

Page A.33

Table A-11N, $C_b = 0.74$

$\Delta p_{t,c-b} = 0.74 \times 0.13 = 0.10$ inch water

When the downstream section of the main stays the same diameter, the loss coefficient is approximately 0.00 and $\Delta p_{t,c-s} = 0.00$ inch of water

Duct Design Fundamentals

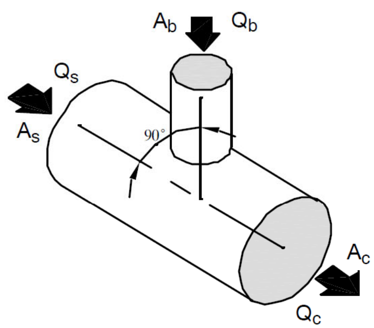
Loss Coefficient Tables

Example: Converging Tee 90° Round Main and Branch. Main is 10" , Branch is 7" . Airflow Main is 1000 cfm. AirFlow Branch is 500 cfm. Standard air.

Table A-10,
Page A.25

Note 8: A = Area (sq. in.). Q= airflow (cfm). V= Velocity (fpm)
Use the velocity pressure (p_{vc}) of the downstream section. Fitting loss TP = C · p_{vc}

B. CONVERGING TEE, 90°, ROUND



Branch, Coefficient C (*See* Note 8)							
O_b/Q_c	A_b/A_c						
	0.1	0.2	0.3	0.4	0.6	0.8	1.0
0.1	0.40	-0.37	-0.51	-0.46	-0.50	-0.51	-0.52
0.2	3.8	0.72	0.17	-0.02	-0.14	-0.18	-0.24
0.3	9.2	2.3	1.0	0.44	0.21	0.11	-0.08
0.4	16	4.3	2.1	0.94	0.54	0.40	0.32
0.5	26	6.8	3.2	1.1	0.66	0.49	0.42
0.6	37	9.7	4.7	1.6	0.92	0.69	0.57
0.7	43	13	6.3	2.1	1.2	0.88	0.72
0.8	65	17	7.9	2.7	1.5	1.1	0.86
0.9	82	21	9.7	3.4	1.8	1.2	0.99
1.0	101	26	12	4.0	2.1	1.4	1.1

Main, Coefficient C (*See* Note 8)										
O_b/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C	0.16	0.27	0.38	0.46	0.53	0.57	0.59	0.60	0.59	0.55

Duct Design Fundamentals

Loss Coefficient Tables

Solution:

Area Main, $A_c = (\pi 10^2 /4) /144 = 0.55\ ft^2$

Area Branch, $A_b = (\pi 7^2 /4) /144 = 0.24\ ft^2$

Velocity, $V_c = 1000/0.55 = 1818$ fpm

Velocity, $V_b = 500/0.24 = 2083$ fpm

Velocity pressure $p_{vc} = (1818/4005)^2 = 0.21$ in water

Velocity pressure $p_{vb} = (2083/4005)^2 = 0.27$ in water

Flow Rate Ratio, $Q_b / Q_c = 500/1000 = 0.50$

Area Rate Ratio, $A_b / A_c = 0.24/0.55 = 0.44$

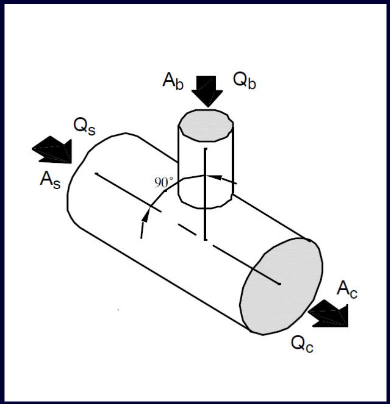


Table A-10, Page A.25

Duct Design Fundamentals

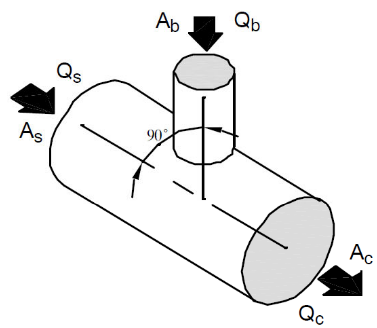
Loss Coefficient Tables

Example: Converging Tee 90° Round Main and Branch. Main is 10", Branch is 7". Airflow Main is 1000 cfm. AirFlow Branch is 500 cfm. Standard air.

Table A-10, Page A.25

Note 8: A = Area (sq. in.). Q= airflow (cfm). V= Velocity (fpm)
Use the velocity pressure (p_{vc}) of the downstream section. Fitting loss TP = C · p_{vc}

B. CONVERGING TEE, 90°, ROUND



C_b= 1.0

Branch, Coefficient C (*See* Note 8)

Q_b/Q_c	A_b/A_c 0.1	0.2	0.3	0.4	0.6	0.8	1.0
0.1	0.40	-0.37	-0.51	-0.46	-0.50	-0.51	-0.52
0.2	3.8	0.72	0.17	-0.02	-0.14	-0.18	-0.24
0.3	9.2	2.3	1.0	0.44	0.21	0.11	-0.08
0.4	16	4.3	2.1	0.94	0.54	0.40	0.32
0.5	26	6.8	3.2	1.1	0.66	0.49	0.42
0.6	37	9.7	4.7	1.6	0.92	0.69	0.57
0.7	43	13	6.3	2.1	1.2	0.88	0.72
0.8	65	17	7.9	2.7	1.5	1.1	0.86
0.9	82	21	9.7	3.4	1.8	1.2	0.99
1.0	101	26	12	4.0	2.1	1.4	1.1

Main, Coefficient C (*See* Note 8)

Q_b/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C	0.16	0.27	0.38	0.46	0.53	0.57	0.59	0.60	0.59	0.55

Duct Design Fundamentals

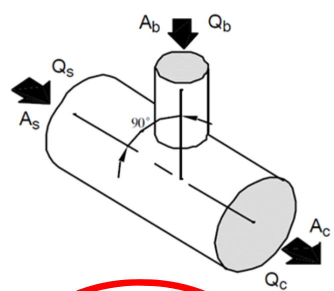
Loss Coefficient Tables

Solution: $C_b = 1.0$, $C_s = 0.53$

$\Delta p_{t,b\text{-}c} = 1.0 \times 0.21 = 0.21$ inch water

$\Delta p_{t,s\text{-}c} = 0.53 \times 0.21 = 0.11$ inch water

B. CONVERGING TEE, 90°, ROUND



$C_b = 1.0$

Branch, Coefficient C (*See* Note 8)

Q_b/Q_c	A_b/A_c 0.1	0.2	0.3	0.4	0.6	0.8	1.0
0.1	0.40	-0.37	-0.51	-0.46	-0.50	-0.51	-0.52
0.2	3.8	0.72	0.17	-0.02	-0.14	-0.18	-0.24
0.3	9.2	2.3	1.0	0.44	0.21	0.11	-0.08
0.4	16	4.3	2.1	0.94	0.54	0.40	0.32
0.5	26	6.8	3.2	1.1	0.66	0.49	0.42
0.6	37	9.7	4.7	1.6	0.92	0.69	0.57
0.7	43	13	6.3	2.1	1.2	0.88	0.72
0.8	65	17	7.9	2.7	1.5	1.1	0.86
0.9	82	21	9.7	3.4	1.8	1.2	0.99
1.0	101	26	12	4.0	2.1	1.4	1.1

Main, Coefficient C (*See* Note 8)

Q_b/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C	0.16	0.27	0.38	0.46	0.53	0.57	0.59	0.60	0.59	0.55

Table A-10, Page A.25

Duct Design Fundamentals

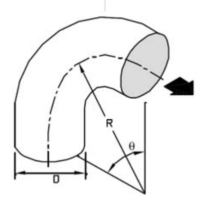
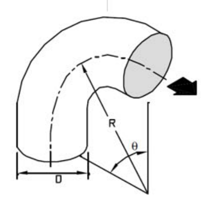
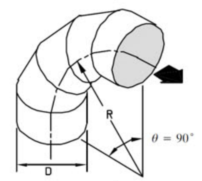
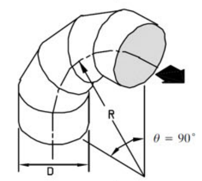
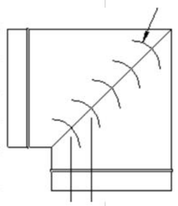
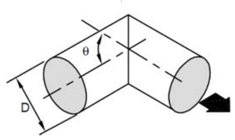
Fitting Efficiency – Round Elbows

Comparison of Round Elbow Losses Loss Coefficients from SMACNA HVAC Systems Duct Design Appendix A

D = 12 inch

Area = 0.79 ft^2

ρ = 0.075 lb_m/ft^3 Standard Conditions

														
			Smooth Radius, R/D = 1.5 (Table A-7A)		**Smooth Radius, R/D = 0.5 (Table A-7A)**		**5 Piece, R/D = 1.5 (Table A-7B)**		**3 Piece, R/D = 1.5 (Table A-7B)**		**Mitered w Vanes (ASHRAE DFDB CD3-20)**		**Mitered without Vanes (Table A-7C)**	
Velocity (fpm)	**Velocity Pressure p_v (inch water)**	**Q = AV Flow Rate (cfm)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**
1000	0.06	785	0.15	0.01	0.71	0.04	0.24	0.01	0.34	0.02	0.45	0.03	1.2	0.07
2000	0.25	1571	0.15	0.04	0.71	0.18	0.24	0.06	0.34	0.09	0.45	0.11	1.2	0.30
3000	0.56	2356	0.15	0.08	0.71	0.40	0.24	0.13	0.34	0.19	0.45	0.25	1.2	0.67
4000	0.99	3142	0.15	0.15	0.71	0.70	0.24	0.24	0.34	0.34	0.45	0.45	1.2	1.19
			Best				Better				Good			

Duct Design Fundamentals

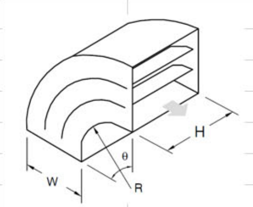
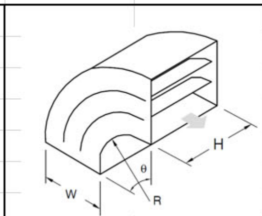
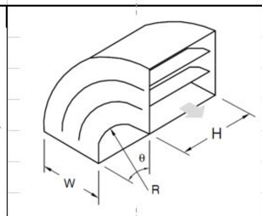
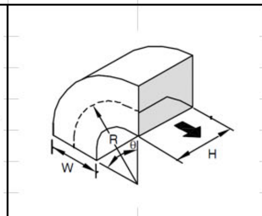
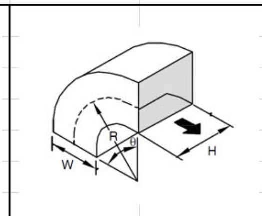
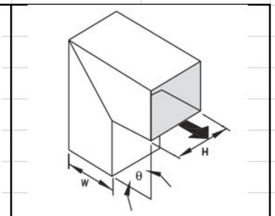
Fitting Efficiency – Rectangular Elbows

Comparison of Round Elbow Losses — Loss Coefficients from SMACNA HVAC Systems Duct Design Appendix A

W x H **12 x** 12 inches **H /W = 1.0**

Area = **1.00 ft^2**

ρ = 0.075 lb$_m$/ft^3 **Standard Conditions**

														
			Smooth Radius w 3 Splitter Vane R/W = 0.50 (Table A-7G)		**Smooth Radius w 2 Splitter Vanes R/W = 0.50 (Table A-7G)**		**Smooth Radius w 1 Splitter Vanes R/W = 0.50 (Table A-7G)**		**Smooth Radius without Vanes R/W = 1 (Table A-7F)**		**Smooth Radius without Vanes R/W = 1.5 (Table A-7F)**		**Mitered without Vanes (Table A-7D)**	
Velocity (fpm)	**Velocity Pressure p_v (inch water)**	**Q = AV Flow Rate (cfm)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**
1000	0.06	1000	0.01	0.00	0.02	0.00	0.05	0.00	0.21	0.01	0.17	0.01	1.2	0.07
2000	0.25	2000	0.01	0.00	0.02	0.01	0.05	0.01	0.21	0.05	0.17	0.04	1.2	0.30
3000	0.56	3000	0.01	0.01	0.02	0.01	0.05	0.03	0.21	0.12	0.17	0.10	1.2	0.67
4000	0.99	4000	0.01	0.01	0.02	0.02	0.05	0.05	0.21	0.21	0.17	0.17	1.2	1.19
			Best				Better				Good			

Duct Design Fundamentals

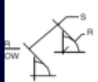
Fitting Efficiency – Rectangular Elbows

Comparison of Round Elbow Losses Loss Coefficients from SMACNA HVAC Systems Duct Design Appendix A

W x H **12 x** 12 inches **H /W = 1.0**

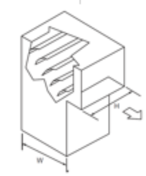
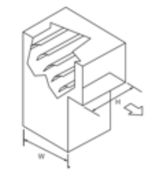
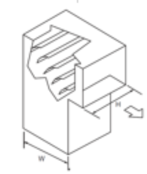
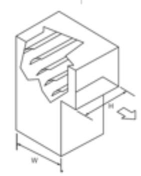
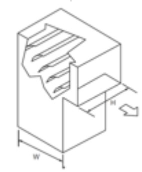
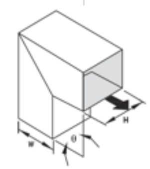
Area = **1.00** ft^2

ρ = 0.075 lb$_m$/ft^3 **Standard Conditions**



Single Thickness

Double hickness

														
			Single Thickness, Mitered w Turing Vanes, R=2.0, S=1.5 (Table A-7H)		**Single Thickness, Mitered w Turing Vanes, R=4.5, S=3.25 (Table A-7H)**		**Double Thickness, Mitered w Turing Vanes, R=4.5, S=3.25 (Table A-7H)**		**Double Thickness, Mitered w Turing Vanes, R=2.0, S=1.5 (Table A-7H)**		**Double Thickness, Mitered w Turing Vanes, R=2.0, S=2.25 (Table A-7H)**		**Mitered without Vanes (Table A-7D)**	
Velocity (fpm)	**Velocity Pressure p_v (inch water)**	**Q = AV Flow Rate (cfm)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**
1000	0.06	1000	0.24	0.01	0.26	0.02	0.27	0.02	0.43	0.03	0.53	0.03	1.2	0.07
1500	0.14	1500	0.23	0.03	0.24	0.03	0.25	0.04	0.42	0.06	0.53	0.07	1.2	0.17
2000	0.25	2000	0.22	0.05	0.23	0.06	0.24	0.06	0.41	0.10	0.50	0.12	1.2	0.30
2500	0.39	2500	0.20	0.08	0.22	0.09	0.23	0.09	0.40	0.16	0.49	0.19	1.2	0.47
			Best				Better		Good					

Notes:

1. Vanes with trailing edges have higher loss coefficients than standard construction.
2. Removing every other vane will double the pressure loss.
3. Turing vanes are 90°. If used in non-90° elbows, the pressure loss will increase.
4. Other elbow withut turning vane configurations can reduce the elbow loss coefficient, including:
 a 45° throat, 90° heel; radiused throat, 90° heal and a 45° throat, radiused heel.

Duct Design Fundamentals

Fitting Efficiency – Diverging Flow Branches

Comparison of Round Diverging Flow Fittings

Loss Coefficients from SMACNA HVAC Systems Duct Design Appendix A

D_c =	12	inch	A_c =	0.79	ft^2	Q_c =	1000	cfm	V_c =	1273	fpm
D_b =	8.5	inch	A_b =	0.39	ft^2	Q_b =	500	cfm	V_b =	1269	fpm
D_s =	8.5	inch	A_s =	0.39	ft^2	Q_s =	500	cfm	V_s =	1269	fpm
A_b/A_c =	0.50		Q_b/Q_c =	0.50		V_b/V_c =	1.00				

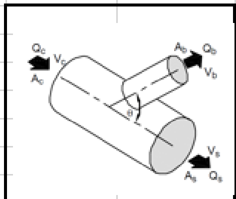
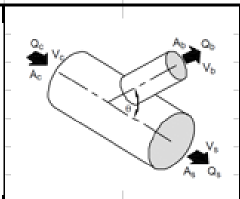
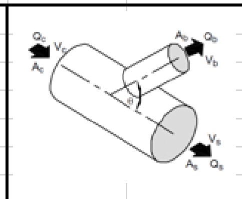
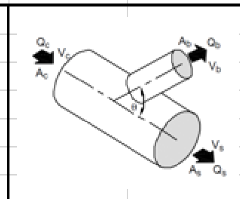
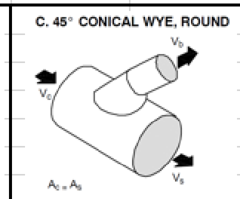
P_{vc} =	0.10	inch water
P_{vb} =	0.10	inch water
P_{vs} =	0.10	inch water

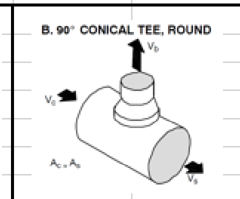
Note 8: A = Area (sq. in.). Q= airflow (cfm). V= Velocity (fpm)
Use the velocity pressure (V_p) of the upstream section. Fitting loss TP = C × V_p

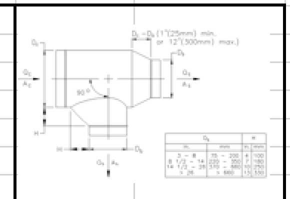
$\rho = 0.075\ lb_m/ft^3$

Standard Conditions

Table A–11 Loss Coefficients, Diverging Junctions (Tees, Wyes), A





		Wye , 30°		Wye , 45°		Wye , 60°		Wye , 90°		Conical Wye		Contical Tee		45° Entry Tee	
Velocity Vu = Vc (fpm)	Velocity Pressure p_v (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)
1273	0.10	0.18	0.02	0.40	0.04	0.68	0.07	1.4	0.14	0.17	0.02	0.42	0.04	0.35	0.04
		Best		Better		Good				Best		Better		Better	
						Of 90° taps		Poor				Better		Best	

Duct Design Fundamentals

Fitting Efficiency – Diverging Flow Branches

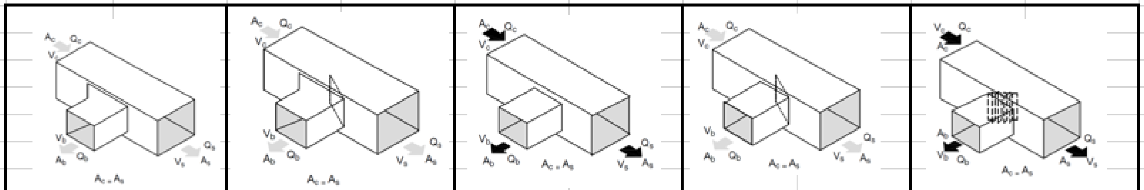
Comparison of Rectangular Diverging Flow Fittings — Loss Coefficients from SMACNA HVAC Systems Duct Design Appendix A

$W_c \times H_c$	12	x	12	inch	A_c =	1.00	ft^2	Q_c =	1000 cfm	V_c = 1000 fpm
$W_s \times H_s$	12	x	12	inch	A_s =	1.00	ft^2	Q_b =	500 cfm	V_s = 500 fpm
$W_b \times H_b$	7	x	7	inch	A_b =	0.34	ft^2	Q_s =	500 cfm	V_b = 1469 fpm
Q_b/Q_c =	0.50		V_b/V_c =	1.47						P_{vc} = 0.06 inch water
										P_{vs} = 0.02 inch water
										P_{vb} = 0.13 inch water

Note 8: A = Area (sq. in.). Q= airflow (cfm). V= Velocity (fpm)
Use the velocity pressure (V_p) of the upstream section. Fitting loss TP = C × V_p

ρ = 0.075 lb_m/ft^3
Standard Conditions

Table A–11 Loss Coefficients, Diverging Junctions (Tees, Wyes) , A



		N. Tee, 45° Main to Branch		O. Tee, 45° Main to Branch w Damper		P. Tee, 90° Main to Branch		Q. Tee, 90° Main to Branch w Damper		R. Tee, 90° Main to Branch w Extracotr	
Velocity Vu = Vc (fpm)	Velocity Pressure p_v (inch water)	Loss Coefficient C	Δp_t (inch water)		Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)
1000	0.06	1.59	0.10	1.62	0.10	1.88	0.12	2.01	0.13	2.09	0.13
		Best		Better, but will increase Loss in Main		Good		Good. But will increase loss in main		Increases Loss in Main, not recommend	

Duct Design Fundamentals

Fitting Efficiency – Diverging Flow Branches

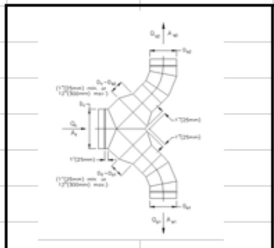
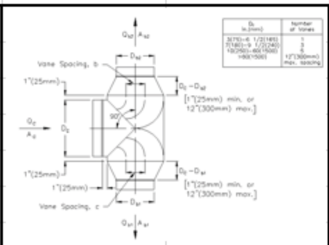
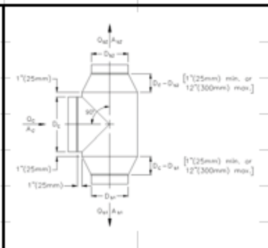
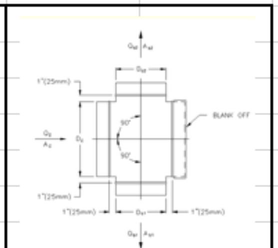
Comparison of Round Diverging Flow Fittings — Loss Coefficients from ASHRAE DFDB

D_c =	12 inch	A_c =	0.79 ft^2	Q_c =	1000 cfm
D_{b1} =	8.5 inch	A_{b1} =	0.39 ft^2	Q_{b1} =	500 cfm
D_{b2} =	8.5 inch	A_{b2} =	0.39 ft^2	Q_{b2} =	500 cfm
V_c =	1273 fpm	P_{vc} =	0.10 inch water		
V_{b1} =	1269 fpm	P_{vb1} =	0.10 inch water		
V_{b2} =	1269 fpm	P_{vb2} =	0.10 inch water		

$\rho = 0.075\ lb_m/ft^3$

Standard Conditions

Loss Coefficients are based on section velocity pressure

		Symmetrical Wye, SD5-22		Bullhead Tee with Vanes, SD5-19		Bullhead Tee without Vanes, SD5-18		Capped Cross, SD5-20	
Velocity V_{b1}	**Velocity Pressure p_v (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**	**Loss Coefficient C**	**Δp_t (inch water)**
1269	0.10	0.16	0.02	0.42	0.04	1.02	0.10	4.38	0.44
		Best		Better		Good		Poor	

Duct Design Fundamentals

Fitting Efficiency –
Diverging Flow Branches

McGill AirFlow Corporation — Duct System Design

Table 1.3
Loss Coefficient Comparisons for Diverging-Flow Fittings

Fitting	Loss Coefficient (C_b)
Y-Branch plus 45° Elbows	0.22
Vee Fitting	0.30
Tee with Turning Vanes plus Branch Reducers (Bullhead Tee with Vanes)	0.45
Tee plus Branch Reducers	1.08
Capped Cross with Straight Branches	4.45
Capped Cross with Conical Branches	4.45
Capped Cross with 1-*foot* Cushion Head	5.4
Capped Cross with 2-*foot* Cushion Head	6.0
Capped Cross with 3-*foot* Cushion Head	6.4

The loss coefficient, C_b, is for a V_b/V_c ratio of approximately 1.0.

Duct Design Fundamentals

Fitting Efficiency – Converging Flow Branches

Comparison of Converging Flow Fittings — Loss Coefficients from SMACNA HVAC Systems Duct Design Appendix A

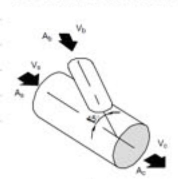
D_c = 12 inch	A_c = 0.79 ft^2	Q_c = 1000 cfm	V_c = 1273 fpm	P_{vc} = 0.10 inch water
D_b = 8.5 inch	A_b = 0.39 ft^2	Q_b = 500 cfm	V_b = 1269 fpm	P_{vb} = 0.10 inch water
D_s = 8.5 inch	A_s = 0.39 ft^2	Q_s = 500 cfm	V_s = 1269 fpm	P_{vs} = 0.10 inch water
A_b/A_c = 0.50	A_s/A_c = 0.50	Q_b/Q_c = 0.50	Q_b/Q_c = 1.00	V_b/V_c = 1.00
				V_s/V_c = 1.00

Note 8: A = Area (sq. in.). Q = Airflow (cfm). V = Velocity (fpm)
Use the velocity pressure (V_{p}) of the downstream section. Fitting loss TP = C × V_p

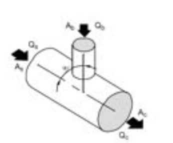
ρ = 0.075 lb_m/ft^3
Standard Conditions

Table A–10 Loss Coefficients, Converging Junctions (Tees, Wyes) , A

A. CONVERGING WYE, ROUND



B. CONVERGING TEE, 90°, ROUND



E. CONVERGING WYE, CONICAL ROUND

			Wye, 45°		Wye, 90°		Conical Wye, 45°	
	Velocity V_d = V_c (fpm)	Velocity Pressure p_v (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	Δp_t (inch water)
Branch	1273	0.10	0.49	0.05	0.88	0.09	0.88	0.09
Main	1273	0.10	0.06	0.01	0.53	0.05		
			Best		Not Recommended		Good	

Duct Design Fundamentals
System Effect

A “***SYSTEM EFFECT FACTOR***” IS A PRESSURE LOSS TO THE FAN CAPACITY – CAUSED BY FAN INLET AND/OR OUTLET RESTRICTIONS TO THE FLOW OF AIR OR OTHER CONDITIONS INFLUENCING THE FAN PERFORMANCE WHEN THE FAN IS INSTALLED IN A HVAC SYSTEM

Duct Design Fundamentals

System Effect

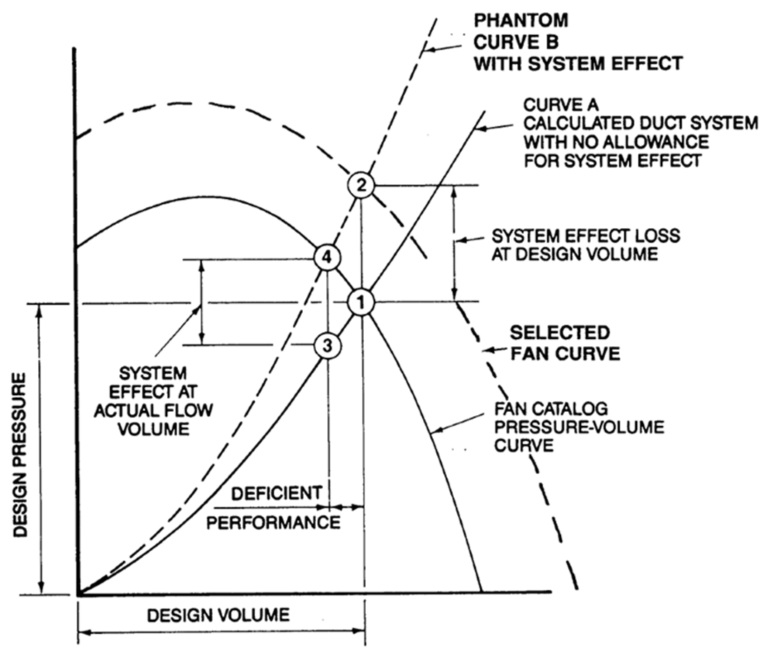


FIGURE 5–53 EFFECTS OF SYSTEM EFFECT

Duct Design Fundamentals

Fan Outlet Effects

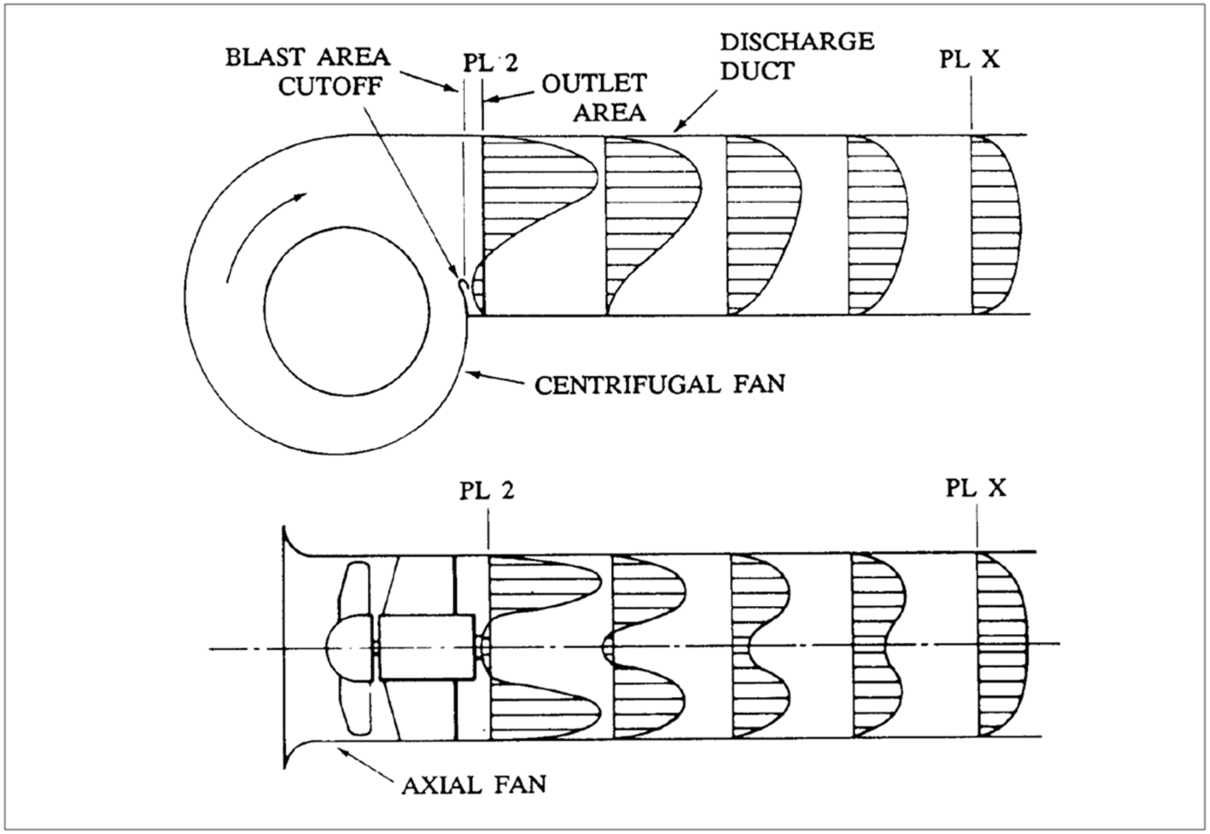


FIGURE 5–52 ESTABLISHMENT OF A UNIFORM VELOCITY PROFILE

Duct Design Fundamentals

Fan Outlet Effects

- For 100 percent energy recovery, the duct and an acceptable transition usually must be as long as the “full effective duct length" before a duct fitting is used.
- Any changes in the discharge duct within the effective duct length, which differ from the duct configuration used when the fan was tested and rated, may cause the fan to perform less efficiently.
- Where uniform flow conditions do not exist, the fan’s performance will be reduce.

Duct Design Fundamentals

Fan Outlet Effects – Effective Length

To Calculate 100 Percent Effective Duct Length, Assume a Minimum of 2-1/2 Hydraulic Duct Diameters for 2500 FPM or Less. Add 1 Duct Diameter for Each Additional 1000 FPM.

Example: 5000 FPM = $5D_h$

$D_h = 4A/P$

For Rectangular, $D_h = 4 \times (a \times b)/(2 \times (a + b))$

Duct Design Fundamentals

Fan Outlet Effects

	No Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
Pressure Recovery	0%	50%	80%	90%	100%
Blast Area Outlet Area	System Effect Curve				
0.4	P	R-S	U	W	–
0.5	P	R-S	U	W	–
0.6	R-S	S-T	U-V	W-X	–
0.7	S	U	W-X	–	–
0.8	T-U	V-W	X	–	–
0.9	V-W	W-X	–	–	–
1.0	–	–	–	–	–

Table 6–1 System Effect Curves for Outlet Ducts

Duct Design Fundamentals

System Effect Curves

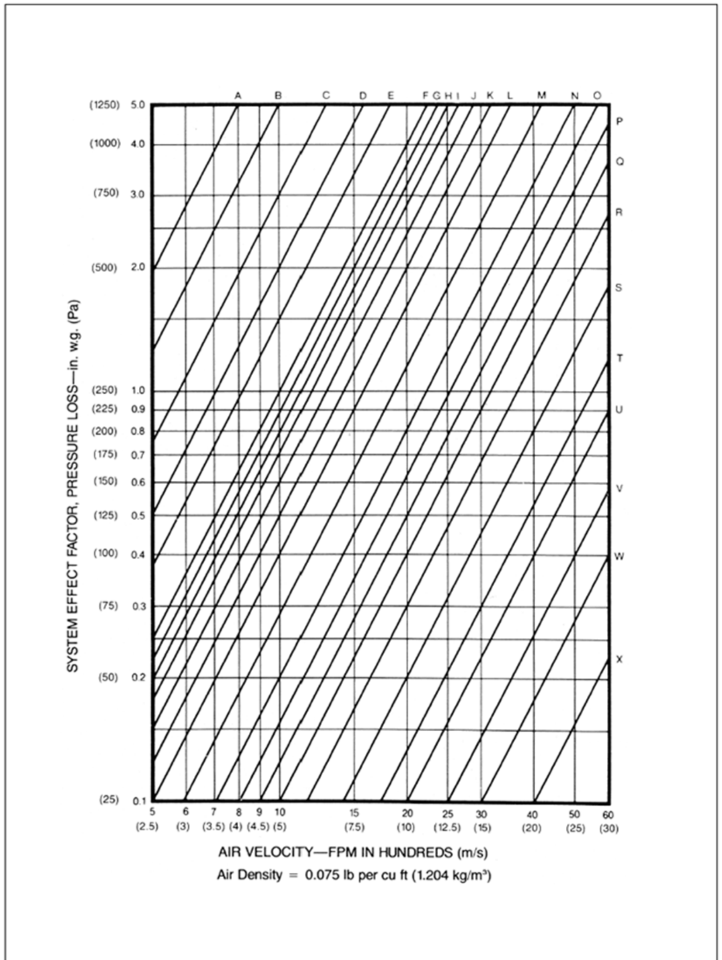


FIGURE 6-1 SYSTEM EFFECT CURVES

See page 6.2 of the HVAC Systems Duct Design Manual

Duct Design Fundamentals

Fan Outlet Effects

	No Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
Pressure Recovery	0%	50%	80%	90%	100%
Blast Area Outlet Area	System Effect Curve				
0.4	P	R-S	U	W	–
0.5	P	R-S	U	W	–
0.6	R-S	S-T	U-V	W-X	–
0.7	S	U	W-X	–	–
0.8	T-U	V-W	X	–	–
0.9	V-W	W-X	–	–	–
1.0	–	–	–	–	–

Table 6–1 System Effect Curves for Outlet Ducts

Duct Design Fundamentals

System Effect Curves

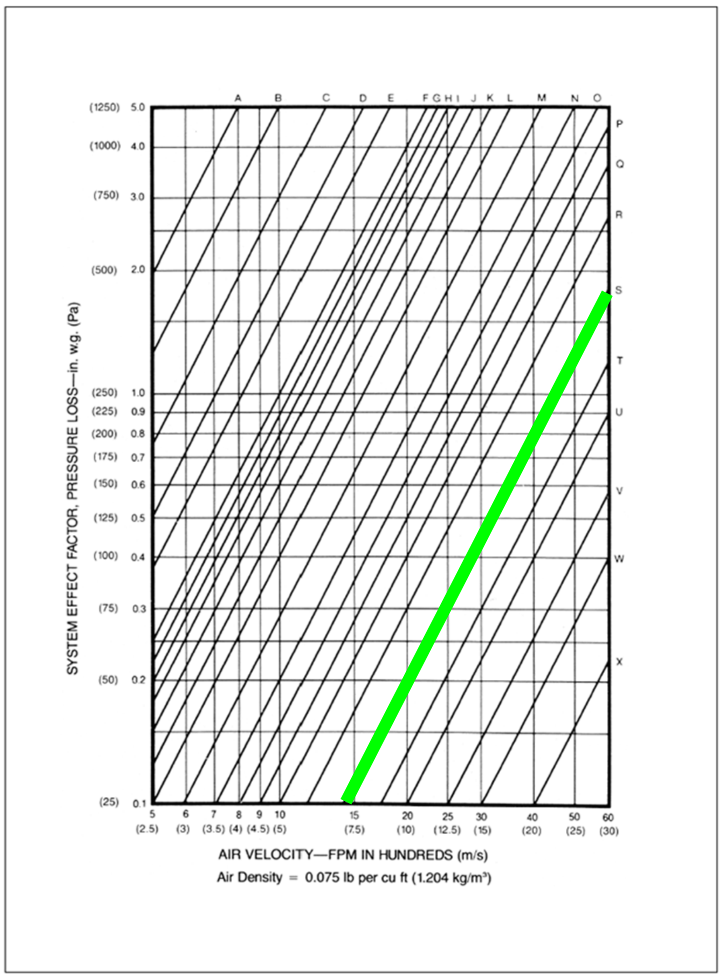
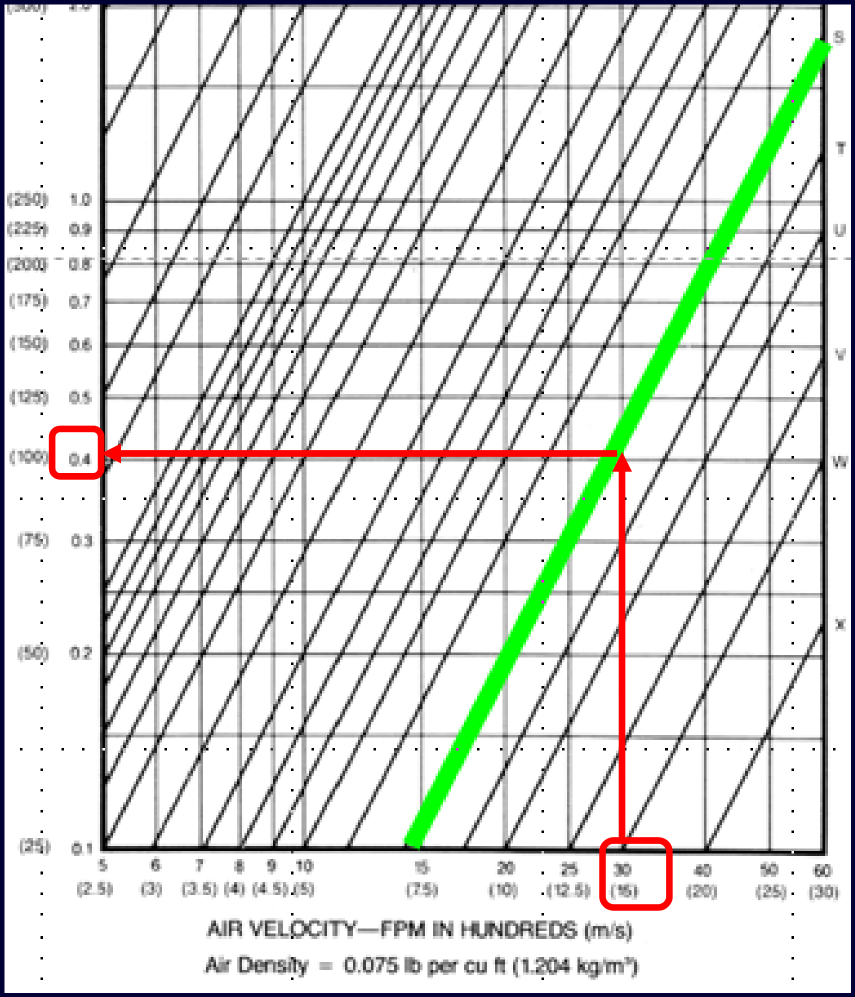


FIGURE 6–1 SYSTEM EFFECT CURVES

Duct Design Fundamentals

System Effect Curves



If the outlet velocity is 3000 fpm, the System Effect is 0.40 inch of water

Duct Design Fundamentals

Fan Outlet Effects – Specifically for Elbows

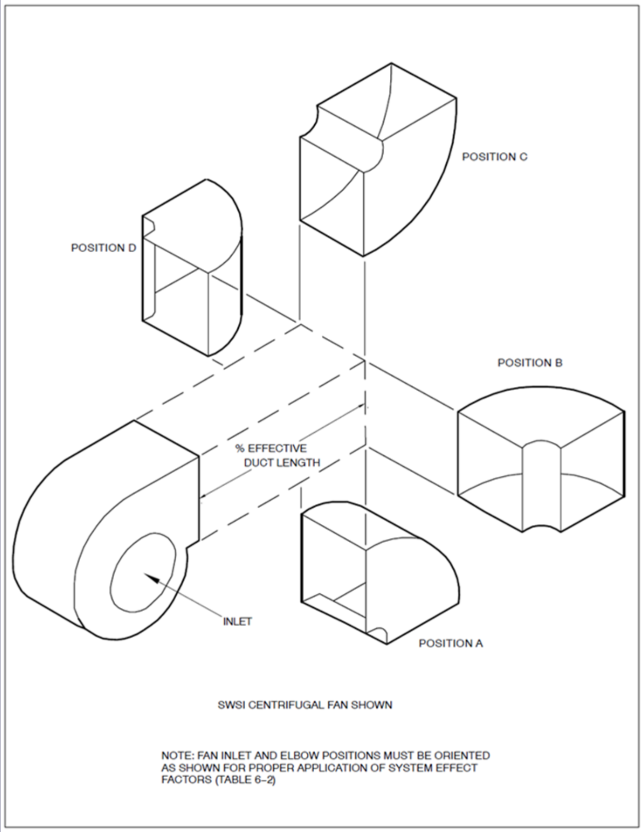


FIGURE 6-3 OUTLET DUCT ELBOWS

Duct Design Fundamentals

Fan Outlet Effects – Specifically for Elbows

Blast Area Outlet Area	Outlet Elbow Position	No Outlet Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
0.4	A	N	O	P-Q	S	NO SYSTEM EFFECT FACTOR
	B	M	M-N	O	R	
	C	L-M	M	N	Q	
	D	L-M	M	N	Q	
0.5	A	P	Q	R	T	
	B	N-O	O-P	P-Q	S	
	C	M-N	N-O	O-P	R-S	
	D	M-N	N-O	O-P	R-S	
0.6	A	Q	Q-R	R-S	U	
	B	P	Q	R	T	
	C	N-O	O-P	P-Q	S	
	D	O	P	Q-R	S-T	
0.7	A	S-T	T	U	W	
	B	R-S	S	T	V	
	C	Q-R	R	S	U-V	
	D	R	R-S	S-T	U-V	
0.8	A	S	S-T	T-U	V-W	
	B	R	R-S	S-T	U-V	
	C	Q	Q-R	R-S	U	
	D	Q-R	R	S	U-V	
0.9	A	S-T	T	U	W	
	B	R-S	S	T	V	
	C	R	R-S	S-T	U-V	
	D	R-S	S	T	V	
1.0	A	R-S	S	T	V	
	B	S-T	T	U	W	
	C	R-S	S	T	V	
	D	R-S	S	T	V	

Table 6–2 System Effect Factor Curves for Outlet Elbows

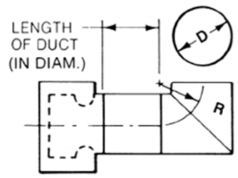
Duct Design Fundamentals

Fan Inlet Effects

- HVAC centrifugal and axial flow fans are tested without any inlet obstructions or duct connections.
- For rated performance, the air must enter the fan uniformly over the inlet area in an axial direction without pre−rotation.
- Non−uniform flow into the inlet is the most common cause of reduced fan performance.
- A poor inlet condition results in an entirely new fan performance.

Duct Design Fundamentals

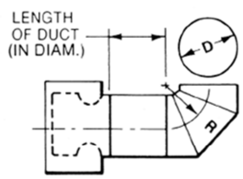
Fan Inlet Effects



SYSTEM EFFECT CURVES

R/D	NO DUCT	2D DUCT	5D DUCT
—	N	P	R-S

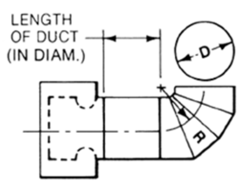
a TWO PIECE MITERED 90° ROUND SECTION ELBOW – NOT VANED



SYSTEM EFFECT CURVES

R/D	NO DUCT	2D DUCT	5D DUCT
0.5	O	Q	S
0.75	Q	R-S	T-U
1.0	R	S-T	U-V
2.0	R-S	T	U-V
3.0	S	T-U	V

b THREE PIECE MITERED 90° ROUND SECTION ELBOW – NOT VANED



SYSTEM EFFECT CURVES

R/D	NO DUCT	2D DUCT	5D DUCT
0.5	P-Q	R-S	T
0.75	Q-R	S	U
1.0	R	S-T	U-V
2.0	R-S	T	U-V
3.0	S-T	U	V-W

c FOUR OR MORE PIECE MITERED 90° ROUND SECTION ELBOW – NOT VANED

FIGURE 6-9 SYSTEM EFFECTS FOR VARIOUS MITERED ELBOWS WITHOUT VANES

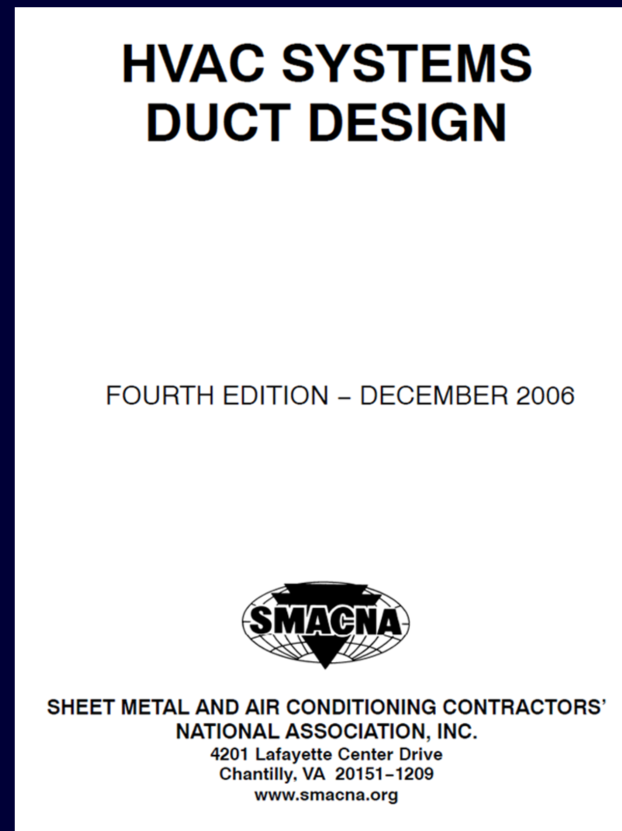
- Many other inlet situations are identified in Chapter 6 of the SMACNA HVAC SYSTEMS DUCT DESIGN manual
- Uses Chart from Figure 6-1

Duct Design Fundamentals

General Fan Connection System Effects

Conditions Include:

- 6.2.1 Fan Outlet Ducts
- 6.2.2 Fan Outlet Diffusers
- 6.2.3 Fan Outlet Duct Elbows
- 6.2.4 Turning Vanes
- 6.2.5 Fan Volume Control Dampers
- 6.2.6 Duct Branches
- 6.3.1 Inlet Ducts
- 6.3.2 Inlet Elbows
- 6.3.3 Inlet Vortex
- 6.3.4 Inlet Duct Vanes
- 6.3.5 Straighteners
- 6.3.6 Enclosures
- 6.3.7 Obstructed Inlets


HVAC SYSTEMS
DUCT DESIGN

FOURTH EDITION – DECEMBER 2006

SMACNA

SHEET METAL AND AIR CONDITIONING CONTRACTORS'
NATIONAL ASSOCIATION, INC.
4201 Lafayette Center Drive
Chantilly, VA 20151-1209
www.smacna.org

Duct Design Fundamentals

ASHRAE Duct Fitting Data Base (DFDB)

ASHRAE developed an Online Duct Fitting Database (DFDB). The database enables the user to select from over 200 fittings, enter information such as airflow and size, and the database outputs velocity, velocity pressure, loss coefficient and pressure loss.

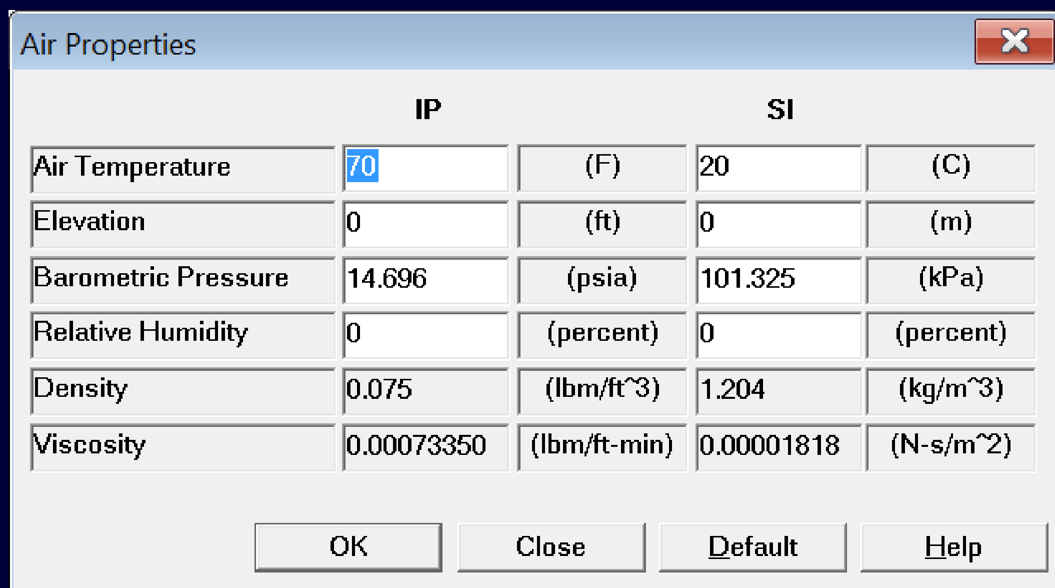
ASHRAE Duct Fitting Database Nomenclature

Fitting Function	Geometry	Category	Sequential Number
S: Supply	D: Round	1: Entries	1, 2, 3 … n
E: Exhaust/Return	R: Rectangular	2: Exits	
C: Common	F: Flat oval	3: Elbows	
		4: Transitions	
		5: Junctions	
		6: Obstructions	
		7: Fan and System Interactions	
		8: Duct-Mounted Equipment	
		9: Dampers	
		10: Hoods	
		11: Straight Duct	

Duct Design Fundamentals

ASHRAE Duct Fitting Data Base (DFDB)

Setting Air Properties

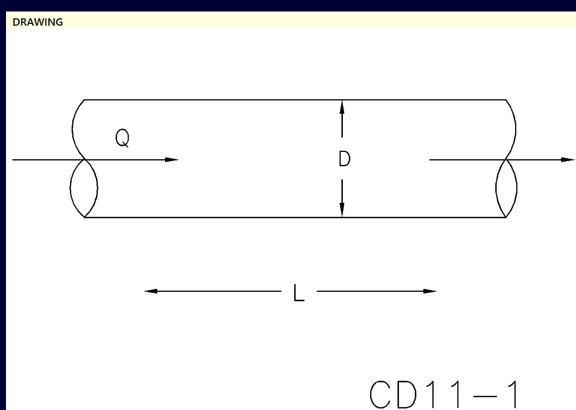


Duct Design Fundamentals

ASHRAE Duct Fitting Data Base (DFDB)

CD11-1 Drawing View

- Supply
- Common
  - Round
    - **Straight Duct (CD11-1)**
    - Straight Duct, Flexible (CD11-2)
    - Straight Duct, Maximum Duct Velocity (CD11-3)



CD11-1 Straight Duct, Round (Colebrook 1939)

INPUT

Diameter (D)	in.	21.0
Length (L)	ft	100
Absolute Roughness (ei)	ft	0.00040
Flow Rate (Q)	cfm	5,000
Density (RHO)	lbm/ft^3	0.075

Calculate

OUTPUT

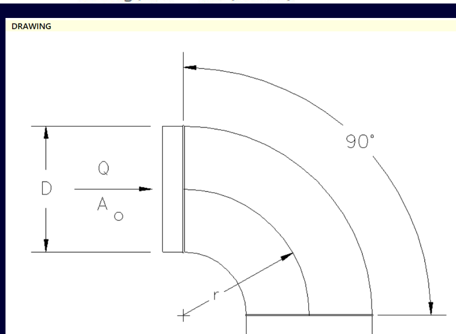
Velocity (V)	fpm	2,079
Velocity Presure (Pv)	in. wg	0.27
Reynolds Number (Re)		369,485
Friction Factor (f)		0.0161
Pressure Loss (Po)	in. wg	0.25

Duct Design Fundamentals

ASHRAE Duct Fitting Data Base (DFDB)

CD3-1 | Drawing View

- Supply
- Common
  - Round
    - Straight Duct (CD11-1)
    - Straight Duct, Flexible (CD11-2)
    - Straight Duct, Maximum Duct Velocity (CD11-3)
    - Straight Duct, Minimum Duct Velocity (CD11-5)
    - Straight Duct, Friction Rate Constant (CD11-4)
    - Elbows
      - Die Stamped
        - **90 deg., r/D = 1.5 (CD3-1)**
        - 90 deg., r/D = 1.0 (CD3-2)



CD3-1 Elbow, Die Stamped, 90 Degree, r/D = 1.5
(UMC 1985, Report SRF785)

INPUT

Diameter (D)	in.	8.0
Flow Rate (Q)	cfm	1,500
Density (RHO)	lbm/ft^3	0.075

Calculate

OUTPUT

Velocity (Vo)	fpm	4,297
Vel Pres at Vo (Pv)	in. wg	1.14
Loss Coefficient (Co)		0.11
Pressure Loss (Po)	in. wg	0.13

Show Air Properties | Show Version History | Show Equations

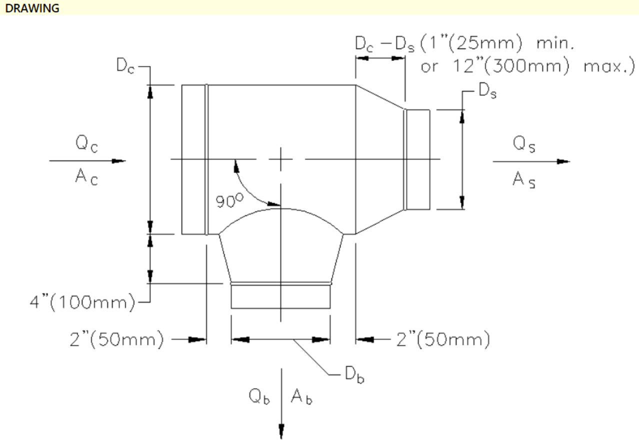
Duct Design Fundamentals

ASHRAE Duct Fitting Data Base (DFDB)

SD5-10 Drawing View

- Supply
  - Round
    - Plenums
    - Exits
    - Transitions
    - Junctions, Diverging
      - Heel-Tapped Elbow (SD5-21)
      - Double Wye (SD5-23)
      - Cross
      - Tee
        - Bullhead
        - Conical Branch
          - **Conical Branch Tapered into Body (SD5-10)**

DRAWING



SD5-10 Tee, Conical Branch Tapered into Body, Diverging
(UMC 1986, Report SRF386)

INPUT

Diameter (Dc)	in.	12.0
Diameter (Db)	in.	6.0
Diameter (Ds)	in.	10.0
Flow Rate (Qc)	cfm	1,500
Flow Rate (Qb)	cfm	300
Density (RHO)	lbm/ft^3	0.075

Calculate

OUTPUT

BRANCH		
Velocity (Vb)	fpm	1,528
Vel Pres at Vb (Pvb)	in. wg	0.14
Loss Coefficient (Cb)		1.11
Branch Pressure Loss (Pob)	in. wg	0.16
MAIN		
Velocity (Vs)	fpm	2,200
Velocity (Vc)	fpm	1,910
Vel Pres at Vs (Pvs)	in. wg	0.30
Vel Pres at Vc (Pvc)	in. wg	0.23
Loss Coefficient (Cs)		0.15
Main Pressure Loss (Pos)	in. wg	0.04

Duct Design Fundamentals

Duct Design Overview

Duct Design Fundamentals

Goals of a High Performance Air System - Duct Design

- Design energy efficient HVAC systems that deliver the proper amount of air to specific areas of the building
- Design balanced systems
- Minimize fan energy use
- Minimize first cost
- Minimize the maintenance cost
- Keep noise levels within the required NC/RC levels
- Provide a comprehensive design to the owner per the Owner's Project Requirements (OPRS)

Duct Design Fundamentals

Designing the Duct System

Step 1__ Determine air volume requirements. Include an allowance for leakage.
Step 2__ Locate duct runs. Avoid unnecessary directional changes.
Step 3__ Locate balancing dampers if necessary.
Step 4__ Determine the allowable noise (NC) levels.
Step 5__ Select design method.
Step 6__ Select the initial duct size.
Step 7__ Determine duct sizes based on the design methodology. Use efficient fittings.
Step 8__ Keep aspect ratios as close to 1 as possible.
Step 9__ Determine system pressure requirements. Include total pressure losses of components.
Step 10__ Analyze the design to improve balancing and reduce material cost..
Step 11__ Select fan according to proper guidelines
Step 12__ Analyze the design to make sure it meets the acoustical requirements.
Step 13__ Select materials that minimize cost and meet SMACNA Duct Construction Standards.
Step 14__ Analyze the life-cycle cost of the design.
Step 15__ Commission the design to make sure it meets the OPR.

Duct Design Fundamentals

Designing the Duct System - Select the Design Method

Design Method	Pros	Cons
Equal Friction	Easier to Use	Does not account for varying lengths, uses same friction loss rate to size 1 ft. length or 100 ft. for example.
	Can Use a Ductulator to Determine Sizes	Fittings don't affect the design only the analysis. The design or size is a function of the friction rate used. Fittings losses must be included in the analysis.
	Good for quickly designing small systems.	The system will not be balanced without additional work or use of dampers.
	Can design return/exhaust or supply systems.	Optimum friction rate is not known. Choosing a friction rate is from experience by rule of thumb.
Static Regain	Larger duct sizes may be used, but offset by smaller sizes in non-critical paths.	Sizing ducts is cumbersome and may require many iterations which are best suited by the use of a computerized duct design program.
	System will be more balanced than equal friction, depending on the available duct sizes allow.	
	Often can use smaller sizes or less efficient and lower cost types of fittings in the non-design legs.	Can only be used on Supply systems.
		Must choose an initial velocity based on guidelines.

Duct Design Fundamentals

Designing the Duct System - The Critical Path

- Critical paths are the duct sections from a fan outlet to the terminal device with the largest total pressure drop for supply systems or from the entrance to the fan inlet with the highest total pressure drop for return or exhaust systems.

- The difference between the critical path and other paths will be excess total pressure. If the path has excess total pressure, it can be used with smaller sections, less efficient fittings, dampers, or the VAV box.

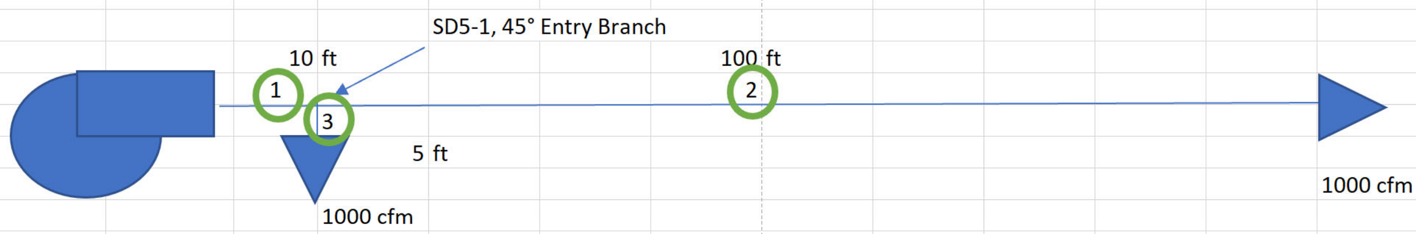
[SMALLER SECTIONS IS THE PREFERRED METHOD; BALANCES AND LOWERS COST]

- In all systems there will be an imbalance because we don't use an infinite amount of duct sizes. It is always recommended to provide designed balanced systems.

Duct Design Fundamentals

Determine the Duct System Method – Sample Equal Friction Design

Example Equal Friction Loss



For p_f/100 = 0.10 inch water

Section 1			Section 2			Section 3		
Q1 =	2000	cfm	Q2 =	1000	cfm	Q3 =	1000	cfm
D1 =	18	inch	D2 =	14	inch	D3 =	14	inch
V1 =	1132	fpm	V2 =	935	fpm	V3 =	935	fpm
p_v1 =	0.08	inch water	p_v2 =	0.05	inch water	p_v3 =	0.05	inch water
p_f 1 =	0.09	inch water /100 ft	p_f2 =	0.09	inch water /100 ft	p_f3 =	0.09	inch water /100 ft
Δp_{D1}=	0.01	inch water	p_D2 =	0.09	inch water	p_D3 =	0.00	inch water
			$\Delta p_{t1\text{-}2,fitting}$	0.01	inch water	$\Delta p_{t1\text{-}3,fitting}$	0.01	inch water
			Outlet Loss	0.05	inch water	Outlet Loss	0.05	inch water
Path 1 -2 Δp =	0.16	inch water						
Path 1 -3 Δp =	0.07	inch water	$\Delta p_{t,1\text{-}2}$	0.15	inch water	$\Delta pt_{,1\text{-}3}$	0.06	inch water
Total Pressure =	0.16	inch water	For Path 1 - 2					
Excess Pressure	0.09	inch water	For Path 1 - 3					

Duct Design Fundamentals

Determine the Duct System Method

Recommend Using Equal Friction for Smaller System with slower velocity.

For HPAS designs, recommend Static Regain w additional Balancing
using even smaller ducts and/or less efficient fittings

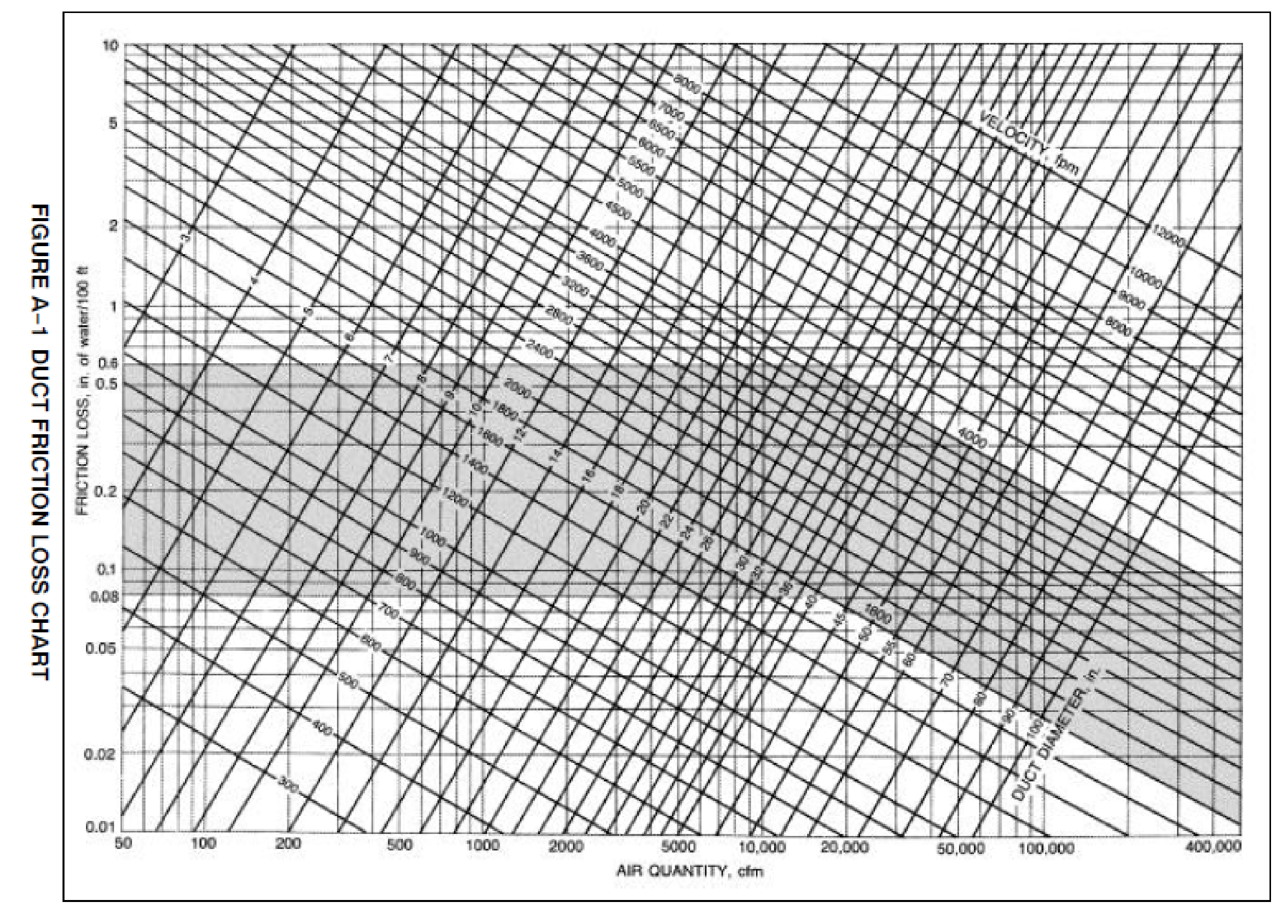
DESIGN BALANCED SYSTEMS

Duct Design Fundamentals

Designing the Duct System - Select the initial duct size

Method 1 - Use Grey Shaded Area

For Air Quantity greater than 20,000 cfm, maximum suggested velocity is 4000 fpm



Duct Design Fundamentals

Designing the Duct System - Select the initial duct size

Maximum Recommended Duct Airflow Velocities to Achieve Specified Acoustic Design Criteria[1]			
Duct Location	**RC or NC Rating in Adjacent Occupancy**	**Maximum Airflow Velocity, Fpm**	
		Rectangular Duct	**Round Duct**
In shaft or above drywall ceiling	45	3500	5000
	35	2500	3500
	25 or less	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25 or less	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25 or less	950	1700

[1]Table 4-1 [Schaffer 2005 (2011)] [Table 8 from ASHRAE 2015 – HVAC Applications Chapter 48, Noise and Vibration Control]

Method 2 - Use Table 8 from Chapter 48 of the ASHRAE – HVAC Application, Noise and Vibration Control.

Duct Design Fundamentals

Designing the Duct System - Select the initial duct size

Method 3 - Use an initial friction rate (inch water / 100 ft), based on the economics of the area

- **Prevailing Energy Cost is High or Installation Labor Cost is Low:** 0.08 to 0.15 in. water per 100 ft

- **Prevailing Energy Cost is Low or Installation Labor Cost High:** 0.30 to 0.60 in. water per 100 ft

Duct Design Fundamentals

Duct Design Methods !

Duct Design – Equal Friction

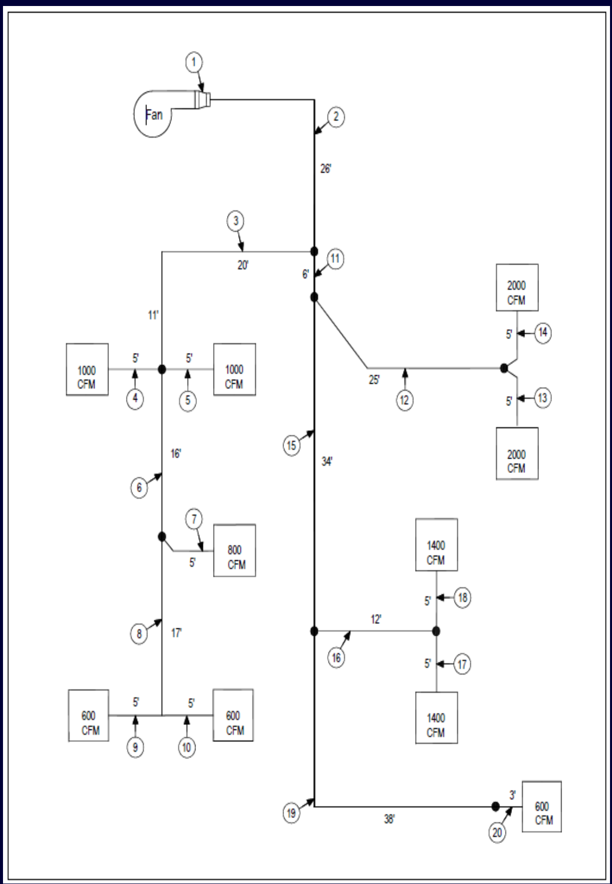
Duct Design Fundamentals

Equal Friction Rate Design Steps

- Layout a single-line drawing of the system, and assign section numbers.
- Locate balancing dampers for Constant Volume systems, not needed for VAV system.
- Determine leakage in each section of ductwork, and add to the air quantity required per the load calculations and system diversity. A good average is include an allowance for about 5% system leakage.
- Determine terminal total pressure requirements for constant volume diffusers, or VAV terminal units.
- Size all main and branch duct at a constant friction rate/maximum duct velocity.
- Calculate the total pressure loss for each section, both supply and return ductwork. Use the "Equal Friction" spreadsheet. For each main and branch of a junction be sure to account for the straight-through and branch loss coefficients.
- Tabulate the total pressure required for each path from the fan to each supply and return terminal.
- Determine the maximum operating pressure; then calculate the excess total pressure at each terminal.
- If excess pressure is greater than 0.1 in. of water, consider using a higher friction rate in non design legs to use smaller sections.
- Less Efficient / less costly elbows might also be used in non-design legs.
- Perform an acoustical analysis of the system . Add insulation or silencers as necessary

Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD

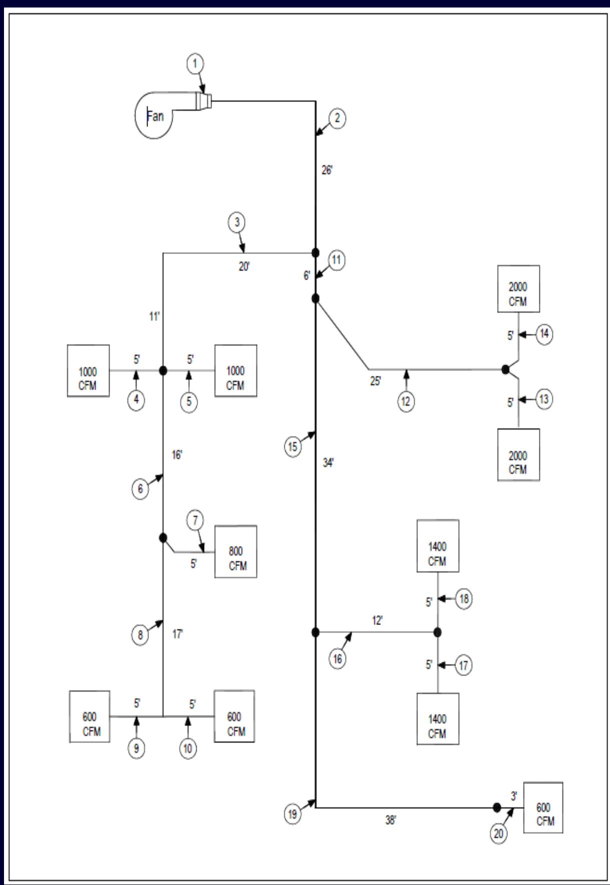


Sample Problem: Size the system shown by the equal friction method. The design air temperature is 69 °F, located in Denver Density (ρ) is 0.061 lb_m/ft^3, zero duct air leakage, Ducts are round spiral galvanized steel. The diffuser and distribution ductwork downstream of the VAV box has a pressure loss of 0.05 in. of water. The VAV terminal units have loss coefficients according to the following Table Size

VAV terminal unit Resistance			
Section	Box Inlet Size (in.)	Airflow (cfm)	Loss Coefficient (C)
4 & 5	10	1000	2.58
7	9	800	2.31
9 & 10	8	600	2.49
13 & 14	14	2000	2.56
17 & 18	12	1400	2.65
20	8	600	2.49

Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD



Assume the first section is located above a suspended acoustical ceiling with an RC requirement of 35 maximum.

Solution: Using the Acoustical Table below, the maximum velocity is 3500 fpm.

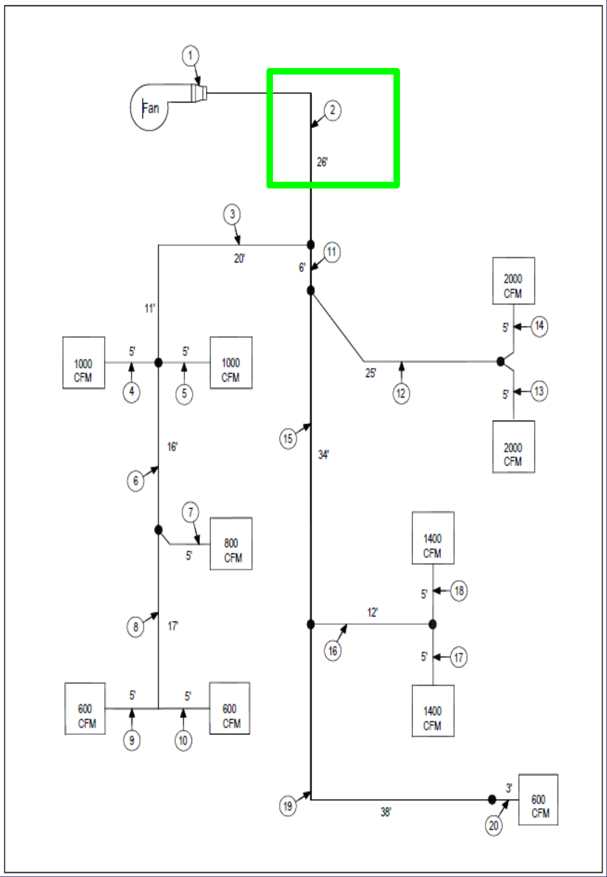
Maximum Recommended Duct Airflow Velocities to Achieve Specified Acoustic Design Criteria[1]

Duct Location	RC or NC Rating in Adjacent Occupancy	Maximum Airflow Velocity, Fpm: Rectangular Duct	Maximum Airflow Velocity, Fpm: Round Duct
In shaft or above drywall ceiling	45	3500	5000
	35	2500	3500
	25 or less	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25 or less	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25 or less	950	1700

[1]Table 4-1 [Schaffer 2005 (2011)] [Table 8 from ASHRAE 2015 – HVAC Applications Chapter 48, Noise and Vibration Control]

Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD



Solution: The total fan airflow is 11,400 CFM. Sizing the first section for the maximum velocity results in a diameter size of 25 inches.

That has a friction loss rate of 0.41 inch water /100 ft. That rate will be used to size the other sections. This is actually Section 2 as Section 1 will be the fan transition. We must also account for the other fitting losses, so a spreadsheet is used to calculate the data for each section

Duct Design Fundamentals

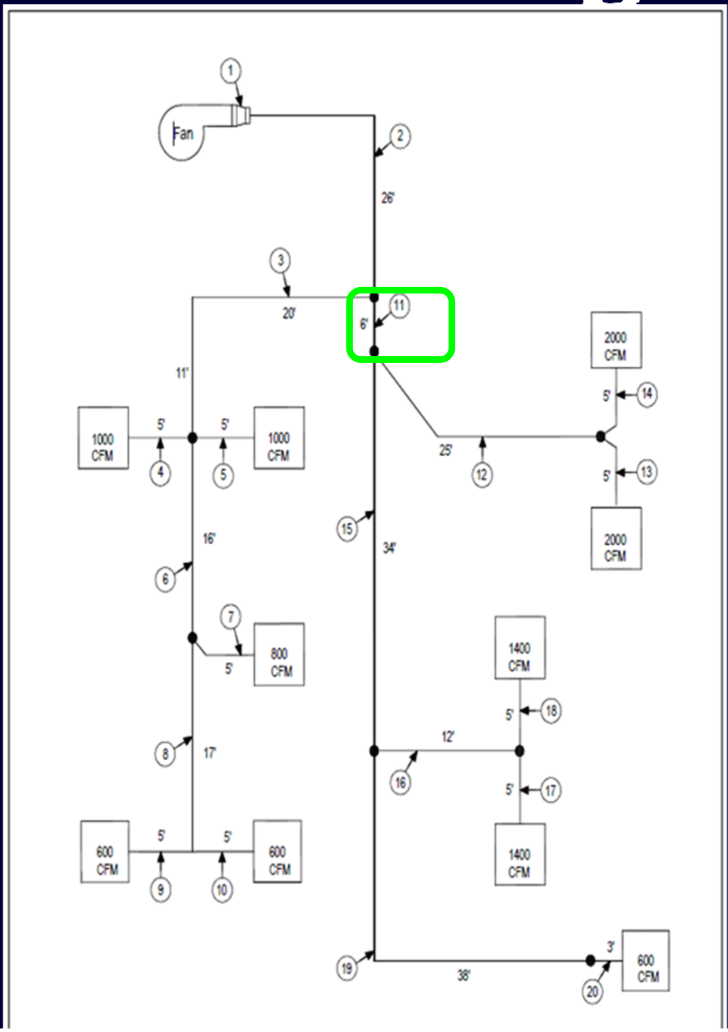
DUCT DESIGN BY THE EQUAL FRICTION METHOD

Equal Friction Example Problem (DDG)

Air Temperature, °F	**69**	**Relative Humidity, %**	**0**
Elevation, ft	**5430**	**Air Density (ρ), lbm/ft³**	**0.061**
Barometric Pressure, psia	**12.032**	**Viscosity (μ), lbm/(ft-min)**	**0.00073245**

Upstream Section	Section	Fitting	ASHRAE Fitting Code	Air Quantity (cfm)	Duct Size (in.)	Velocity (fpm)	Duct Length (ft)	Velocity Pressure, p_v (in. wg)	Loss Coefficient, C	Total Pressure Loss (in. wg)
		Source		Source					Source	
		Drawings	DFDB	Drawing	DFDB	DFDB	Drawing	DFDB	DFDB	∑
1	2	Duct	CD11-4/CD11-1	11400	25	3344	26			0.11
		Elbow, 90°	CD4-9						0.13	
		Transition: H1=27.0",W1=20.0",L=24" (Theta1=5°,Theta2=12°)	SD4-2						0.01	
		Sized at Maximum Velocity of 3500 fpm						0.57	0.14	0.08
Section Total										**0.19**
2	11	Duct	CD11-1	7400	21	3077	11			0.05
		Tee, 45° Entry, Main (Dc=25, Ds=21, Db=17)	SD5-12						0.14	
								0.48	0.14	0.07
Section Total										**0.12**

Duct Design Fundamentals



DUCT DESIGN BY THE EQUAL
FRICTION METHOD ,
Section 11

Duct Design Fundamentals

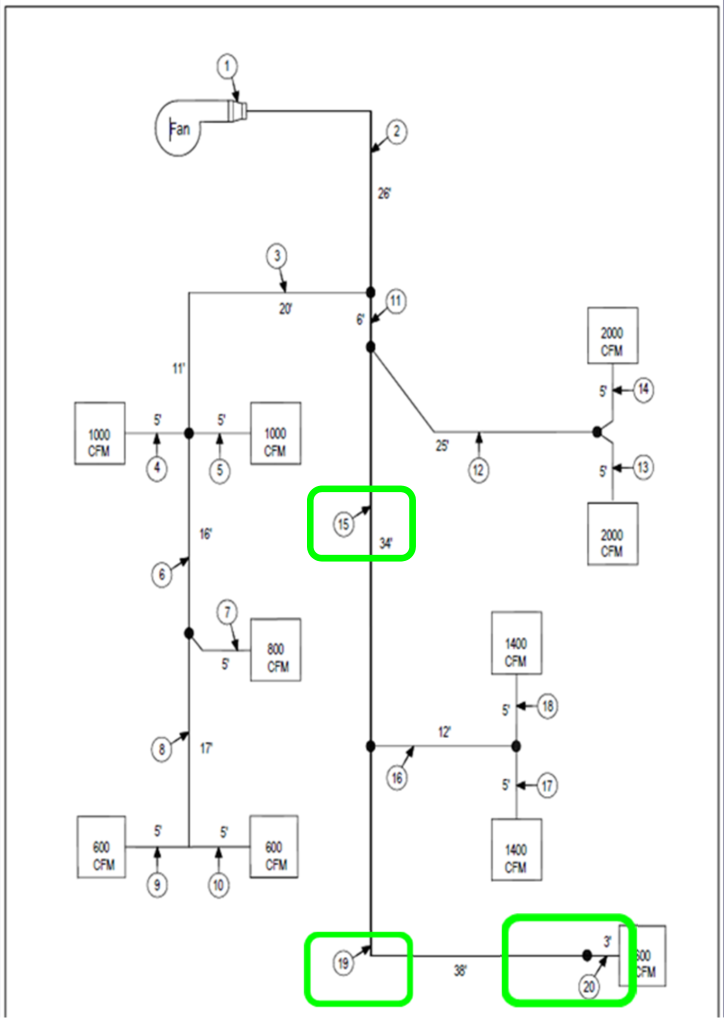
DUCT DESIGN BY THE EQUAL FRICTION METHOD

Equal Friction Example Problem (DDG)

Air Temperature, °F	**69**	**Relative Humidity, %**	**0**
Elevation, ft	**5430**	**Air Density (ρ), lbm/ft^3**	**0.061**
Barometric Pressure, psia	**12.032**	**Viscosity (μ), lbm/(ft-min)**	**0.00073245**

Upstream Section	Section	Fitting	ASHRAE Fitting Code	Air Quantity (cfm)	Duct Size (in.)	Velocity (fpm)	Duct Length (ft)	Velocity Pressure, p_v (in. wg)	Loss Coefficient, C	Total Pressure Loss (in. wg)
		Source		Source					Source	
		Drawings	DFDB	Drawing	DFDB	DFDB	Drawing	DFDB	DFDB	∑
1	2	Duct	CD11-4/CD11-1	11400	25	3344	26			0.11
		Elbow, 90°	CD4-9						0.13	
		Transition: H1=27.0",W1=20.0",L=24" (Theta1=5°,Theta2=12°)	SD4-2						0.01	
		Sized at Maximum Velocity of 3500 fpm						0.57	0.14	0.08
Section Total										**0.19**
2	11	Duct	CD11-1	7400	21	3077	11			0.05
		Tee, 45° Entry, Main (Dc=25, Ds=21, Db=17)	SD5-12						0.14	
								0.48	0.14	0.07
Section Total										**0.12**

Duct Design Fundamentals



DUCT DESIGN BY THE EQUAL FRICTION METHOD ,

Section 15, 19 and 20

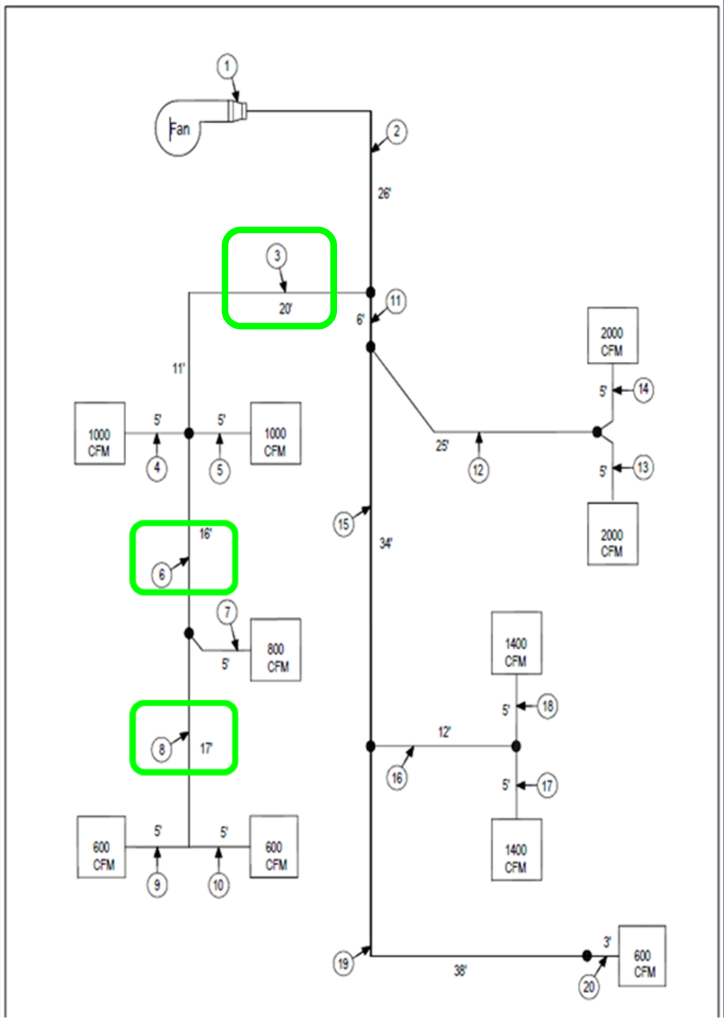
Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD

11	15	Duct	CD11-1	3400	16	2435	23			0.09
		Wye, 45° (Dc=21, Ds=16, Db=17)	SD5-1						0.14	
								0.30	0.14	0.04
Section Total										**0.13**

15	19	Duct	CD11-1	600	8	1719	38			0.18
		Tee,45° Entry, Main (Dc=16, Ds=8, Db=15)	SD5-12						0.23	
		Elbow 90°	CD3-9						0.23	
								0.15	0.46	0.07
Section Total										**0.25**
19	20	Flexible Duct (36.5 inches long, 38 inches fully extended, 4% compression)	CD11-2	600	8	1719	3			0.04
		Transition Round to Round Do=8, D1=8	SD4-1						0	
		VAV Box	CD8-11						2.49	
		Distribution and Diffuser								0.05
								0.15	2.49	0.37
Section Total										**0.46**

Duct Design Fundamentals



DUCT DESIGN BY THE EQUAL FRICTION METHOD , Section 3, 6 and 8

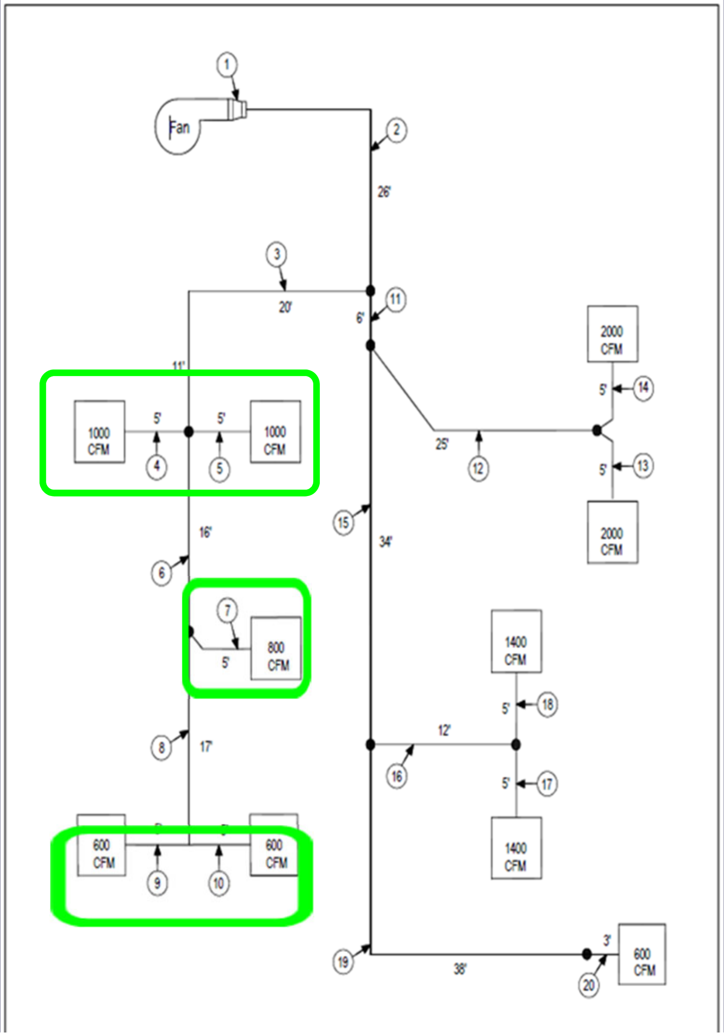
Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD

2	3	Duct	CD11-1	4000	17	2538	31			0.12
		Tee, 45° Entry, Branch (Dc=25, Ds=21, Db=17)	SD5-12						0.75	
		Elbow 90°	CD4-9						0.15	
								0.33	0.90	0.30
Section Total										**0.42**
3	6	Duct	CD11-1	2000	13	2170	16			0.06
		Coss,45° Entry, Main (Dc=17, Ds=13, Db1=Db2=10)	SD5-26						0.14	
								0.24	0.14	0.03
Section Total										**0.09**

6	8	Duct	CD11-1	1200	11	1818	17			0.06
		Wye, 45° Branch with 45° Elbow, Branch 90° to Main (Dc=13, Ds=11, Db=9)	SD5-4						0.14	
								0.17	0.14	0.02
Section Total										**0.08**

Duct Design Fundamentals



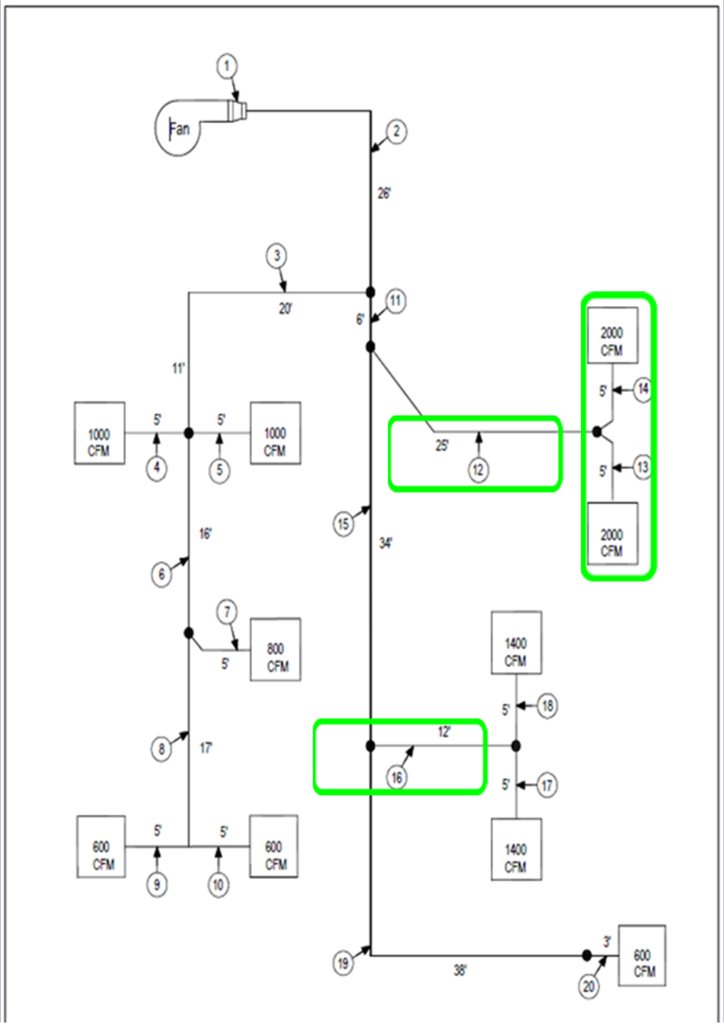
DUCT DESIGN BY THE EQUAL FRICTION METHOD , Section 4/5, 9/10 and 7

Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD

8	9 & 10	Duct (sized to match VAV terminal unit inlet)	CD11-1				5			0.02
		Bullhead Tee with Vanes, Branch	SD5-19	600	8	1719			0.48	
		(Dc=11, Db1=8, Db2=8)								
		VAV terminal unit	CD8-11						2.49	
		Distribution and Diffuser								0.05
		-						0.15	2.97	0.45
Section Total										**0.52**
3	4 & 5	Duct (sized to match VAV terminal unit inlet)	CD11-1				5			0.02
		Coss,45° Entry, Branch	SD5-26	1000	10	1833			0.96	
		(Dc=17, Ds=13, Db1=Db2=10)								
		VAV terminal unit	CD8-11						2.58	
								0.17	3.54	0.60
		Distribution and Diffuser								0.05
Section Total										**0.67**
6	7	Duct (sized to match VAV terminal unit inlet)	CD11-1				5			0.02
		Wye, 45° Branch with 45° Elbow, Branch 90° to Main	SD5-4	800	9	1811			0.62	
		(Dc=13, Ds=11, Db=9)								
		VAV terminal unit	CD8-11						2.31	
		Distribution and Diffuser								0.05
								0.17	2.93	0.50
Section Total										**0.57**

Duct Design Fundamentals



DUCT DESIGN BY THE EQUAL FRICTION METHOD ,

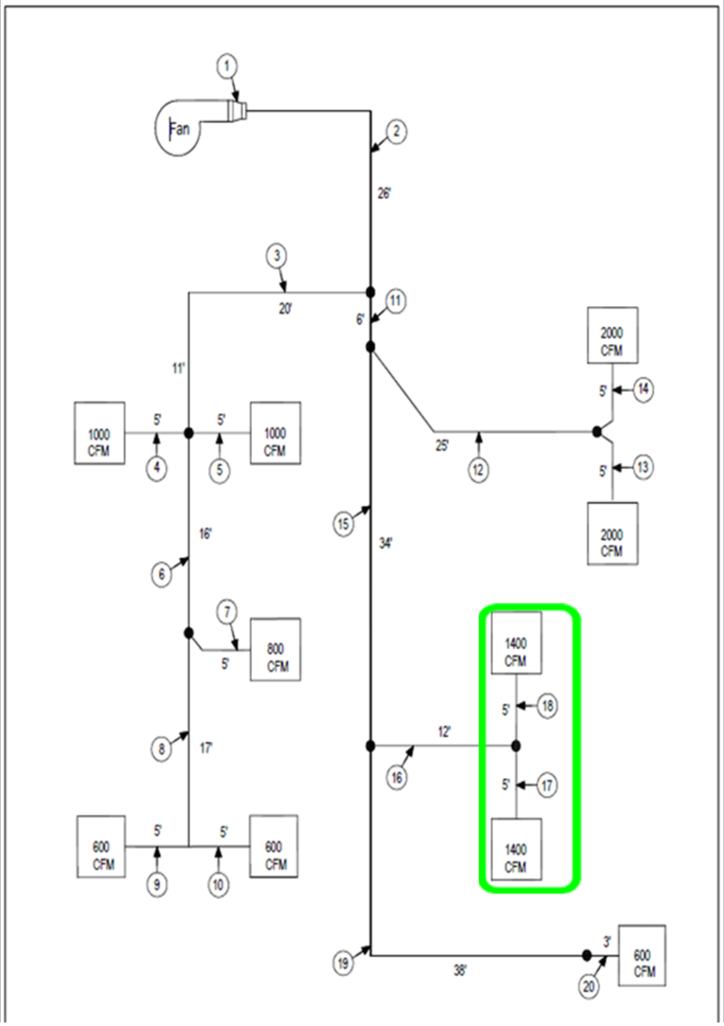
Section 12, 16 and 13/14

Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD

11	12	Duct	CD11-1				25			0.10
		Wye, 45° (Dc=21, Ds=16, Db=17)	SD5-1	4000	17	2538			0.61	
		Elbow 45°	CD4-14						0.10	
								0.33	0.71	0.23
Section Total										**0.33**
15	16	Duct	CD11-1				12			0.04
		Tee,45° Entry, Branch Dc=16, Ds=8, Db=15	SD5-12	2800	15	2282			0.41	
								0.27	0.41	0.11
Section Total										**0.15**
12	13 & 14	Duct (sized to match VAV terminal unit inlet)	CD11-1				5			0.01
		Symmetrical Wye w/45° Elbows (Dc=17, Db1=14, Db2=14)	SD5-22	2000	14	1871			0.48	
		VAV terminal unit	CD8-11						2.56	
		Distribution and Diffuser								0.05
								0.18	3.04	0.55
Section Total										**0.61**

Duct Design Fundamentals



DUCT DESIGN BY THE EQUAL FRICTION METHOD ,

Section 17, 18

Duct Design Fundamentals

DUCT DESIGN BY THE EQUAL FRICTION METHOD

16	Duct (sized to match VAV terminal unit inlet)	CD11-1	1400	12	1783	5			0.02
17 & 18	Bullhead Tee with Vanes, Branch (Dc=15, Db1=12, Db2=12)	SD5-19						0.75	
	VAV terminal unit	CD8-11						2.65	
	Distribution and Diffuser								0.05
	-						0.16	3.40	0.54
Section Total									**0.61**

Duct Design Fundamentals

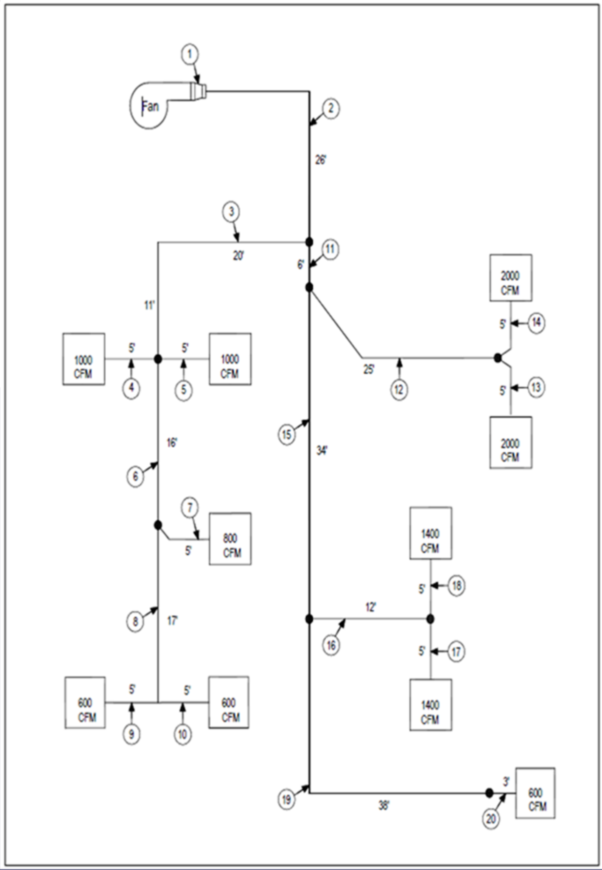
DUCT DESIGN BY THE EQUAL FRICTION METHOD

Summary of Example

Section Pressure Drop

Section	P_t (in wg)
1/2	0.19
3	0.42
4 & 5	0.67
6	0.09
7	0.57
8	0.08
9 &10	0.52
11	0.12
12	0.33
13 & 14	0.61
15	0.13
16	0.15
17 & 18	0.61
19	0.25
20	0.46

PATH A/B:		Path C:		Path D/E:		Path F/G:		Path H/I:		Path J:	
Section	TP (in. wg)	Section	TP (in. wg)	Section	TP (in. wg)	Section	TP (in. wg)	Section	TP (in. wg)	Section	TP (in. wg)
1/2	0.19	1/2	0.19	1/2	0.19	1/2	0.19	1/2	0.19	1/2	0.19
3	0.42	3	0.42	3	0.42	11	0.12	11	0.12	11	0.12
4/5	0.67	6	0.09	6	0.09	12	0.33	15	0.13	15	0.13
Total	1.28	7	0.57	8	0.08	13/14	0.61	16	0.15	19	0.25
		Total	1.27	9/10	0.52	Total	1.26	17/18	0.61	20	0.46
				Total	1.30			Total	1.20	Total	1.15



Duct Design Fundamentals

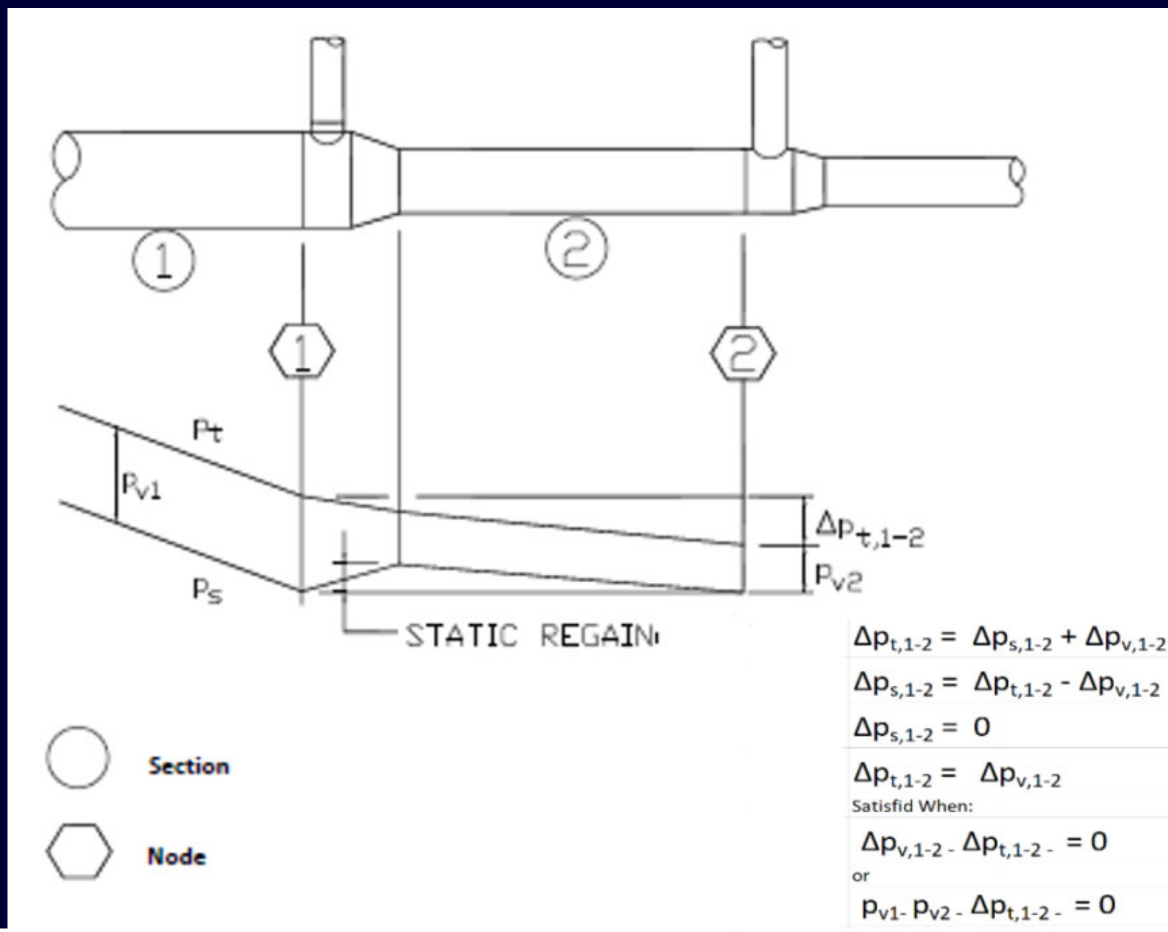
DUCT DESIGN BY THE EQUAL FRICTION METHOD

UN-BALANCE

Path	TP (in. wg)	Excess Pressure (in. wg)	% Deviation
A/B (4/5)	1.28	0.02	1.3
C (7)	1.27	0.03	2.1
D/E (9/10)	1.30	0.00	0.0
F/G (13/14)	1.26	0.04	3.1
H/I (17/18)	1.20	0.09	7.1
J (20)	1.15	0.14	11.1

Duct Design Fundamentals

Duct Design – Static Regain



$\Delta p_{t,1-2} = \Delta p_{s,1-2} + \Delta p_{v,1-2}$

$\Delta p_{s,1-2} = \Delta p_{t,1-2} - \Delta p_{v,1-2}$

$\Delta p_{s,1-2} = 0$

$\Delta p_{t,1-2} = \Delta p_{v,1-2}$

Satisfid When:

$\Delta p_{v,1-2} - \Delta p_{t,1-2} = 0$

or

$p_{v1} - p_{v2} - \Delta p_{t,1-2} = 0$

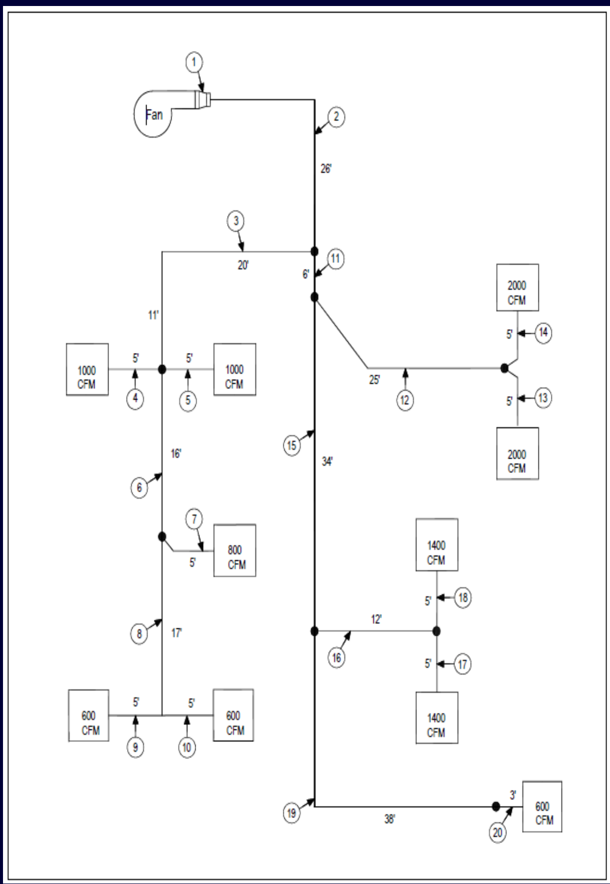
Duct Design Fundamentals

Duct Design – Static Regain

- Layout a single-line drawing of the system, and assign section numbers.
- Locate balancing dampers for Constant Volume systems, not needed for VAV system.
- Determine leakage in each section of ductwork, and add to the air quantity required per the load calculations and system diversity. A good average is include an allowance for about 5% system leakage.
- Determine terminal total pressure requirements for constant volume diffusers, or VAV terminal units.
- Size fan discharge duct (first supply air section after the fan) at the maximum recommended initial duct velocity
- Size the straight-through sections first using $p_{v1} – p_{v2} – \Delta_{pt,1-2}$. Use the "static regain" spreadsheet.
- Size the branches using the same method up to VAV terminal units, if any. Use the junction upstream velocity to determine p_{v1}.
- Size ductwork downstream of VAV terminal units by the equal friction method.
- Tabulate the total pressure required for each path from the fan to each supply terminal, and calculate the excess total pressure at each terminal.
- Design should be reasonably in balance. If not, adjust the appropriate branch by decreasing duct size or use less efficient fittings. Unbalance of 0.1 in. of water is acceptable (well within the accuracy of the fitting loss coefficients).
- Perform an acoustical analysis of the system (consult Chapter 10). Provide lined duct or sound attenuators where necessary.

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD



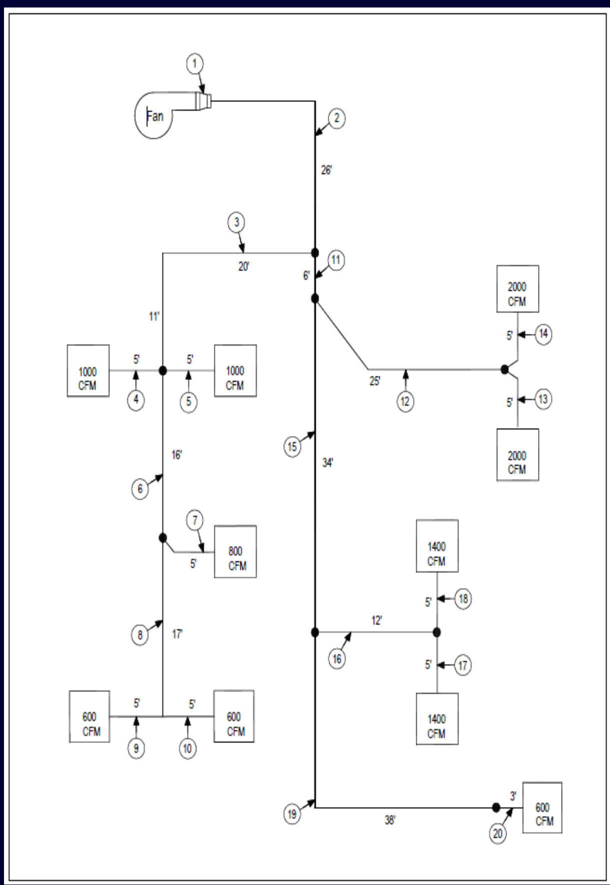
Sample Problem: Size the system shown by the static regain method. The design air temperature is 69 °F, located in Denver Density (ρ) is 0.061 lb_m/ft^3, zero duct air leakage, Ducts are round spiral galvanized steel. The diffuser and distribution ductwork downstream of the VAV box has a pressure loss of 0.05 in. of water. The VAV terminal units have loss coefficients according to the following Table Size

VAV terminal unit Resistance			
Section	Box Inlet Size (in.)	Airflow (cfm)	Loss Coefficient (C)
4 & 5	10	1000	2.58
7	9	800	2.31
9 & 10	8	600	2.49
13 & 14	14	2000	2.56
17 & 18	12	1400	2.65
20	8	600	2.49

Duct Design Fundamentals

SMACNA

DUCT DESIGN BY THE STATIC REGAIN METHOD



Assume the first section is located above a suspended acoustical ceiling with an RC requirement of 35 maximum.

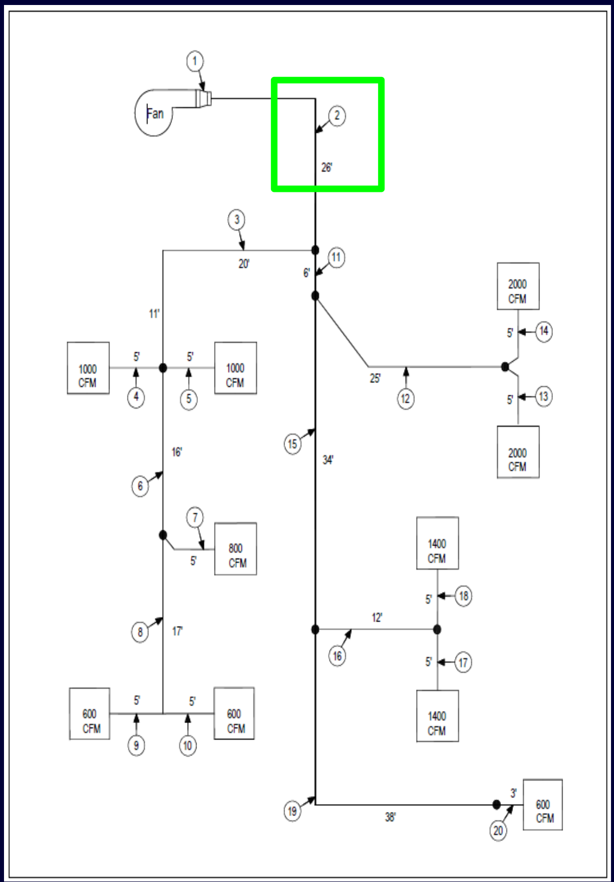
Solution: Using the Acoustical Table below, the maximum velocity is 3500 fpm.

Maximum Recommended Duct Airflow Velocities to Achieve Specified Acoustic Design Criteria[1]			
Duct Location	RC or NC Rating in Adjacent Occupancy	Maximum Airflow Velocity, Fpm	
		Rectangular Duct	Round Duct
In shaft or above drywall ceiling	45	3500	5000
	35	2500	3500
	25 or less	1700	2500
Above suspended acoustic ceiling	45	2500	4500
	35	1750	3000
	25 or less	1200	2000
Duct located within occupied space	45	2000	3900
	35	1450	2600
	25 or less	950	1700

[1]Table 4-1 [Schaffer 2005 (2011)] [Table 8 from ASHRAE 2015 – HVAC Applications Chapter 48, Noise and Vibration Control]

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD



Solution: The total fan airflow is 11,400 CFM. Sizing the first section for the maximum velocity results in a size of 25 inches.

This is actually Section 2 as Section 1 will be the fan transition. We must also account for the other fitting losses, so a spreadsheet is used to calculate the data for each section

Duct Design Fundamentals

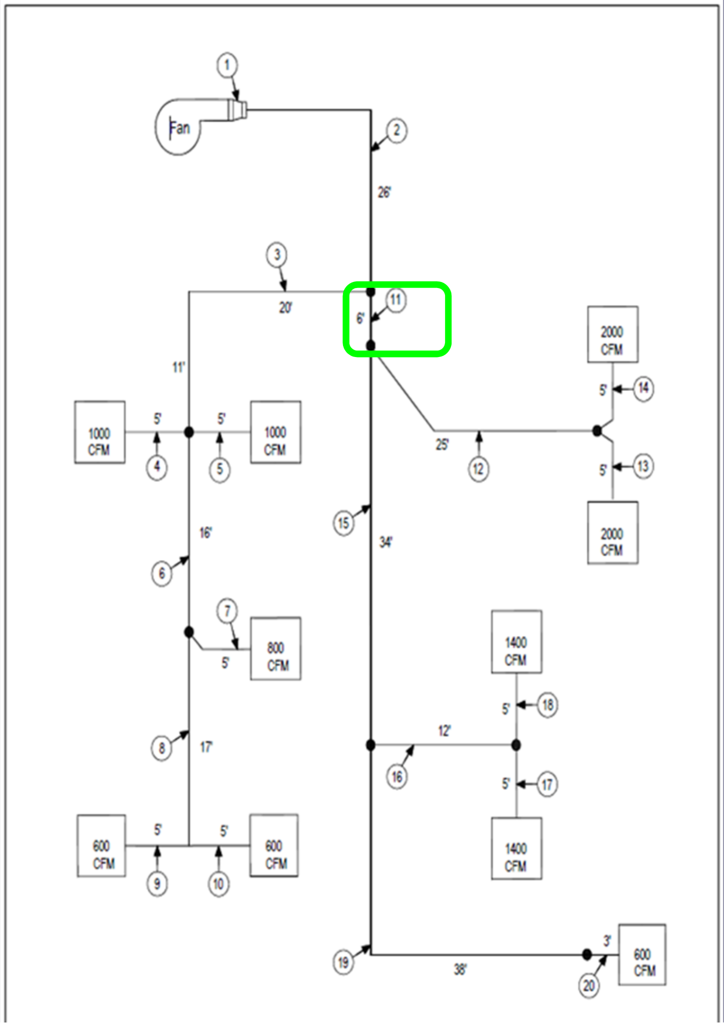
DUCT DESIGN BY THE STATIC REGAIN METHOD

Static Regain Spreadsheet

Air Temperature, °F	69	Relative Humidity, %	0	[redacted]
Elevation, ft	5430	Air Density, lbm/ft³	0.061	
Barometric Pressures, psia	12.032	Viscosity (μ), lbm/(ft-min)	0.00073245	

Upstream Section	Section	Fitting	ASHRAE Fitting Code ……….	Air Quantity (cfm)	Duct Size (in.)	Velocity (fpm)	Duct Length (ft)	Velocity Pressure, p_v (in. wg)	Loss Coefficient, C	Total Pressure Loss (in. wg)	Regain (In. wg) $[p_{v1} - p_{v2}] - \Delta p_t$
		Source									
		Drawings	DFDB	Drawings	Iteration	DFDB	Drwing	DFDB	DFDB	Σ	Static Regain Calc
1	2*	Duct	CD11-1	11400	25	3334	26			0.11	
		Elbow	CD3-9						0.13		
		Transition: H1= 20", W1= 27", L=24" (Theta1=17°, Theta2=0°)	SD4-2						0.01		
		Sized at Maximum Velocity of 3500 fpm						0.57	0.14	0.08	
Section Total ………										**0.19**	
2	11a	Duct	CD11-1	24	25	2171	11			0.02	
		Tee, 45° Entry, Main: Dc=25, Ds=25, Db=25	SD5-1						0.15		
								0.24	0.15	0.04	(0.57 - 0.24) - 0.06
Section Total ………										0.06	0.27

Duct Design Fundamentals



DUCT DESIGN BY THE Static Regain METHOD , Section 11

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

Static Regain Spreadsheet

Air Temperature, °F	69	Relative Humidity, %	0
Elevation, ft	5430	Air Density, lbm/ft³	0.061
Barometric Pressures, psia	12.032	Viscosity (μ), lbm/(ft-min)	0.00073245

Upstream Section	Section	Fitting	ASHRAE Fitting Code ………..	Air Quantity (cfm)	Duct Size (in.)	Velocity (fpm)	Duct Length (ft)	Velocity Pressure, p_v (in. wg)	Loss Coefficient, C	Total Pressure Loss (in. wg)	Regain (In. wg) $[p_{v1} - p_{v2}] - \Delta p_t$
				Source							
		Drawings	DFDB	Drawings	Iteration	DFDB	Drwing	DFDB	DFDB	Σ	Static Regain Calc
1	2*	Duct	CD11-1	11400	25	3334	26			0.11	
		Elbow	CD3-9						0.13		
		Transition: H1= 20", W1= 27", L=24" (Theta1=17º, Theta2=0º)	SD4-2						0.01		
		Sized at Maximum Velocity of 3500 fpm						0.57	0.14	0.08	
Section Total ………										0.19	
2	11a	Duct	CD11-1	24	25	2171	11			0.02	
		Tee, 45° Entry, Main: Dc=25, Ds=25, Db=25	SD5-1						0.15		
								0.24	0.15	0.04	(0.57 - 0.24) - 0.06
Section Total ………										0.06	0.27

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

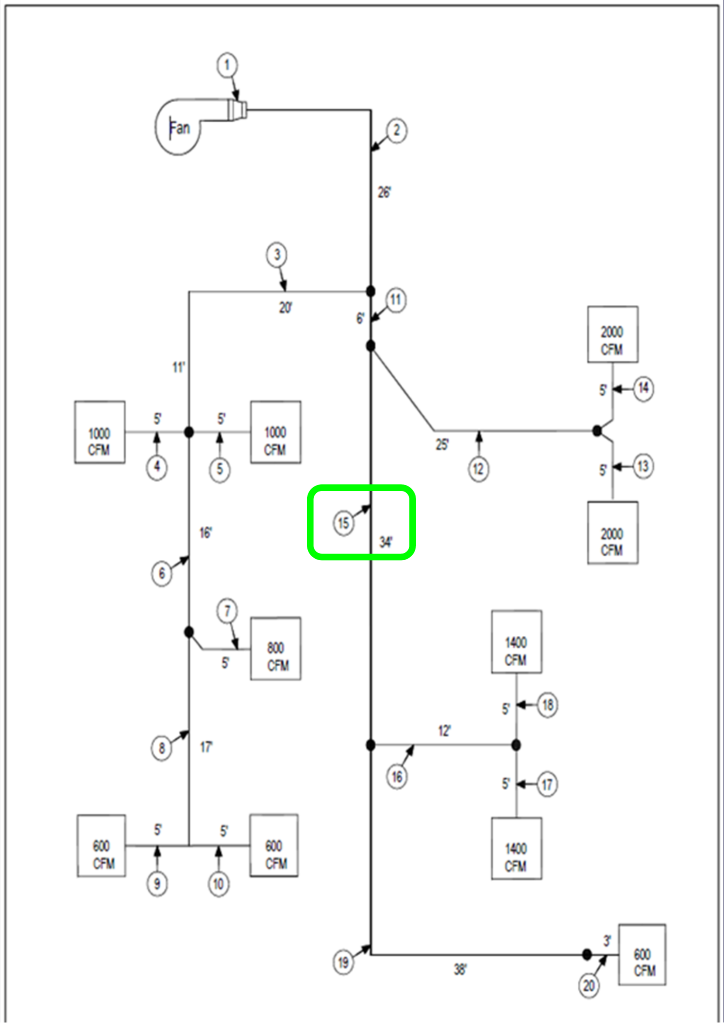
2	**11b**	Duct	CD11-1	7400	24	2355	11			0.02	
		Tee, 45° Entry, Main: Dc=25, Ds=24, Db=24	SD5-12						0.15		
								0.28	0.15	0.04	(0.57-0.28)-0.06
Section Total										0.06	0.23
2	**11c**	Duct	CD11-1	7400	23	2565	11			0.03	
		Tee, 45º Entry, Main Dc=25, Ds=23, Db=23	SD5-12						0.14		
								0.34	0.14	0.05	(0.57-0.34)-0.08
Section Total										0.08	0.15

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

2	11d*	Duct	CD11-1	7400	22	2803	11			0.04	
		Tee, 45° Entry, Main: Dc=25, Ds=22, Db=22	SD5-12						0.14		
								0.40	0.14	0.06	(0.57-0.40)-0.10
Section Total										**0.10**	0.07
2	11e	Duct	CD11-1	7400	21	3077	11			0.04	
		Tee, 45° Entry, Main: Dc=25, Ds=21, Db=21	SD5-12						0.14		
								0.48	0.14	0.07	(0.57-0.48)-0.11
Section Total										0.11	-0.02

Duct Design Fundamentals



DUCT DESIGN BY THE Static Regain METHOD ,
Section 15

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

11	15a	Duct	CD11-1	3400	22	1288	23			0.02	
		Wye, 45° , Main: Dc=22, Ds=22, Db=22	SD5-1						0.27		
								0.08	0.27	0.02	(0.40 - 0.08) - 0.04
Section Total										0.04	0.28
11	15b	Duct	CD11-1	3400	21	1414	23			0.02	
		Wye, 45° , Main: Dc=22, Ds=21, Db=21	SD5-1						0.24		
								0.10	0.24	0.02	(0.40- 0.10) - 0.04
Section Total										0.04	0.26
11	15c	Duct	CD11-1	3400	20	1558	23			0.03	
		Wye, 45° , Main: Dc=22, Ds=20, Db=20	SD5-1						0.19		
								0.12	0.19	0.02	(0.40 - 0.12) - 0.05
Section Total										0.05	0.23

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

11	15d	Duct	CD11-1	3400	19	1727	23			0.04	
		Wye, 45° , Main: Dc=22, Ds=19, Db=19	SD5-1						0.17		
								0.15	0.17	0.03	(0.40 - 0.15) - 0.07
Section Total										0.07	0.18
11	15e	Duct	CD11-1	3400	18	1924	23			0.05	
		Wye, 45° , Main: Dc=22, Ds=18, Db=18	SD5-1						0.16		
								0.19	0.16	0.03	(0.40-0.19)-0.08
Section Total										0.08	0.13
11	15f*	Duct	CD11-1	3400	17	2157	23			0.07	
		Wye, 45° y, Main: Dc=22, Ds=17, Db=17	SD5-1						0.14		
								0.24	0.14	0.03	(0.40-0.24)-0.10
Section Total										**0.10**	0.06

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

11	15g	Duct	CD11-1	3400	16	2435	23			0.09	
		Wye, 45° y, Main: Dc=22, Ds=16, Db=16	SD5-1						0.14		
								0.30	0.14	0.04	(0.40-0.30)-0.13
Section Total										0.13	-0.03

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

11	15d	Duct	CD11-1	3400	19	1727	23			0.04	
		Wye, 45° , Main: Dc=22, Ds=19, Db=19	SD5-1						0.17		
								0.15	0.17	0.03	(0.40 - 0.15) - 0.07
Section Total										0.07	0.18
11	15e	Duct	CD11-1	3400	18	1924	23			0.05	
		Wye, 45° , Main: Dc=22, Ds=18, Db=18	SD5-1						0.16		
								0.19	0.16	0.03	(0.40-0.19)-0.08
Section Total										0.08	0.13
11	15f*	Duct	CD11-1	3400	17	2157	23			0.07	
		Wye, 45° y, Main: Dc=22, Ds=17, Db=17	SD5-1						0.14		
								0.24	0.14	0.03	(0.40-0.24)-0.10
Section Total										**0.10**	0.06

Duct Design Fundamentals

SMACNA

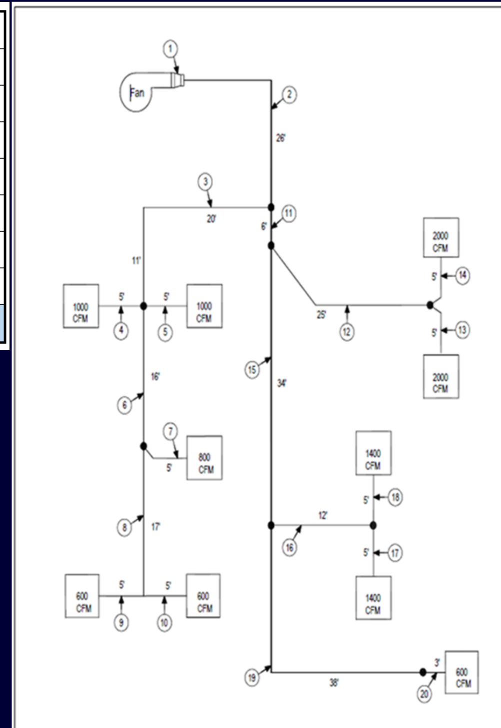
DUCT DESIGN BY THE STATIC REGAIN METHOD

Summary of Example

Section Pressure Drop

Section	P_t (in wg)
1	0.0
2	0.19
3	0.37
4 & 5	0.61
6	0.04
7	0.53
8	0.03
9 &10	0.48
11	0.10
12	0.26
13 & 14	0.54
15	0.10
16	0.11
17 & 18	0.56
19	0.15
20	0.49

Path A/B:		Path C:		Path D/E:		Path F/G:		Path H/I:		Path J:	
Section	TP, in.wg	Section	TP, in.wg	Section	TP, in.wg	Section	TP, in.wg	Section	TP, in.wg	Section	TP, in.wg
1	0.0	1	0.0	1	0.0	1	0.0	1	0.0	1	0.0
2	0.19	2	0.19	2	0.19	2	0.19	2	0.19	2	0.19
3	0.37	3	0.37	3	0.37	11	0.10	11	0.10	11	0.10
4/5	0.61	6	0.04	6	0.04	12	0.26	15	0.10	15	0.10
Total	1.16	7	0.53	8	0.02	13/14	0.54	16	0.11	19	0.15
		Total	1.12	9/10	0.48	Total	1.08	17/18	0.56	20	0.49
				Total	1.09			Total	1.06	Total	1.04



Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

UN-BALANCE

Path	TP (in. wg)	Excess Pressure (in. wg)	% Deviation
A/B (4/5)	1.16	0.00	0
C (7)	1.12	0.04	4
D/E (9/10)	1.09	0.07	6
F/G (13/14)	1.08	0.08	7
H/I (17/18)	1.06	0.11	9
J (20)	1.04	0.13	11

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

Comparison with Equal Friction

Comparison with Equal Fricition

	Static Regain		Equal Friction	
Path	TP (in. wg)	Excess Pressure (in. wg)	TP (in. wg)	Excess Pressure (in. wg)
A/B (4/5)	1.16	0.00	1.28	0.02
C (7)	1.12	0.04	1.27	0.03
D/E (9/10)	1.09	0.07	1.30	0.00
F/G (13/14)	1.08	0.08	1.26	0.04
H/I (17/18)	1.06	0.11	1.20	0.09
J (20)	1.04	0.13	1.15	0.14

Duct Design Fundamentals

DUCT DESIGN BY THE STATIC REGAIN METHOD

Comparison with Equal Friction

	Static Regain Design		Equal Friction Design		Larger	Higher
Section	Pt (in wg)	Size (inch)	Pt (in wg)	Size (inch)	Size	Δp_t
1	0.0	20 x 27 to 25 Transition	0.00	20 x 27 to 25 Transition		
2	0.19	**25**	0.19	**25**		
3	0.37	**20**	0.42	**17**	SR	EF
4 & 5	0.61	**10**	0.67	**10**		EF
6	0.04	**16**	0.09	**13**	SR	EF
7	0.53	**9**	0.57	**9**		EF
8	0.03	**14**	0.08	**11**	SR	EF
9 &10	0.48	**8**	0.52	**8**		EF
11	0.10	**22**	0.12	**21**	SR	EF
12	0.26	**21**	0.33	**17**	SR	EF
13 & 14	0.54	**14**	0.61	**14**		EF
15	0.10	**17**	0.13	**16**	SR	EF
16	0.11	**17**	0.15	**15**	SR	EF
17 & 18	0.56	**12**	0.61	**12**		EF
19	0.15	**9**	0.25	**8**	SR	EF
20	0.49	**8**	0.46	**8**		SR

Duct Design Fundamentals

Step 10__ Analyze the design to improve balancing and reduce material cost.

Step 11__ Select fan according to proper guidelines – See Section 4.8, page 4.6 of the SMACNA HVAC System Duct Design Manual and AMCA Manuals

Step 12__ Analyze the design to make sure it meets the acoustical requirements. See Chapter 10 Designing For Sound and Vibration of the SMACNA HVAC System Duct Design Manual or the SMACNA Sound and Vibration Manual, First Edition – December 2004

Step 13__ Select materials that minimize cost and meet the SMACNA Duct Construction Standards Metal and Flexible, Third Edition – 2005

Step 14__ Analyze the life-cycle cost of the design

Step 15__ Commission the design to make sure it meets the OPR. Reference the SMACNA HVAC Commissioning Manual, Second Edition - 2013

Duct Design Fundamentals
Acoustics

HVAC
SOUND AND VIBRATION
MANUAL

FIRST EDITION – DECEMBER, 2004

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Duct Design Fundamentals

Acoustical Analysis Overview

Page 10.3

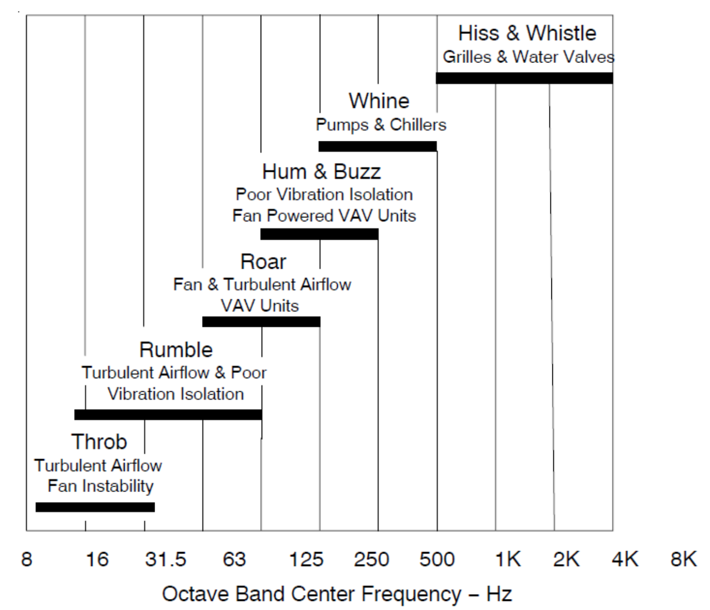

FIGURE 10–4 FREQUENCY RANGES OF THE MOST LIKELY SOURCES OF ACOUSTICAL COMPLAINTS

Duct Design Fundamentals

Acoustical Analysis Overview

Page 10.4

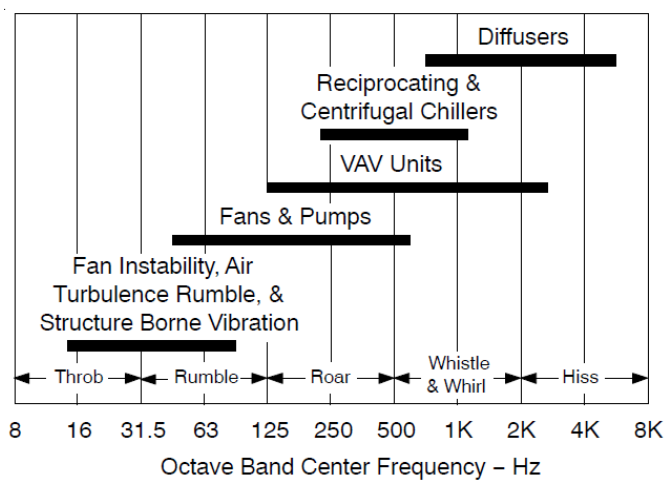

FIGURE 10–5 FREQUENCY AT WHICH DIFFERENT TYPES OF MECHANICAL EQUIPMENT GENERALLY CONTROL SOUND SPECTRA

Duct Design Fundamentals

Acoustical Analysis Overview

Page 10.5

Sound Source	Path Nos.
Circulating fans; grilles; registers; diffusers; unitary equipment in room	1
Induction coil and fan-powered variable air-volume mixing units	1, 2
Unitary equipment located outside of room served, remotely located air-handling equipment, such as, fans, blowers, dampers, duct fittings and air washers	2, 3
Compressors, pumps, and other reciprocating and rotating equipment (excluding air-handling equipment)	4, 5, 6
Cooling towers; air-cooled condensers	4, 5, 6, 7
Exhaust fans; window air conditioners	7, 8
Sound transmission between rooms	9, 10

	Transmission Paths	Recommended Noise Reduction Methods
1	Direct sound radiated from sound source to ear Reflected sound from floors, walls, and ceilings	Direct sound can be controlled only by selecting quiet Reflected sound is controlled by adding sound absorption to the room and to equipment location.
2	Air- and structure-borne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into room	Design duct and fittings for low turbulence; locate high velocity ducts in non-critical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers.
3	Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1	Select fans for minimum sound power; use ducts lined with sound-absorbing material; use duct silencers or sound plenums in supply and return air ducts
4	Noise is transmitted through equipment room walls and floors to adjacent rooms	Locate equipment rooms away from critical areas; use masonry blocks or concrete for equipment room walls and floor.
5	Building structure transmits vibration to adjacent walls and ceilings, from which it radiates as sound into a room by Path 1	Mount all machines on properly designed vibration isolators; masonry blocks or concrete for equipment room walls and floor.
6	Vibration transmission along pipes and duct walls	Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts, and vibrating machines.
7	Noise radiated to outside enters room windows	Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment.
8	Inside noise follows Path 1	Select quiet equipment.
9	Noise transmitted to an air diffuser in a room into duct and out through an air diffuser in another	Design and install duct attenuation to match transmission loss of wall between rooms.
10	Sound transmission through, over, and around	Extend partition to ceiling slab and tightly seal all around; seal all pipe, conduit, duct, and other partition penetrations.

Table 10–1 Sound Sources, Transmission Paths, and Recommended Noise Reduction Methods

Duct Design Fundamentals

Acoustical Analysis Overview

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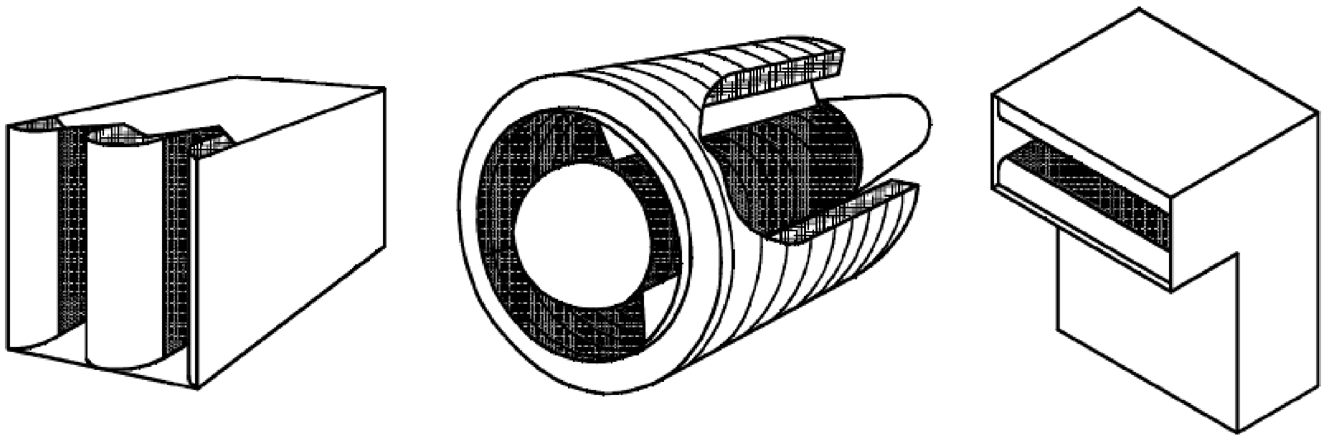

(a) Rectangular Dissipative Duct Silencer

(b) Circular Dissipative Duct Silencer

(c) Rectangular Dissipative Elbow Duct Silencer

FIGURE 10–6 DISSIPATIVE PASSIVE DUCT SILENCERS

Duct Design Fundamentals

Acoustical Analysis Overview

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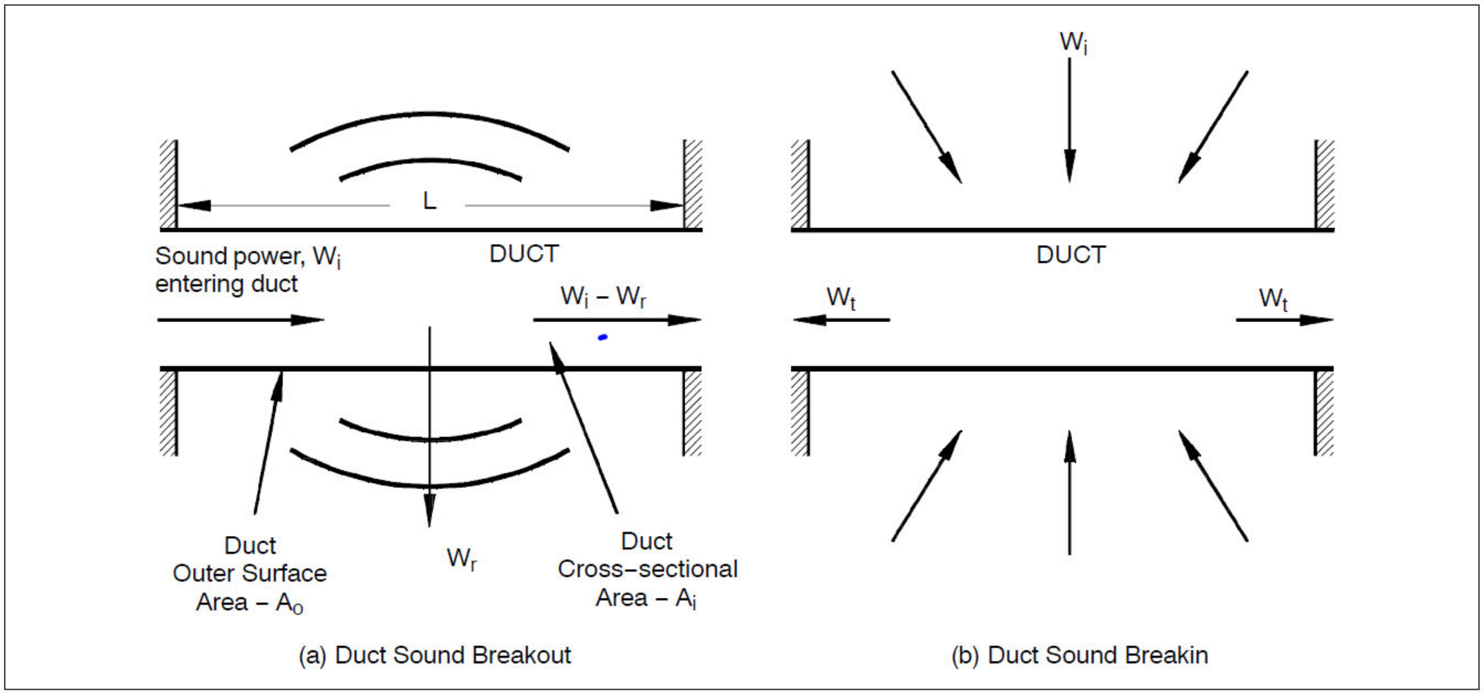


FIGURE 10–9 BREAKOUT AND BREAK–IN OF SOUND IN DUCTS

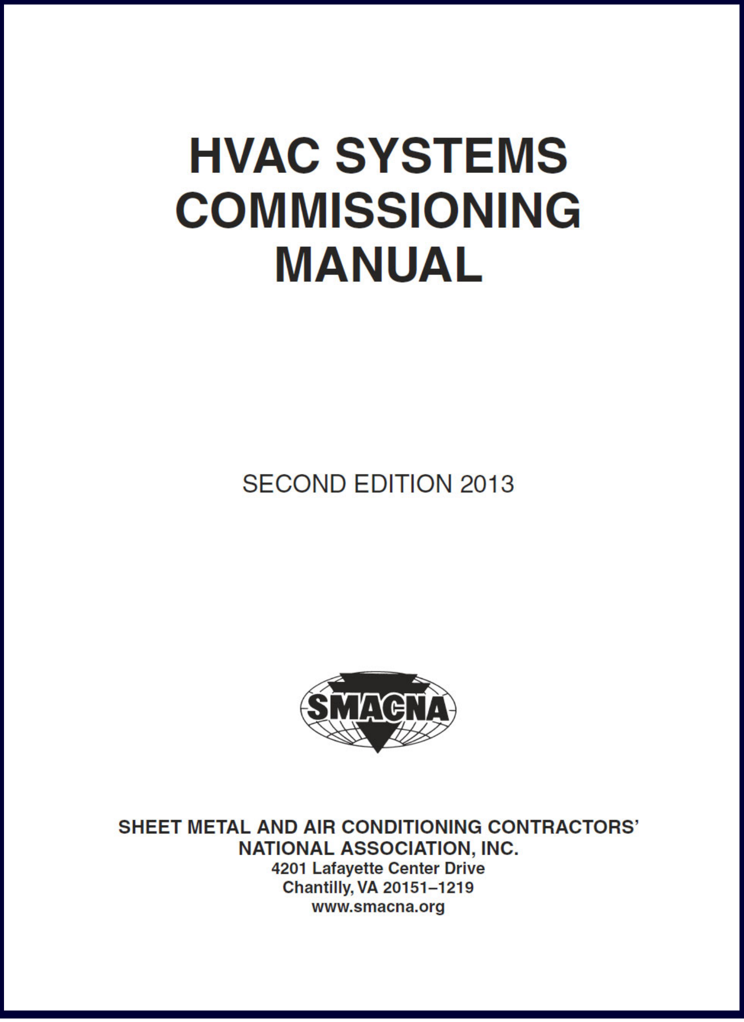
Duct Design Fundamentals

Step 13__ Select materials that minimize cost and meet the SMACNA Duct Construction Standards Metal and Flexible, Third Edition – 2005

Step 14__ Analyze the life-cycle cost of the design

Step 15__ Commission the design to make sure it meets the OPR. Reference the SMACNA HVAC Commissioning Manual, Second Edition - 2013

Duct Design Fundamentals
Commissioning


HVAC SYSTEMS
COMMISSIONING
MANUAL

SECOND EDITION 2013

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www.smacna.org

Duct Design Fundamentals
Commissioning

- Commissioning may be defined as: “the process of advancing systems from a state of static physical completion to a state of full, demonstrated, and documented working order, according to the owner’s project requirements and the design requirements

- The owner’s operating staff are instructed in correct systems operation and maintenance.

- The full commissioning process should be planned and documented. Planning should begin as early as possible to ensure the owner’s project requirements are understood and suitable quality assurance strategies are utilized.

- The quality assurance process should be documented to provide an auditable record of the process.

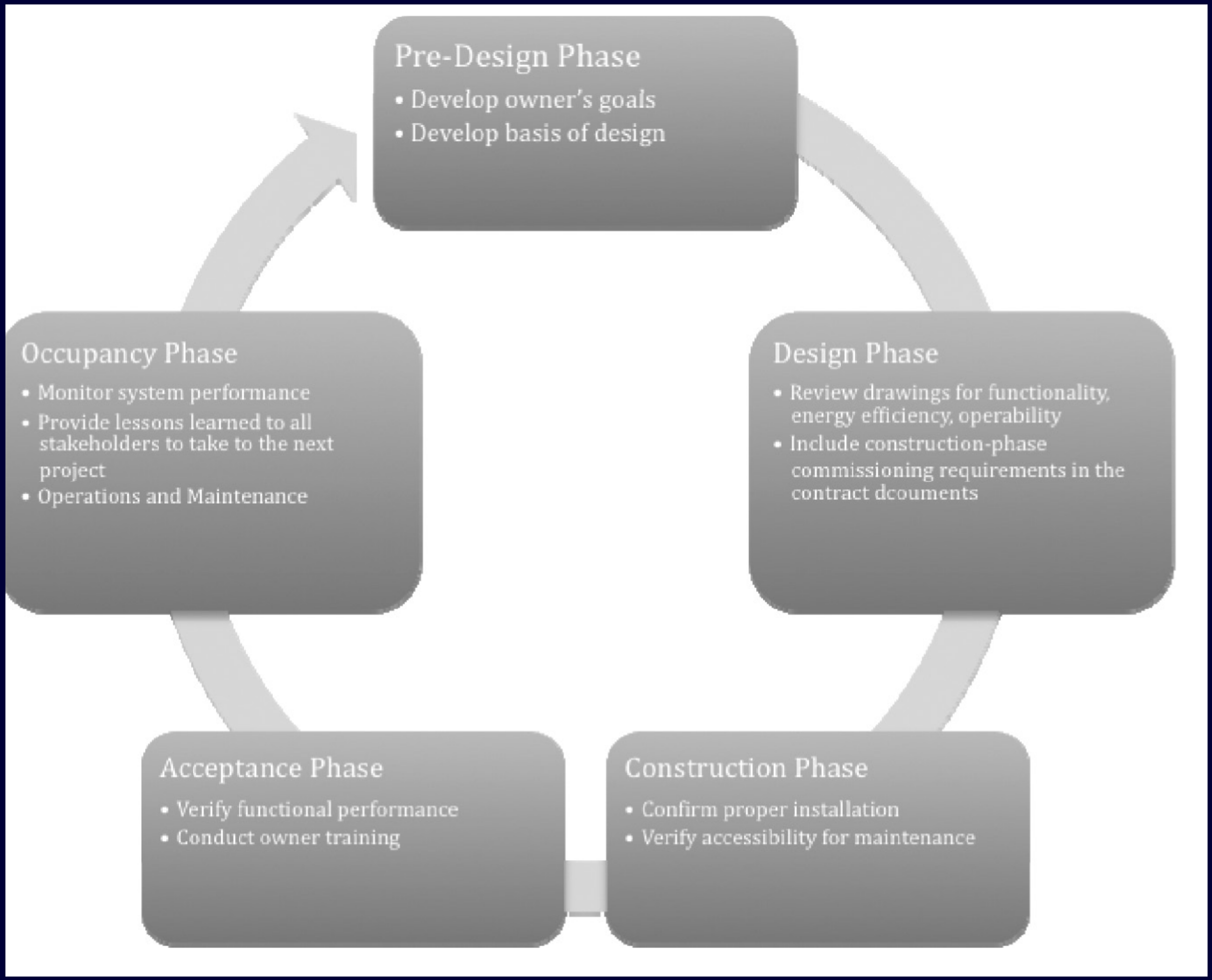
Duct Design Fundamentals
Commissioning

Examples of Equipment Included:

- Hot water and steam boilers; with atmospheric or power burners; gas, oil, or combination gas/oil fired.
- Chillers; with reciprocating, scroll, screw, or centrifugal compressors; air-or water- cooled; with or without condensers; and including heat recovery models.
- Cooling towers, closed-circuit heat rejectors, and both air cooled and evaporative condensers.
- Hot water, chilled water, and condensing water pumps associated with the preceding.
- Constant volume, single zone air systems (including all components such as fans, coils, furnaces, condensing units, dampers, and controls, as applicable).
- Condensing boilers.
- Primary and secondary piping systems.
- Variable flow piping or pumping systems.
- Variable Air Volume (VAV) Systems (including various components such as terminal units and Variable Frequency Drives

Duct Design Fundamentals

Commissioning



Duct Design Fundamentals
Commissioning

Chapter 6. Level 1 , Basic Commissioning, The commissioning agent's first task is to pull together:

• The Owner's Project Requirements

• Statement of design intent

• Schedule information

• List of equipment and systems needing to be commissioned,

• List of sub trades, suppliers, and other contractors (most commonly the electrical contractor) who will be involved in the commissioning process, and

• All submittal data and controls sequence descriptions needed to prepare commissioning checklists.

Duct Design Fundamentals Commissioning

Chapter 6 Level 1 , Basic Commissioning - Also includes

All the checks and tests are carried out to suit the schedule requirements of the project.

Duct Design Fundamentals Commissioning Additional Chapters

HVAC SYSTEMS COMMISSIONING MANUAL

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