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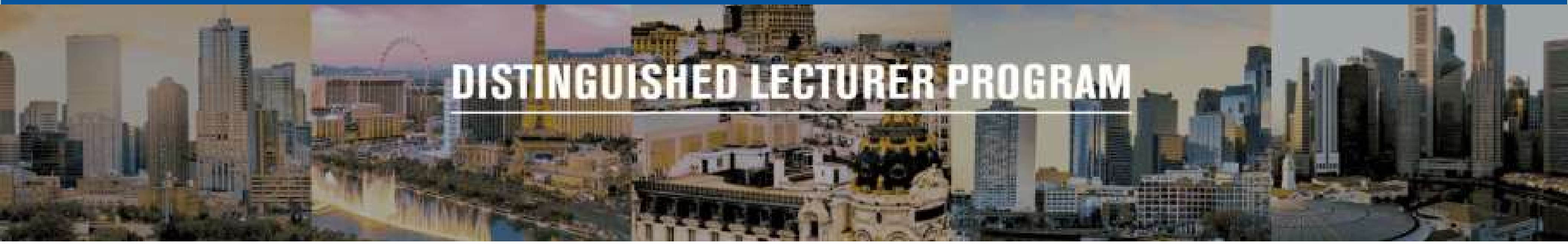

Exhaust Duct Design

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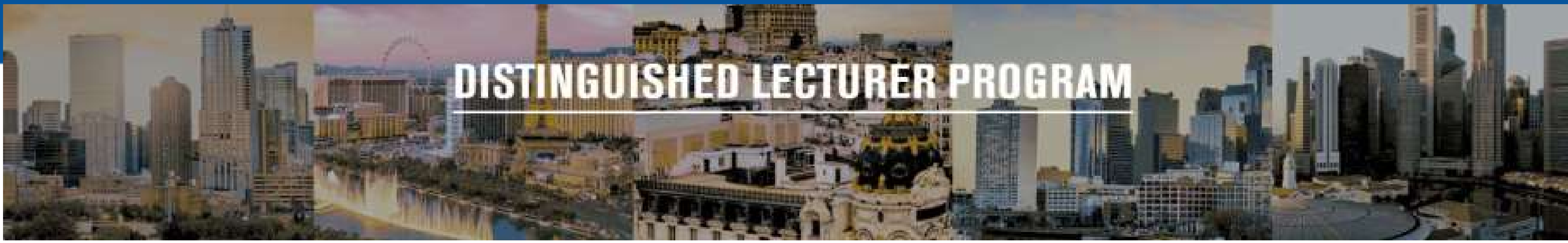

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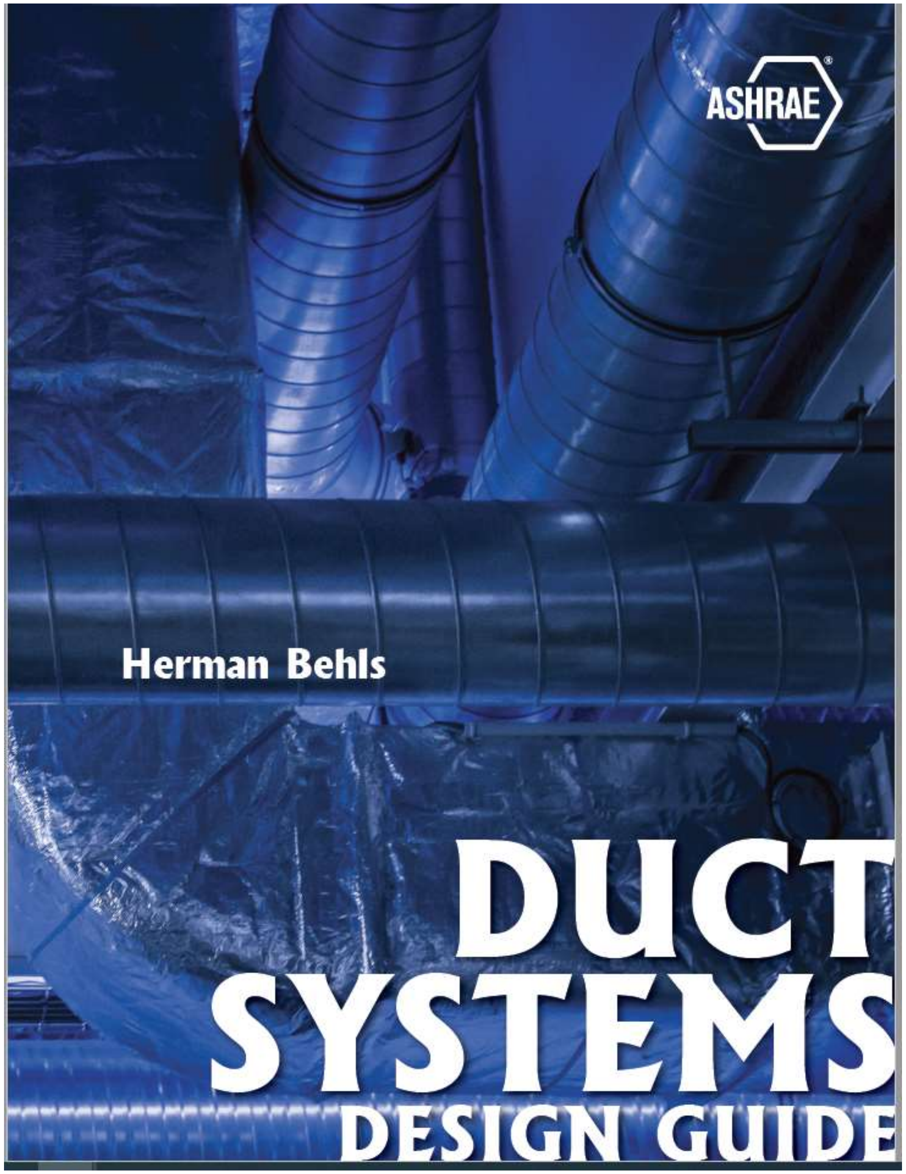
Duct Systems Design Guide



Exhaust Ventilation Air System

A typical local exhaust ventilation systems consist of the following basic elements:

- Hood to capture pollutants, vapors, and/or excessive heat
- Ducts to transport polluted air to an air-cleaning device or vent the exhaust air from the building
- Air-cleaning device to remove captured pollutants from the airstream for recycling or disposal
- Air-moving device (e.g., fan or high-pressure air ejector) to provide motive power to overcome system resistance
- Exhaust stack to discharge system air to the atmosphere

Exhaust Ventilation Air System

These elements are covered in detail by the following chapters of the American Conference of Governmental Industrial Hygienists (ACGIH) publication *Industrial Ventilation: A Manual of Recommended Practice for Design* (2019), or *ASHRAE Handbook—HVAC Applications* (2019):

Hoods:	ACGIH chapters 6 and 13
Air-cleaning devices:	ACGIH chapter 8
Fans:	ACGIH chapter 7
Stack design:	ACGIH chapter 5, Section 5.12, and/or ASHRAE chapter 45

Duct Design

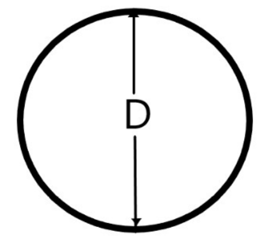
Learning Objectives

- Overview – Basic Equations
- Pressure Losses
- Hoods
- Duct Shape
- Duct Fittings for Exhaust
- Transport Velocity
- Duct Sizing
- Example Design

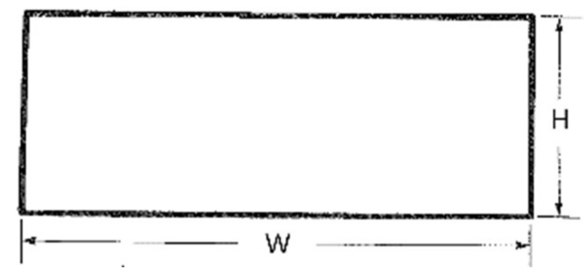
Basic Equations

Cross-sectional Areas

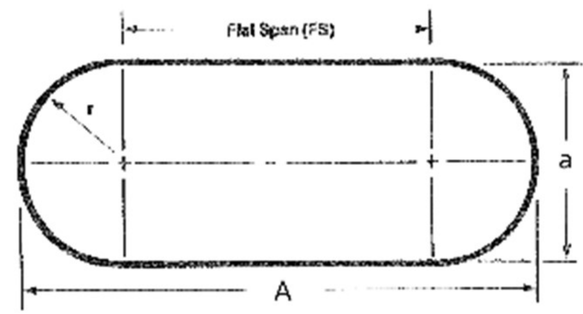
Round: $A_d = \frac{\pi D^2}{4}$



Rectangular : $A_d = WH$



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



Basic Equations

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

If Q (cfm[L/s]) and A (ft^2 [m^2]) are known, the duct velocity, V (fpm, m/s) can be calculated

Example 1: If the volume flow rate in a 22 in. (560 mm) duct is, Q = 5000 cfm (2360 L/s), what is the average velocity of air in the duct.

D = 22 inch (1.83 ft) [560 mm]

$$A_d = \frac{\pi(1.83)^2}{4} = 2.64 \text{ ft}^2 \ (.25 \text{ m}^2)$$

V = 5000 / 2.64 = 1894 fpm [(2360/.25/ 1000) = 9.6 m/s]

Basic Equations

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

Example 2: If the design volume flow rate is 13,000 cfm (6135 L/s) and the velocity is 4000 fpm (20.3 m/s), what is the diameter.

A_d = Q / V = 13,000 / 4000 = 3.25 ft^2 (Multiply by 144 to get in^2) = *468 in^2*
[A_d = Q / V = 6135 / 20.3/1000 = 0.30 m^2]

$$D = \sqrt{4\,Ad/\pi}$$

$$D = \sqrt{4\,x\,468/\pi} = 24.4 \text{ inch}$$

$$D = \sqrt{4\,x\,.3/\pi} = 0.62 \text{ m (618 mm)}$$

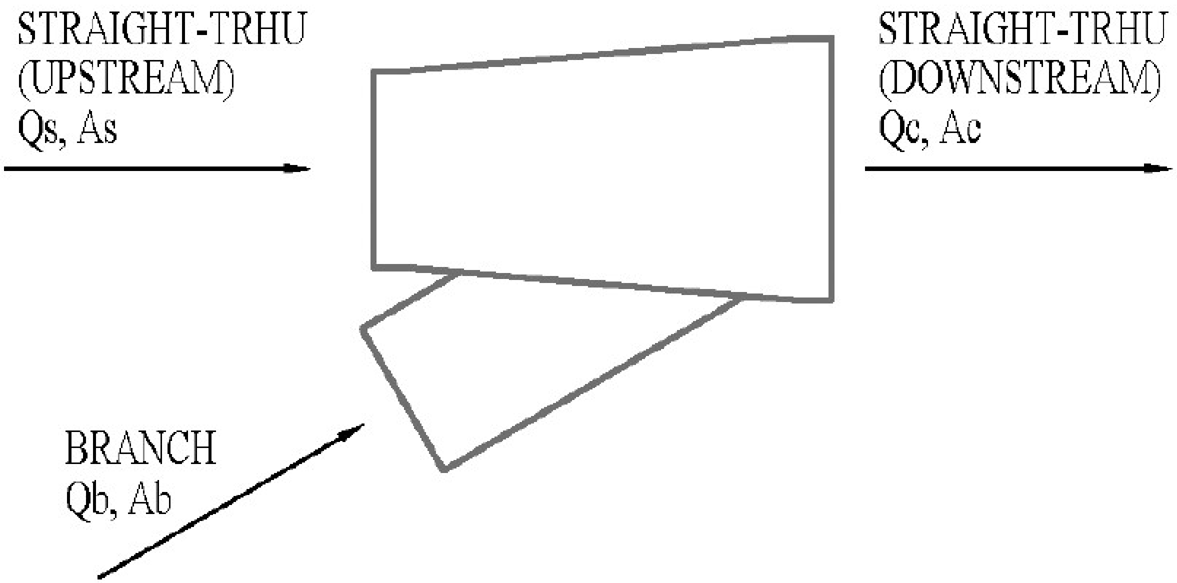
Basic Equations - Converging Flow

According to the law of conservation of mass, the volume flow rate after flows converge is equal to the sum of the flows before convergence at constant density.

$$Q_c = Q_b + Q_s$$

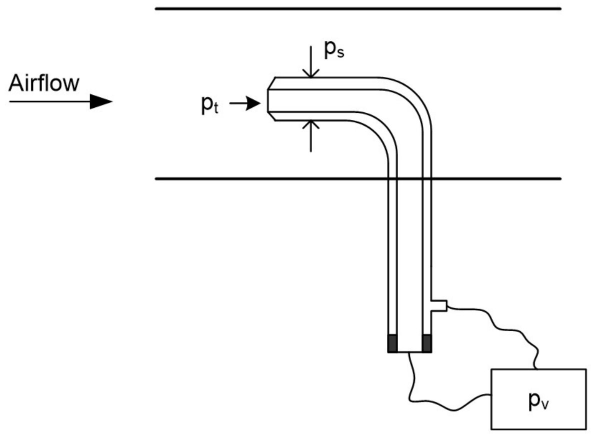
Where:

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



Pressure

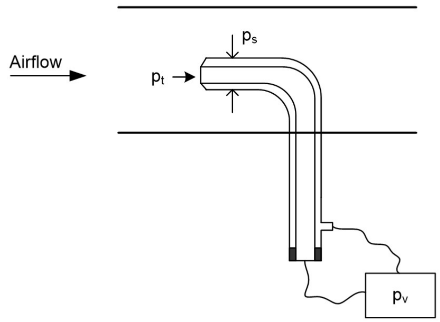
$$p_t = p_s + p_v$$



Pitot-static tube

Total Pressure

- Total pressure (p_t) represents the total energy of the air flowing in a duct system.
- Energy cannot be created or increased except by adding work or heat (typically at the fan)
- Energy and thus total pressure must always decrease from an inlet to the fan or once the air leaves 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***.



Static Pressure

- Static Pressure is a 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, 1 atm~ 407 in. of water [101.325 kPa]
- Static pressure will decrease with an increase of velocity pressure
- Static pressure can increase if there is a decrease in velocity pressure (static regain)

Velocity Pressure

- **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**

Velocity Pressure

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

Where:

p_v = velocity pressure, in. of water (Pa)

V = velocity, ft/min (m/s)

ρ = density, lb_m/ft^3 (Kg/m^3)

SI $$p_v = \rho V^2/2$$

For standard conditions, $\rho = 0.075\ lb_m/ft^3$ ($1.204\ kg/m^3$)

Pressure – Changes in Pressure

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

Derived from the Bernoulli Equation

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

(ASHRAE 2017 Handbook, Chapter 21)

Pressure Losses

Friction Losses

Dynamic Losses

Pressure Losses

Darcy-Weisbach Equation (ASHRAE 2017 Handbook, Chapter 21)

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

Where:

- f = friction factor
- L = Length, ft (m)
- D_h = hydraulic diameter, ft (m)
- p_v = velocity pressure, in wg (Pa)
- C = loss coefficient

Left hand side is the Darcy Equation for the friction losses.
Right Hand Side is the Weisbach Equation for fittings or other dynamic losses.

The ASHRAE Duct Fitting Database Determines Friction Losses and Fitting Losses and Coefficients and includes over 200 types of fittings

Pressure Losses

Friction – Colebrook Equation

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{12\varepsilon}{3.7D_h} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

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 (ft[mm])*, which is determined experimentally.

Pressure Losses (from ASHRAE 2021 Handbook) page 21.7

Table 1 Duct Roughness Factors

1	2	3
	Absolute Roughness ε, ft {mm}	
Duct Type/Material	**Range**	**Roughness Category**
Drawn tubing (Madison and Elliot 1946)	0.0000015 {0.00046}	Smooth 0.0000015 {0.00046}
PVC plastic pipe (Swim 1982)	0.00003 to 0.00015 {0.009 to 0.046}	Medium smooth 0.00015 {0.046}
Commercial steel or wrought iron (Moody 1944)	0.00015 {0.046}	
Aluminum, round, longitudinal seams, crimped slip joints, 3 ft {0.91 m} spacing (Hutchinson 1953)	0.00012 to 0.0002 {0.037 to 0.061}	
Friction chart:		
Galvanized steel, round, longitudinal seams, variable joints (Vanstone, drawband, welded. Primarily beaded coupling), 4 ft {1.22 m} joint spacing (Griggs et al. 1987)	0.00016 to 0.00032 {0.049 to 0.098}	Average 0.0003 {0.09}
Galvanized steel, spiral seams, 10 ft {3.05 m} joint spacing (Jones 1979)	0.0002 to 0.0004 {0.061 to 0.12}	
Galvanized steel, spiral seam with 1, 2, and 3 ribs, beaded couplings, 12 ft {3.66 m} joint spacing (Griggs et al. 1987)	0.00029 to 0.00038 {0.088 to 0.116}	
Galvanized steel, rectangular, various type joints (Vanstone, drawband, welded. Beaded coupling), 4 ft {1.22 m} spacing[a] (Griggs and Khodabakhsh-Sharifabad 1992)	0.00027 to 0.0005 {0.082 to 0.15}	
Phenolic duct, aluminum foil on the interior face, sections connected with a four-bolt flange and cleat joint (Idem and Paruchuri 2018)		
5 ft {1.52 m} spacing:	0.00049 to 0.00128 {0.149 to 0.391}	
10 ft {3.05 m} spacing:	0.00025 to 0.00098 {0.075 to 0.298}	
Wright Friction Chart:		
Galvanized steel, round, longitudinal seams, 2.5 ft {0.76 m} joint spacing, ε = 0.0005 ft {0.15 mm}	Retained for historical purposes [See Wright (1945) for development of friction chart]	
Flexible duct, nonmetallic and wire, fully extended (Abushakra et al. 2004; Culp 2011)	0.0003 to 0.003 {0.09 to 0.9}	Medium rough 0.003 {0.9}
Galvanized steel, spiral, corrugated,[b] Beaded slip couplings, 10 ft {3.05 m} spacing (Kulkarni et al. 2009)	0.0018 to 0.0030 {0.54 to 0.91}	
Fibrous glass duct, rigid (tentative)[c]	—	
Fibrous glass duct liner, air side with facing material (Swim 1978)	0.005 {1.52}	
Fibrous glass duct liner, air side spray coated (Swim 1978)	0.015 {4.57}	Rough 0.01 {3.0}
Flexible duct, metallic corrugated, fully extended	0.004 to 0.007 {1.2 to 2.1}	
Concrete (Moody 1944)	0.001 to 0.01 {0.30 to 3.0}	

[a]Griggs and Khodabakhsh-Sharifabad (1992) showed that ε values for rectangular duct construction combine effects of surface condition, joint spacing, joint type, and duct construction (cross breaks, etc.), and that the ε-value range listed is representative.
[b]Spiral seam spacing was 4.65 in. {119 mm} with two corrugations between seams. Corrugations were 0.75 in. {19 mm} wide by 0.23 in. {6 mm} high (semicircle).
[c]Subject duct classified "tentatively medium rough" because no data available.

Pressure Losses
(from ASHRAE 2021 Handbook)

Table 1 Duct Roughness Factors

1	2	3
	Absolute Roughness ε, ft {mm}	
Duct Type/Material	**Range**	**Roughness Category**
Galvanized steel, round, longitudinal seams, variable joints (Vanstone, drawband, welded. Primarily beaded coupling), 4 ft {1.22 m} joint spacing (Griggs et al. 1987)	0.00016 to 0.00032 {0.049 to 0.098}	Average 0.0003 {0.09}
Galvanized steel, spiral seams, 10 ft {3.05 m} joint spacing (Jones 1979)	0.0002 to 0.0004 {0.061 to 0.12}	
Galvanized steel, spiral seam with 1, 2, and 3 ribs, beaded couplings, 12 ft {3.66 m} joint spacing (Griggs et al. 1987)	0.00029 to 0.00038 {0.088 to 0.116}	
Galvanized steel, rectangular, various type joints (Vanstone, drawband, welded. Beaded coupling), 4 ft {1.22 m} spacing[a] (Griggs and Khodabakhsh-Sharifabad 1992)	0.00027 to 0.0005 {0.082 to 0.15}	

Pressure Losses

Dynamic

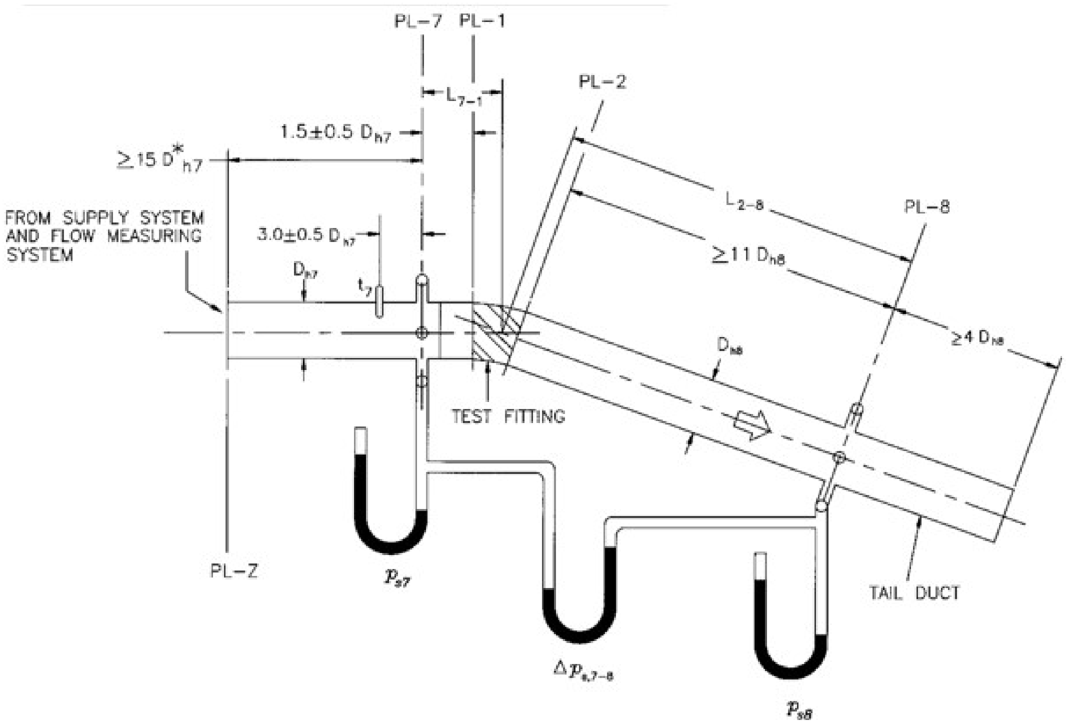
The right-hand side of the Darcy-Weisbach Equation is the Weisbach Equation

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

Pressure Losses

Dynamic -How Loss Coefficients are Determined

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



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

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

Pressure Losses

Dynamic – Loss Coefficients , ASHRAE Duct Design Database

$$\boldsymbol{\Delta p_{t,fitting} = C * pv, \;\; C = \frac{\Delta p_{t,fitting}}{p_v}}$$

ASHRAE Duct Fitting Database (DFDB)

- Has 232 Fittings
- Calculates Loss of Round, Rectangular and Flat Oval Duct and Fittings
- Calculates and Takes into Account Density – Can Change Air Properties
- Determines Pressure Loss Base on Input Dimensions and Flow Rates
- Can Look at Complete Fitting Loss Coefficient Table Data, Print it or Export it to Excel
- Can Lookup Fittings in Table View by Filters
- Results in I-P or SI

Pressure Losses

Example Using ASHRAE Duct Design Database I-P

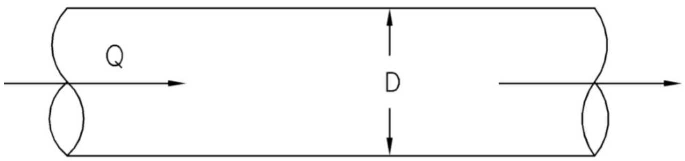
Friction Loss, 10” Diameter, Airflow is 1000 cfm, L = 100 ft, ε = 0.0003 ft

CD11-1 Straight Duct, Round
(Colebrook 1939)

INPUT		
Diameter (D)	in.	10
Length (L)	ft	100
Absolute Roughness (ei)	ft	0.0003
Flow Rate (Q)	cfm	1000
Density (RHO)	lbm/ft^3	0.075

Calculate

OUTPUT		
Velocity (V)	fpm	1,833
Velocity Presure (Pv)	in. wg	0.21
Reynolds Number (Re)		156,017
Friction Factor (f)		0.0186
Pressure Loss (Po)	in. wg	0.47



Pressure Losses

Example Using ASHRAE Duct Design Database SI

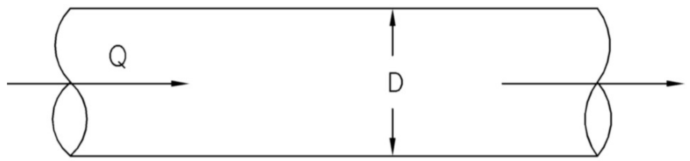
riction Loss, 254 mm Diameter, Airflow is 472 L/s, L = 30 m ,ε = 0.09 mm

CD11-1 Straight Duct, Round
(Colebrook 1939)

INPUT		
Diameter (D)	mm	254
Length (L)	m	30
Absolute Roughness (ei)	mm	.09
Flow Rate (Q)	L/s	472
Density (RHO)	kg/m^3	1.204

Calculate

OUTPUT		
Velocity (V)	m/s	9.3
Velocity Presure (Pv)	Pa	52
Reynolds Number (Re)		156,719
Friction Factor (f)		0.0185
Pressure Loss (Po)	Pa	114.4



Pressure Losses

Example Using ASHRAE Duct Design Database I-P

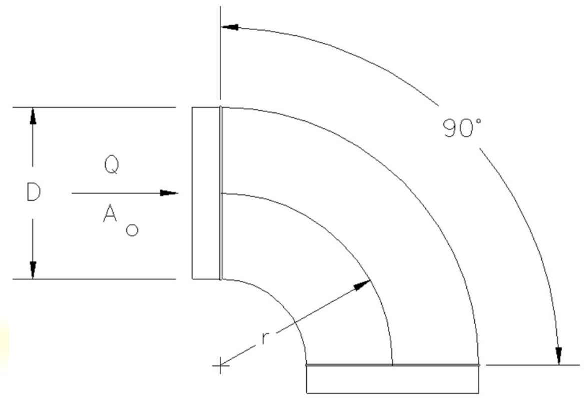
Example: 10" Dia, 90° Smooth Radius Elbow, R/D = 1.5. Airflow is 1000 acfm. Elevation is 5000 ft.

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

INPUT

Diameter (D)	in.	10
Flow Rate (Q)	cfm	1000
Density (RHO)	lbm/ft^3	0.062

Calculate



OUTPUT

Velocity (Vo)	fpm	1,833
Vel Pres at Vo (Pv)	in. wg	0.17
Loss Coefficient (Co)		0.11
Pressure Loss (Po)	in. wg	0.02

Pressure Losses

Example Using ASHRAE Duct Design Database SI

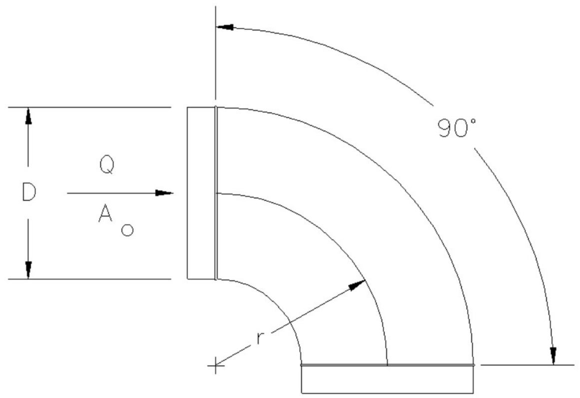
Example: 250 mm Dia, 90° Smooth Radius Elbow, R/D = 1.5. Airflow is 472 L/s. Elevation is 1524 m.

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

INPUT		
Diameter (D)	mm	250
Flow Rate (Q)	L/s	472
Density (RHO)	kg/m^3	0.996

Calculate

OUTPUT		
Velocity (Vo)	m/s	7.6
Vel Pres at Vo (Pv)	Pa	29
Loss Coefficient (Co)		0.11
Pressure Loss (Po)	Pa	3.1



Pressure Losses

Example Using ASHRAE Duct Design Database I-P

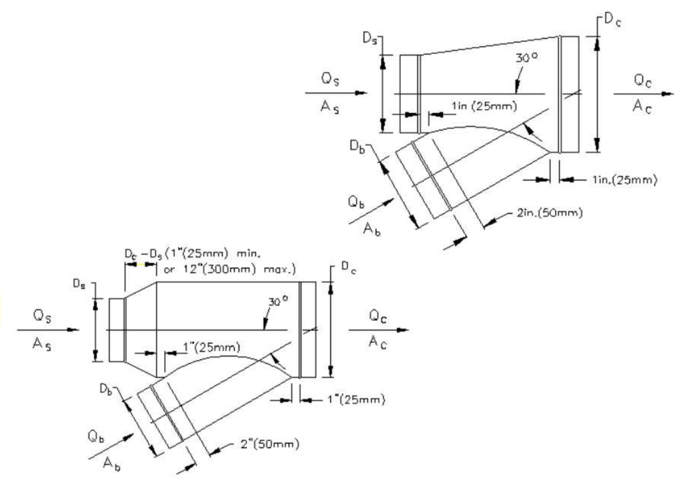
Example: D_s = 10 in., D_b= 8 in. D_c=12 in., Q_s= 2200 cfm and Q_b =1400 cfm. Elevation is 5000 ft.

ED5-1 Wye, 30 Degree, Converging
(Sepsy 1973)

INPUT		
Diameter (Ds)	in.	10
Diameter (Db)	in.	8
Diameter (Dc)	in.	12.0
Flow Rate (Qs)	cfm	2200
Flow Rate (Qb)	cfm	1400
Density (RHO)	lbm/ft^3	0.062

Calculate | Load Defaults

OUTPUT		
BRANCH		
Velocity (Vb)	fpm	4,011
Vel Pres at Vb (Pvb)	in. wg	0.83
Loss Coefficient (Cb)		0.12
Branch Pressure Loss (Pob)	in. wg	0.10
MAIN		
Velocity (Vs)	fpm	4,034
Velocity (Vc)	fpm	4,584
Vel Pres at Vs (Pvs)	in. wg	0.84
Vel Pres at Vc (Pvc)	in. wg	1.09
Loss Coefficient (Cs)		-0.03
Main Pressure Loss (Pos)	in. wg	-0.03



Pressure Losses

Example Using ASHRAE Duct Design Database SI

Example: D_s = 250 mm, D_b= 200 mm D_c = 300 mm, Q_s= 1050 L/s and Q_b = 660 L/s Elevation is 1630 m.

ED5-1 Wye, 30 Degree, Converging
(Sepsy 1973)

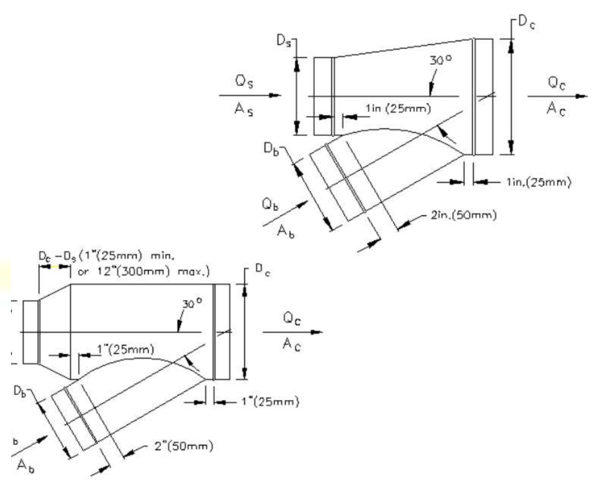
INPUT

Diameter (Ds)	mm	250
Diameter (Db)	mm	200
Diameter (Dc)	mm	300
Flow Rate (Qs)		1050
Flow Rate (Qb)	L/s	660
Density (RHO)	kg/m^3	0.989

Calculate Load Defaults

OUTPUT

BRANCH		
Velocity (Vb)	m/s	21.0
Vel Pres at Vb (Pvb)	Pa	218
Loss Coefficient (Cb)		0.09
Branch Pressure Loss (Pob)	Pa	20
MAIN		
Velocity (Vs)	m/s	21.4
Velocity (Vc)	m/s	24.2
Vel Pres at Vs (Pvs)	Pa	226
Vel Pres at Vc (Pvc)	Pa	289
Loss Coefficient (Cs)		-0.02
Main Pressure Loss (Pos)	Pa	-6



Pressure Losses

Friction Efficiency – Roughness vs Velocity, I-P

Example: 24" Round Duct, L = 100 ft, Standard Density

Using ASHRAE Databas **Standard Density**

			Standard Galvanized (ε = 0.0003 ft)	Corrugated Duct (ε = 0.003 ft)
Velocity (fpm)	Velocity Pressure p_v (in. wg)	Q = AV Flow Rate (cfm)	Δp_f Friction Loss (in. wg)	Δp_f Friction Loss (in. wg)
1000	0.06	3150	0.05	0.07
2000	0.25	6300	0.19	0.28
3000	0.56	9450	0.41	0.62
4000	0.99	12550	0.71	1.09

Pressure Losses

Friction Efficiency – Roughness vs Velocity, I-P

Example: 610" Round Duct, L = 30 m, Standard Density

Using ASHRAE Database, SI **Standard Density**

			Standard Galvanized (ε = 0.09 mm)	Lined Duct, Corrugated (ε = 0.9 mm)
Velocity (m/s)	Velocity Pressure p_v (Pa)	Q = AV Flow Rate (L/s)	Δp_f Friction Loss (Pa)	Δp_f Friction Loss (Pa)
5.1	16	1500	13.0	17.7
10.1	61	2950	46.0	66.9
15.1	136	4400	98.3	147.7
20.1	243	5875	171.0	262.3

Pressure Losses

Friction Efficiency – Roughness vs Velocity

Example: 24” (610 mm) Round Duct, L = 100 ft (30 m), Standard Density using ASHRAE DFDB

Observations:

- **Factor of 13+!! Increase in Pressure Loss when Velocity is Increase by a Factor of 4, From 1000 to 4000 fpm (5 to 20 m/s)**
  - **0.05 in wg (13 Pa) increased to 0.71 in wg (171 Pa)**
- **Factor of only 1.2 to 1.4 Increase in Pressure Loss When Roughness (ε) is Increased by a Factor of 10**
  - **At 1000 fpm (5 m/s) , 0.05 in wg (13 Pa) increased to 0.07 in wg (17.7 Pa)**
  - **At 4000 fpm (20 m/s), 0.71 in wg (171 Pa) increased to 1.09 in wg (262 Pa)**

Pressure Losses

Equivalent Round for Rectangular and Flat Oval Duct – Converting Duct Sizes

Rectangular:
$$D_e = \frac{1.30(WH)^{0.625}}{(W+H)^{0.250}}$$

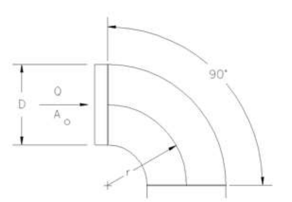
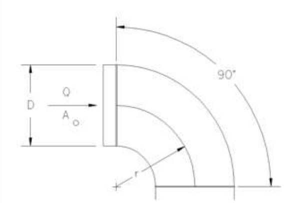
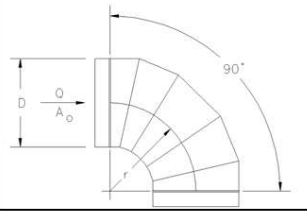
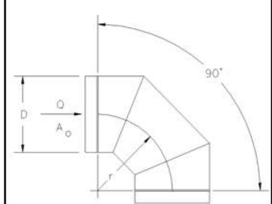
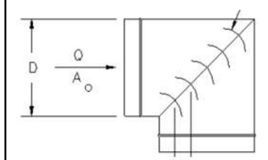
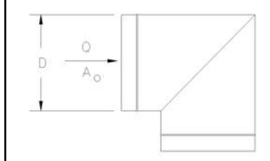
Flat oval:
$$D_e = \frac{1.55AR^{0.625}}{P^{0.250}} = \frac{1.55\left[\frac{\pi}{4}a^2 + a(A-a)\right]^{0.625}}{[\pi a + 2(A-a)]^{0.250}}$$

D_e= Equivalent Round, in (mm)
AR = Cross-section Area, in^2 (mm^2)
W= Rectangular Width, in (mm)
H = Rectangular Height, in (mm)
A = Flat Oval Major Dimensions, in (mm)
a = Flat Oval Minor Dimensions, in (mm)

Pressure Losses

Fitting Efficiency – Round Elbows

Example: Diameter = 10 inch, Standard Density using ASHRAE DFDB

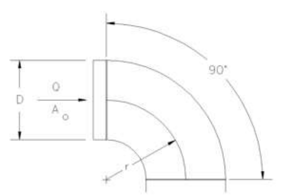
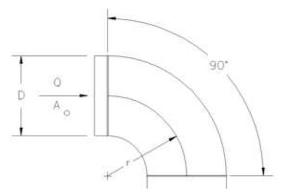
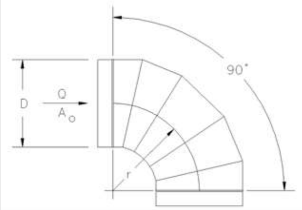
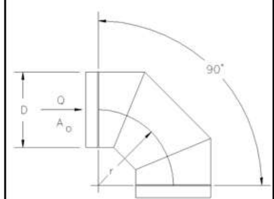
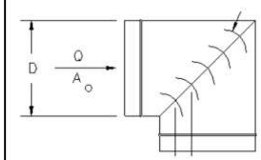
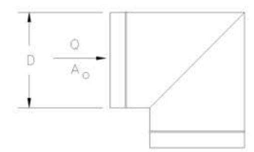
From ASHRAE DFDB														
			Smooth Radius, R/D = 1.5		Smooth Radius, R/D = 1.0		5 Piece, R/D = 1.5		3 Piece, R/D = 1.5 (Table		Mitered w Vanes		Mitered without Vanes	
Velocity (fpm)	Velocity Pressure p_v (inch water)	Q = AV Flow Rate (cfm)	Loss Coefficient C	Δp_t (inch water)	Loss Coefficient C	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	545	0.11	0.01	0.24	0.01	0.20	0.01	0.34	0.02	0.48	0.03	1.19	0.07
2000	0.25	1090	0.11	0.03	0.24	0.06	0.20	0.05	0.34	0.09	0.48	0.12	1.19	0.30
3000	0.56	1635	0.11	0.06	0.24	0.13	0.20	0.11	0.34	0.19	0.48	0.27	1.19	0.67
4000	0.99	2175	0.11	0.11	0.24	0.24	0.20	0.20	0.34	0.34	0.48	0.48	1.19	1.18
			Best		Better		Better		Good		Good		BAD	

Pressure Losses

Fitting Efficiency – Round Elbows

Example: Diameter = 250 mm, Standard Density using ASHRAE DFDB

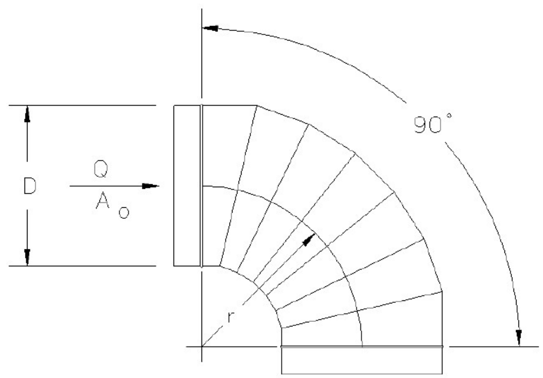
From ASHRAE DFDB, SI

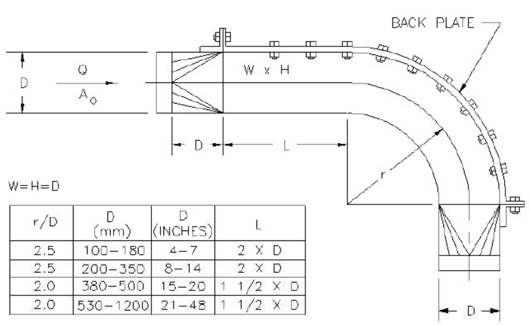







			Smooth Radius, R/D = 1.5		Smooth Radius, R/D = 1.0		5 Piece, R/D = 1.5		3 Piece, R/D = 1.5 (Table		Mitered w Vanes		Mitered without Vanes	
Velocity (m/s)	Velocity Pressure p_v (Pa)	Q = AV Flow Rate (L/s)	Loss Coefficient C	Δp_t (Pa)	Loss Coefficient C	Δp_t (Pa)	Loss Coefficient C	Δp_t (Pa)	Loss Coefficient C	Δp_t (Pa)	Loss Coefficient C	Δp_t (Pa)	Loss Coefficient C	Δp_t (Pa)
5.2	17	257	0.11	1.87	0.24	4.08	0.20	3.40	0.34	5.78	0.48	8.16	1.19	20.23
10.5	66	514	0.11	7.26	0.24	15.84	0.20	13.20	0.34	22.44	0.48	31.68	1.19	78.54
15.7	149	771	0.11	16.39	0.24	35.76	0.20	29.80	0.34	50.66	0.48	71.52	1.19	177.31
20.9	263	1026	0.11	28.93	0.24	63.12	0.20	52.60	0.34	89.42	0.48	126.24	1.19	312.97
			Best		Better		Better		Good		Good		BAD	

Pressure Losses

Preferred Duct Fittings - Elbows

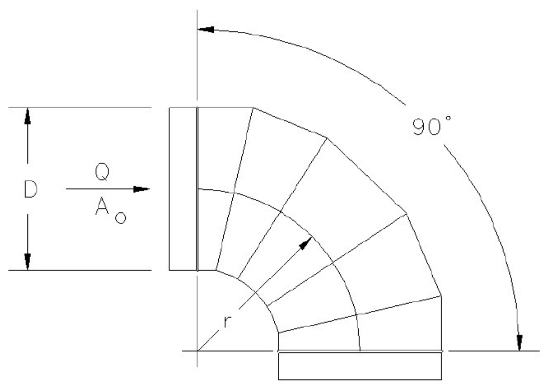




r/D	D (mm)	D (INCHES)	L
2.5	100–180	4–7	2 X D
2.5	200–350	8–14	2 X D
2.0	380–500	15–20	1 1/2 X D
2.0	530–1200	21–48	1 1/2 X D

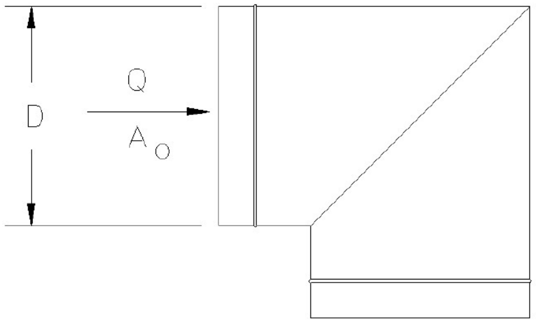
PREFERRED

CD3-10 (7-Gore, 90°, r/D = 2.5)
CD3-11 (Flat-back, 90°)



ACCEPTABLE

CD3-9 (5-Gore, 90°, r/D = 1.5)

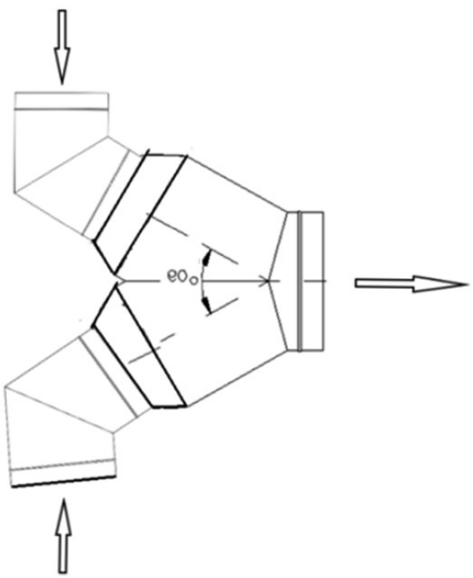


AVOID

CD3-15 (Mitered, 90°)

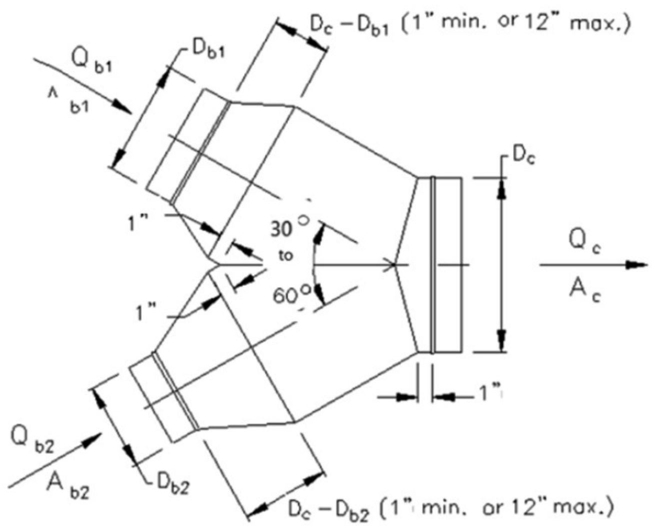
Pressure Losses

Preferred Duct Fittings - Wyes



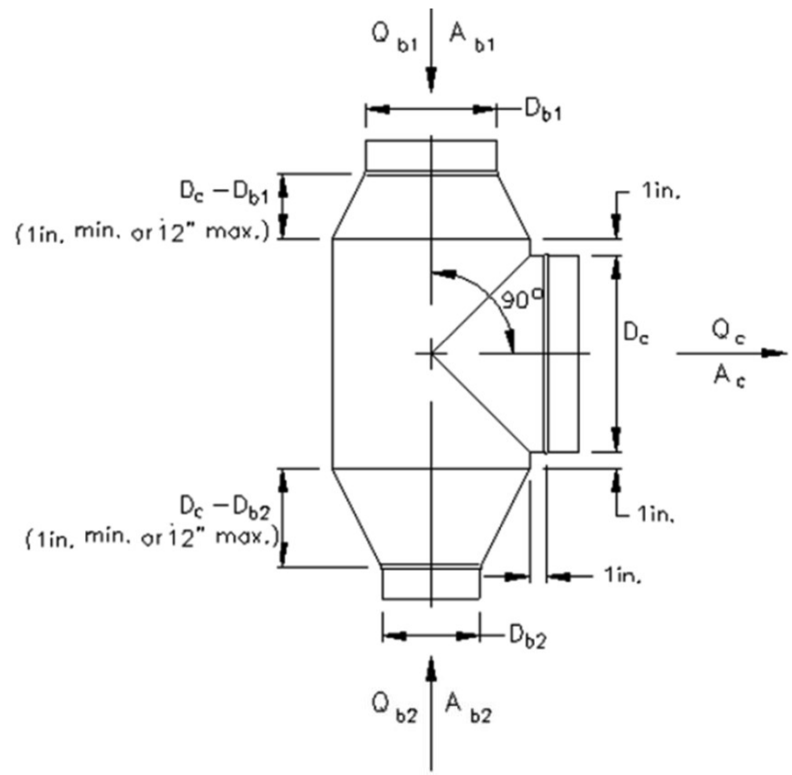
PREFERRED

ED5-9 (60°)
plus CD3-16 (60°)



PREFERRED

ED5-9 (60°)

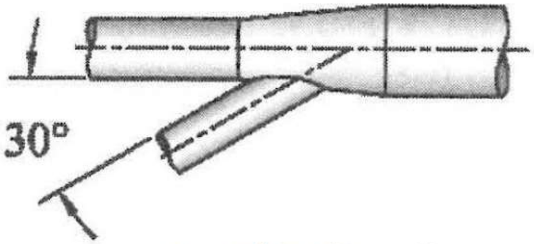


AVOID

ED5-4 Bullhead Tee
without Vanes

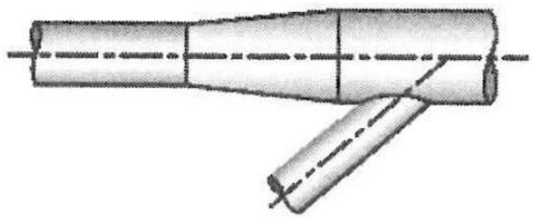
Pressure Losses

Preferred Duct Fittings – Branches



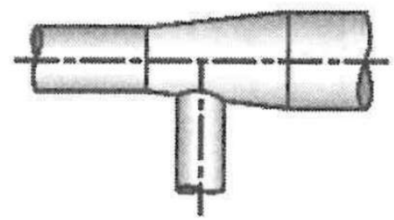
PREFERRED

ED5-1(30° Wye)



NOT RECOMMENDED

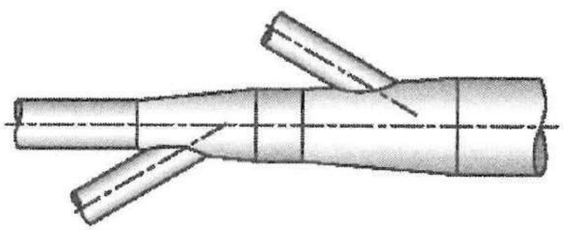
ED4-1 (Wye)
plus ED5-1 (Transition)



AVOID

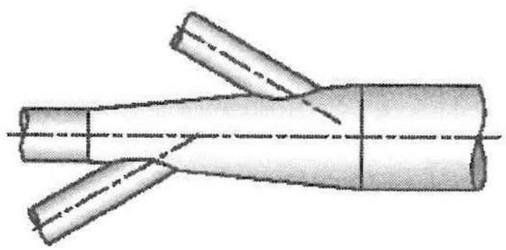
ED5-3 (Tee)

Junctions (Laterals and Tees)



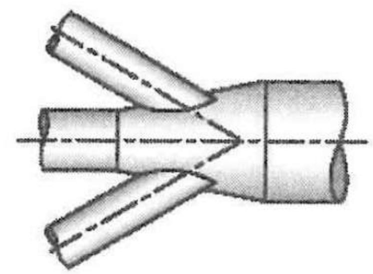
PREFERRED

ED5-1 Wye



ACCEPTABLE

ED5-1 Wye

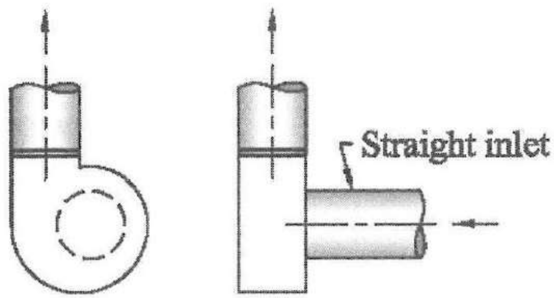


AVOID

ED5-10 Double Wye, 45°
Close Coupled

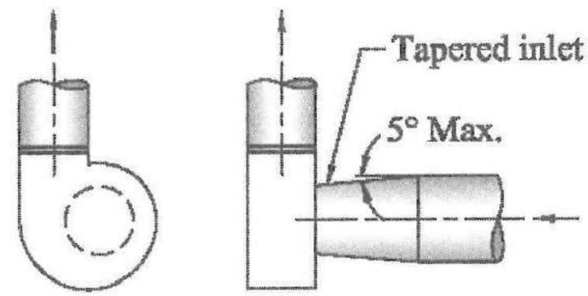
Pressure Losses

Preferred Duct Fittings – Fan Inlet Connections



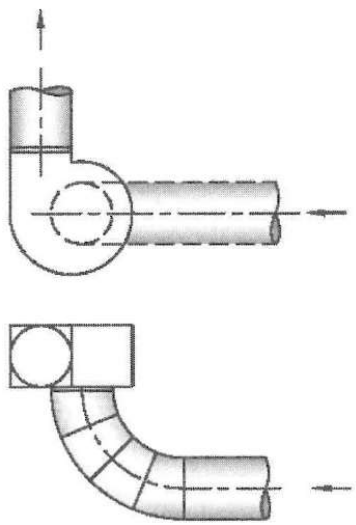
PREFERRED

ED7-2 (Centrifugal, Single Width Single Inlet [SWSI])

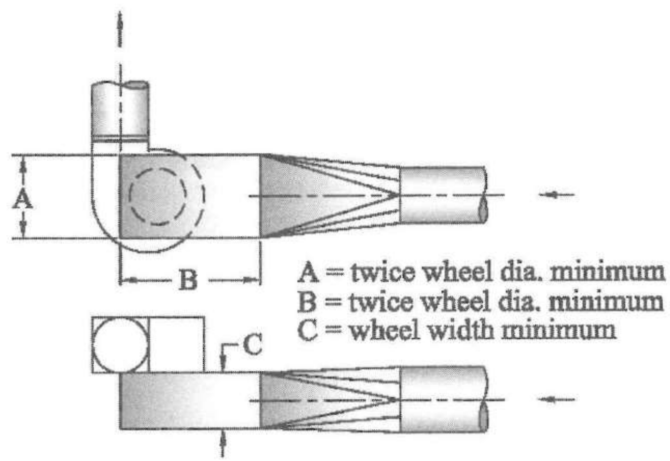


PREFERRED

ED7-2 (Centrifugal, SWSI) with SD4-1 (Transition)



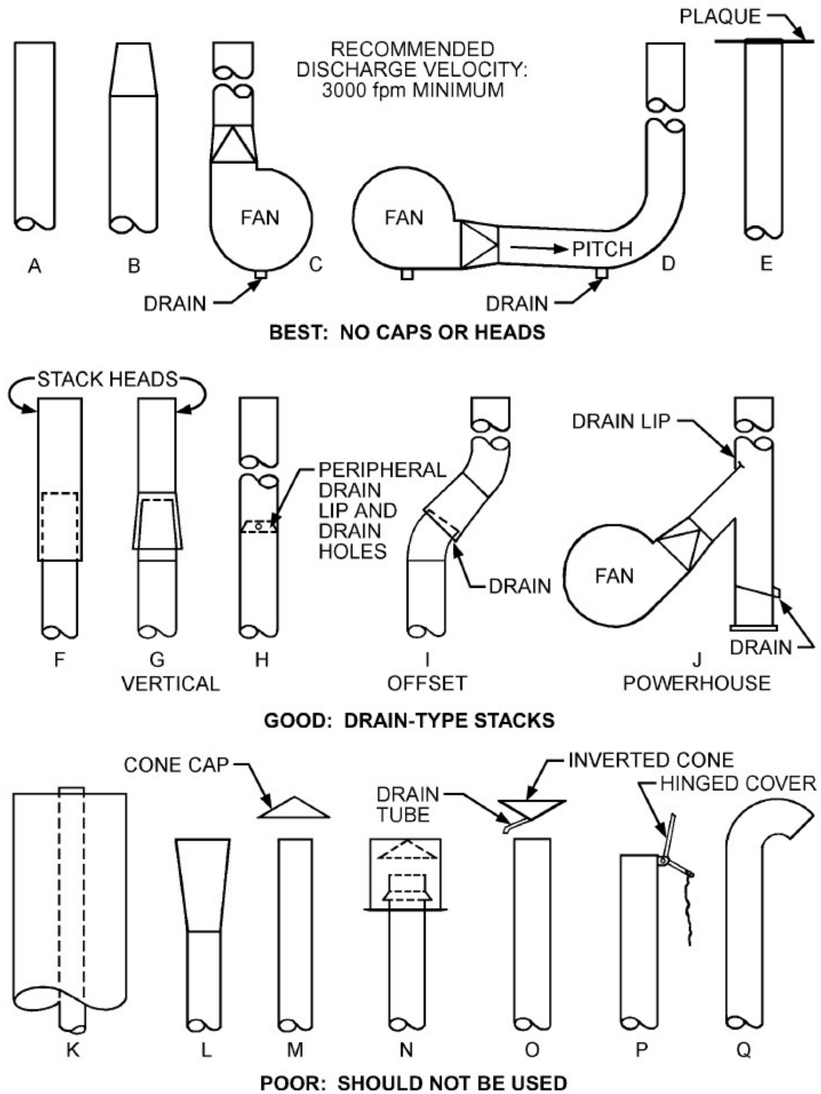
ACCEPTABLE



ACCEPTABLE

Pressure Losses

Preferred Duct Fittings – Stacks



Designing the Exhaust Duct System Overview

- Step 1__Determine air volume requirements based on the required capture velocity and Hood intake area. Include an allowance for leakage.
- Step 2__Determine the type of Hood and Location.
- Step 3__Locate duct runs. Avoid unnecessary directional changes
- Step 4__Determine the allowable noise (NC) levels.
- Step 5__Determine the minimum transport velocity
- Step 6__Determine duct sizes to maintain the transport velocity
- Step 7__Use round sizes when possible
- Step 8__Determine system pressure requirements. Include total pressure losses of components.
- Step 9__Sum the losses in each path to the fan.

Designing the Exhaust Duct System Overview

- Step 10__Determine the design leg(s)
- Step 11__Determine the required fan operating pressure
- Step 12__ Analyze the design to improve balancing and reduce material cost.
- Step 13__Select fan according to proper guidelines for the operating pressure and maximum total volume flow rate
- Step 14__Analyze the design to make sure it meets the acoustical requirements.
- Step 15__Select materials that minimize cost and meet SMACNA Duct Construction Standards.
- Step 16__ Analyze the life-cycle cost of the design.
- Step 17__Commission the design to make sure it meets the Owner's Project Requirements (OPRS)

Pressure Losses – The Design Leg

Critical Path

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

Designing the Duct System Overview

Selecting the Design Method

Use the *Manual of Recommended Practice of Design* (AGCIH 2019) to calculate hood airflow rates

- Air quantities are actual airflow based on the air density
- Hood velocity determines the effectiveness of the hood regardless of the acfm. If the actual airflow is not high enough the velocity will not capture the air contaminants.
- Hoods are designed for particulate control, not collections although there often is a collector.
- Particles that settle out should be cleaned up to prevent reentrainment due to foot traffic and air currents.
- Velocity pressure should be corrected for density.

Designing the Duct System

Transport (Conveying) Velocity – Constant Velocity Design Method

Called Constant Velocity Design Method because You Must Maintain a Constant Minimum Transport Conveying Velocity So Contaminants Don't Fall Out of the Airstream

- For vapors, gases and smoke, you can design with Equal Friction (See the ***Duct Systems Design Guide*** (DSDG) chapter on Designing with Equal Friction). Velocities should still be in the range of 1000 to 2000 fpm (5 to 10 m/s)

- Table 2-1 in the in the ***SMACNA Round Industrial Duct Constructions Standards*** (Round IDCS) Third Edition are Ranges of Minimum Transport (Conveying) Velocities for varius materials

Designing the Duct System

Transport (Conveying) Velocity – Constant Velocity Design Method

Duct Class	Nature of Contaminant	Examples	Con-centration	Abrasion	Minimum Conveying Velocities fpm (m/s)
1	Gases	Non–abrasive, non–corrosive applications, including contaminated duct sections of make–up air and general ventilation systems, and gaseous emission control systems.	None	None	1000 – 2000 (5 – 10)
	Fumes, Vapors, Smoke and Aerosols (Spray, Mists, and Fog)	Zinc and aluminum oxide fumes, welding fumes, paint overspray, etc.	Light	None	2000 – 2500 (10 – 13)
2	Very Fine, Light Dust	Cotton lint, wood flour, litho powder, etc.	Light	Light	2500 – 3000 (13 – 15)
	Dry Dusts and Powders	Fine rubber dust, Bakelite molding powder dust, jute lint, cotton dust, light shavings, leather shavings, soap dust, dry fine sawdust, grain dust, and buffing and polishing dust	Low	Moderate	3000 – 4000 (15 – 20)

Designing the Duct System

Transport (Conveying) Velocity – Constant Velocity Design Method

Duct Class	Nature of Contaminant	Examples	Con-centration	Abrasion	Minimum Conveying Velocities fpm (m/s)
3	Average Industrial Dust	Class 3 materials in low to moderate concentrations, including granite dust, silica flour, material handling (general), brick cutting, clay dust, foundry (general), limestone dust, abrasive cleaning operations, dryers, kilns, boiler breaching, sand handling, manganese, steel chips, coke, etc.	Moderate	High	3500 – 4000 (18 – 20)
		Class 2 materials in moderate to high concentrations, including sawdust (heavy and wet), grinding dust, buffing lint (dry), wool jute dust (shaker waste), coffee beans, shoe dust, etc.	High	Moderate	
		Class 3 materials in high concentra			

Designing the Duct System

Transport (Conveying) Velocity – Constant Velocity Design Method

Duct Class	Nature of Contaminant	Examples	Con-centration	Abrasion	Minimum Conveying Velocities fpm (m/s)
4	Heavy Dusts	Class 3 materials in high concentrations, metal turnings, foundry shakeout and tumbling barrels, sand blast dust, wood blocks, hog waste, brass turnings, cast iron boring dust, lead dust, etc.	High	High	4000 – 4500 (20 – 23)
	Heavy, Moist, and Sticky Dusts	Lead dust with small chips, moist cement dust, wet furnace slag, wet mortar, buffing lint (sticky), quick lime dust, etc.	High	High	4500 and up (23 and up)
5	Corrosive Fumes	Corrosive applications; laboratory fume hoods, plating tanks containing corrosive chemicals, etc.	Light	None	1000 – 2000 (5 – 10)

Table 2–1 Duct Classes and Minimum Conveying Velocities

Designing the Duct System

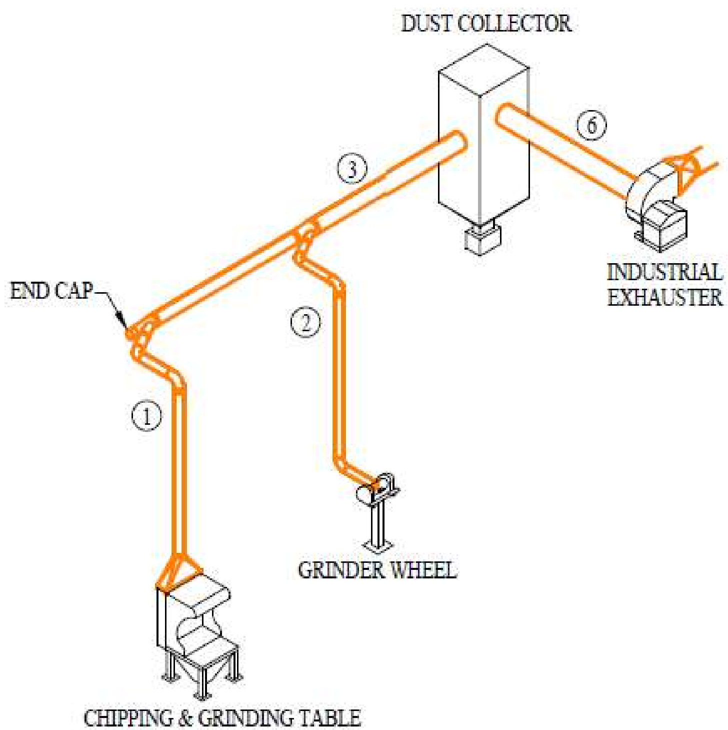
Constant (Transport) Design Method Steps

- **Size all main and branch duct at the constant transport velocity. Round duct sizes down so as to maintain the minimum required velocity.**
- **Calculate the total pressure loss for each section including hoods, duct, junctions, collectors or other items.**
- **If by hand, a spreadsheet will be helpful**
- **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 <u>for each path</u> from the hood inlets to the fan)**
- **Determine the critical path and maximum operating pressure**
- **Determine the excess pressure for each non-critical path**
- **Use smaller sizes or additional airflow in the non-critical paths to balance the system (don't use blast gates or dampers unless Class 1)**

Designing the Duct System

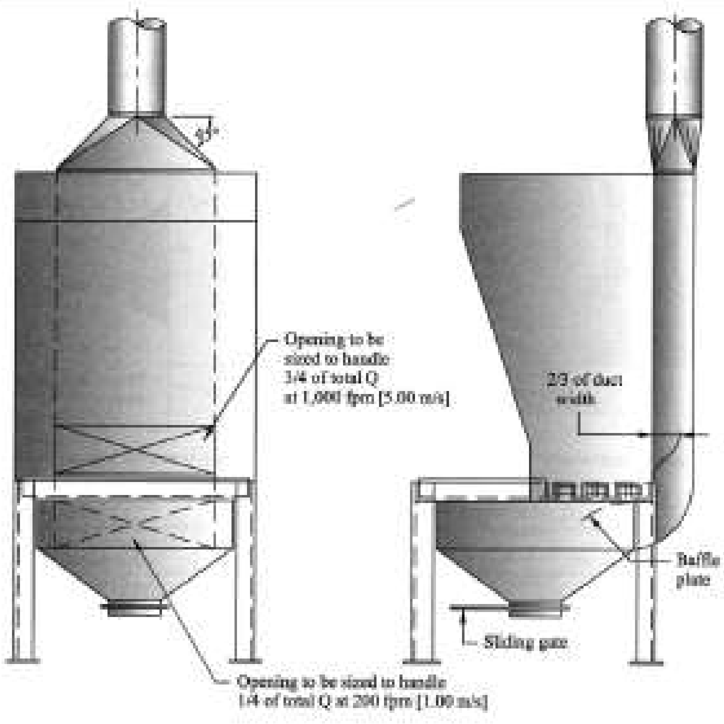
Example

Size the system shown using constant minimum velocity. ε = 0.0003 ft (0.12 mm) . RH%=50. The design parameters are shown in the Table. Size to 0.5-inch (12 mm) sizes. Used the ASHRAE DFDB for Calculations



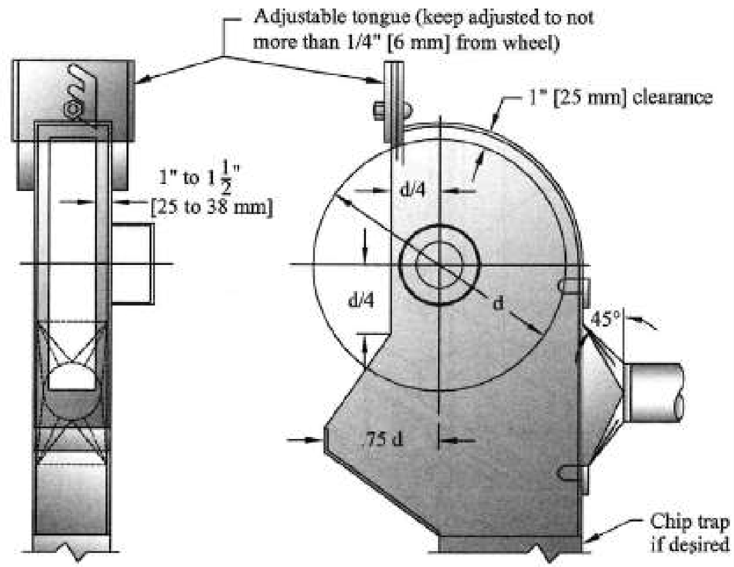
Designing the Duct System

Example – Hoods Used



Q = 150 acfm/ft² [0.75 am³/s/m²] opening
Minimum duct velocity = 3,500 fpm [17.50 m/s]
F_h = 0.25

Chipping and Grinding Table



EXHAUST FLOW RATES, acfm [am³/s]

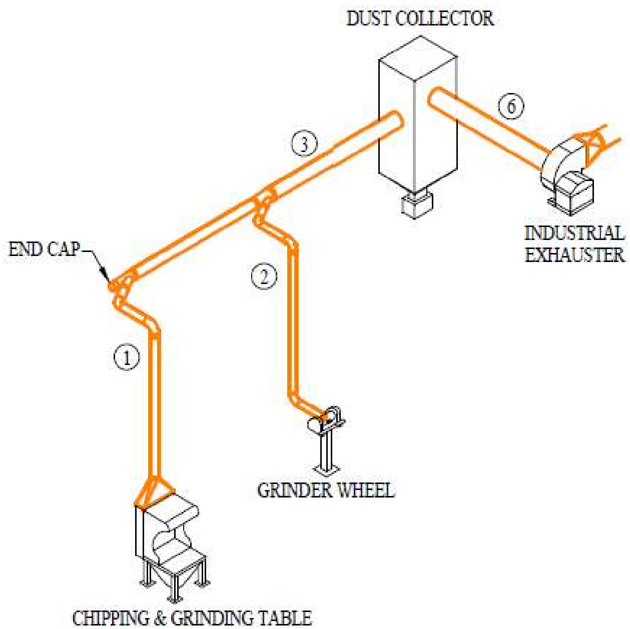
Wheel dia. inches	[mm]	Wheel width inches	[mm]	Good enclosure* acfm	[am³/s]	Poor enclosure acfm	[am³/s]
Up to 5	[Up to 125]	1	[25]	220	[0.11]	220	[0.11]
5 to 10	[125 to 250]	1.5	[38]	220	[0.11]	300	[0.15]
10 to 14	[250 to 350]	2	[50]	300	[0.15]	500	[0.25]
14 to 16	[350 to 400]	2	[50]	390	[0.20]	610	[0.31]
16 to 20	[400 to 500]	3	[75]	500	[0.25]	740	[0.37]
20 to 24	[500 to 600]	4	[100]	610	[0.31]	880	[0.44]
24 to 30	[600 to 750]	5	[125]	880	[0.44]	1,200	[0.60]
30 to 36	[750 to 900]	6	[150]	1,200	[0.60]	1,600	[0.80]

* No more than 25% of wheel exposed.
Minimum duct velocity = 4,000 fpm [20.00 m/s]
F_h = 0.65 for straight take-off
F_h = 0.40 for tapered take-off

Grinding Wheel Hood

Designing the Duct System - Example

		Minimum Velocity		Hood	Air Required		Temperature		Density		Length	
Section	**Hood**	**fpm**	**m/s**	**Loss Coefficient**	**cfm**	**L/s**	**°F**	**°C**	**lb_m/ft^3**	**kg/m^3**	**ft**	**m**
1	VS-80-19 Chipping & Grinding Table	3500	17.5	0.25	800	378	90	32	0.072	1.147	38	11.6
2	VS-80-11 Grinding Wheel	4000	20	0.40	500	236	90	32	0.072	1.147	20	6.1
3		4000	20		1300	614	90	32	0.072	1.147	30	9.1
Collector Δp = 3 in wg (746.5 Pa)					1300	614	90	32	0.072	1.147		
6	Duct Between Collector and Fan	Friction Rate 0.2 in wg/100 ft (1.64 Pa/m)			1300	614	90	32	0.072	1.147	15	4.6



Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses I-P

Sections 1 and 2

Constant Velocity Duct Design Example   ε = 0.0003 ft   RH=50%

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Section	Parent	Brother	Fitting Description	ASHRAE Fitting Code	Air Qty, acfm	Temp., °F	Density, lbm/ft3	Minimum Velocity, fpm (Table 2-1)	Maximum Duct Area (in^2)	Maximum Duct Dia., D_e, in.	Duct Size D (W x H, A x a), in.	Actual Velocity, fpm	Duct Length, ft	Velocity Pressure, pv, in. of water	Loss Coef-ficient C0	Δp_t, in. of water
				Source												
				DFDB	Drawing	Drawing	DFDB	Round IDCS	Q/V	$\sqrt{4\ Ad/\pi}$	Round Down	DFDB	Drawing	DFDB	ACGIH or DFDB	Σ
1	3	2	Hood: ACGIH, VS-80-19	ACGIH - IVM	800	90	0.072								0.25	
			Duct	CD11-1				3500	32.9	6.47	6	4074	38	[Round Dia]		1.45
			90° Flat-back Elbow	CD3-11											0.08	
			Capped wye with elbow: Db=6 in., Dc=6	ED5-6											0.61	
			Wye, main: Ds=6 in., Dc=7.5 in., Db=4.5in.	ED5-1											-0.13	
														0.99	0.81	0.80
Section 1 Total ...																2.25
2	3	1	Hood: ACGIH (2010), VS-80-11[b] (Tapered Takeoff)	ACGIH - IVM	500	90	0.072								0.40	
			Duct	CD11-1				4000		4.79	4.5	4527	20	[Round Dia]		1.33
			90° Flat-back Elbow	CD3-11											0.09	
			90° Flat-back Elbow	CD3-11											0.09	
			45° Die Stamped Elbow	CD3-3											0.12	
			Wye, branch: Ds=6 in., Dc=7.5 in., Db=4.5in.	ED5-1											0.34	
														1.22	1.04	1.27
Section 2 Total ...																2.60

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses SI

Sections 1 and 2

Constant Velocity Duct Design Example ε = 0.12 mm RH=50%

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Section	Parent	Brother	Fitting Description	ASHRAE Fitting Code	Air Qty, aL/s	Temp., °C	Density, Kg/m³	Minimum Velocity, m/s (Table 2-1)	Maximum Duct Area (m²)	Maximum Duct Dia., D_e, mm.	Duct Size D (W x H, A x a), mm	Actual Velocity, m/s	Duct Length, m	Velocity Pressure, pv, Pa	Loss Coef-ficient C0	Δp_t, Pa
				Source												
				DFDB	Drawing	Drawing	DFDB	Round IDCS	Q/V	$\sqrt{4\,Ad/\pi}$	Round Down	DFDB	Drawing	DFDB	ACGIH or DFDB	Σ
1	3	2	Hood: ACGIH, VS-80-19ᵃ	ACGIH - IVM	378	32	1.147								0.25	
			Duct	CD11-1				17.5	0.0216	165.84	152	20.8	11.6	[Round Dia]		384
			90' Flat-back Elbow	CD3-11											0.08	
			Capped wye with elbow: Db=152 mm, Dc=152	ED5-6											0.61	
			Wye, main: Ds=152 mm., Dc=191 mm., Db=114 mm	ED5-1											-0.13	
														249	0.81	201.7
Section 1 Total																**585.7**
2	3	1	Hood: ACGIH (2010), VS-80-11ᵇ (Tapered Takeoff)	ACGIH - IVM	236	32	1.147								0.40	
			Duct	CD11-1				20	0.0118	122.57	114.0	23.1	6.1	[Round Dia]		353
			90' Flat-back Elbow	CD3-11											0.09	
			90' Flat-back Elbow	CD3-11											0.09	
			45° Die Stamped Elbow	CD3-3											0.12	
			Wye, branch: Ds=152 mm, Dc=191 mm, Db=114 mm	ED5-1											0.34	
														306	1.04	318.24
Section 2 Total																**671.24**

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses I-P

Sections 3, Collector and 6

3	Collector	--	Duct	CD11-1	1300	90	0.072	4000		7.72	7.5	4237	30	[Round Dia]		0.94
														1.07	0	0.00
Section 3 Total																0.94
--	--	--	Collector													3
6	Fan	--	Duct	CD11-1, size at 0.2 in. water/100 ft, ε = 0.0004 ft	1300	90	0.072	.		--	13	1410	15	[Round Dia]		0.03
			Bellmouth (collector to duct): D1=18 in., Ho=120 in., Wo =72in., bellmouth radius=4	ER2-1, Loss Coefficient based on V_1											0.03	
			Transition to fan inlet: D1=13 ¼ in., Do=18 in., L=24 in. (θ = 12°)	ED4-1											0.17	
														0.03	0.20	0.01
Section 6 Total																0.04

Path Total Pressure Loss:

Terminal	Path	Path Total Pressure Losses (in. water)	Path Total Pressure (in. of water)	Imbalance (in. of water)
Hood	1-3-Collector-6	2.25+0.94+3.00+0.02	6.23	0.35
Hood	2-3-Collector-6	2.60+0.58+3.00+0.02	6.57	0

5.3% dif

[a] ACGIH (2010) Chipping and Grinding Table: 48 in. (W) by 36 in. (H) opening.

[b] ACGIH (2010) Grinding Wheel Hood: 18 in. wheel diameter, 3 in. wheel width.

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses SI

Sections 3, Collector and 6

3	Collector	--	Duct	CD11-1	614	32	1.147	20	0.0307	197.71	191	21.4	9.1	[Round Dia]		239.9
														263	0	0.00
Section 3 Total ...																**239.90**
--	--	--	Collector ...													**746.5**
6	Fan	--	Duct	CD11-1, size at 1.64 Pam, ε = .12 mm	614	32	1.147	.		--	332	7.1	4.6	[Round Dia]		7.5
			Bellmouth (collector to duct): D1=457 mm., Ho=3048mm, Wo =1829mm, bellmouth radius=100 mm	ER2-1, Loss Coefficient based on V_1											0.03	
			Transition to fan inlet: D1=337 mm, Do=457 mm, L=610 in. (θ = 12°)	ED4-1											0.17	
														29	0.20	5.80
Section 6 Total ...																**13.30**

Path Total Pressure Loss:

Terminal	Path	Path Total Pressure Losses (Pa)	Path Total Pressure (Pa)	Imbalance (Pa)
Hood	1-3-Collector-6	585.7 +239.9 +746.5 +13.3	1585.4	85.5
Hood	2-3-Collector-6	671.2 +239.9 +746.5 +13.3	1670.9	0

[a] ACGIH (2010) Chipping and Grinding Table: 1219 mm. (W) by 914 mm (H) opening.

[b] ACGIH (2010) Grinding Wheel Hood: 457 mm wheel diameter, 76 mm wheel width.

5.1% dif

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses

Imbalance

I-P

Path	Path Total Pressure (in. of water)	Imbalance (in. of water)
1-3-Collector-6	6.23	0.35
2-3-Collector-6	6.57	0

5.3% dif

SI

Path	Path Total Pressure (Pa)	Imbalance (Pa)
1-3-Collector-6	1585.4	85.5
2-3-Collector-6	1670.9	0

5.1% dif

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses

Balancing with Airflow

$$Q_c = Q_L \left(\frac{\Delta p_H}{\Delta p_L} \right)^{1/2}$$

Q_c = the Corrected Airflow for Balancing, cfm (L/s)
Q_L = the Original Airflow in the Section that Needs Balancing, cfm (L/s)
Δp_H = Higher Pressure Loss in the Section to be Balanced Against , in. wg (Pa)
Δp_L = Lower Pressure Loss in the Section to be Balanced Against , in. wg (Pa)

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses

Balancing with Airflow

Example Balancing with Airflow – Increase Airflow in Section 1 to Balance the System.

	I-P			SI		
Section 2	ΔP_H =	2.60	in wg	ΔP_H =	671.2	Pa
Section 1	ΔP_L =	2.25	in wg	ΔP_L =	585.7	Pa
	Q1 =	800	cfm	Q1 =	378	L/s
	New Q_1 =	860	cfm	New Q_1 =	405	L/s

$$Q_c = Q_L \left(\frac{\Delta p_H}{\Delta p_L} \right)^{1/2}$$

Designing the Duct System

Balancing with Airflow

Example – Revisiting the Spreadsheet Calculate Sizes and Pressure Losses Sections 1 and 2, I-P

Constant Velocity Duct Design Example - Balancing   Keep sizes, increase flow rate

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Section	Parent	Brother	Fitting Description	ASHRAE Fitting Code	Air Qty, acfm	Temp., °F	Density, lbm/ft3	Minimum Velocity, fpm (Table 2-1)	Maximum Duct Area (in²)	Maximum Duct Dia., D_e, in.	Duct Size D (W x H, A x a), in.	Actual Velocity, fpm	Duct Length, ft	Velocity Pressure, pv, in. of water	Loss Coefficient C0	Δp_t, in. of water
				Source												
				DFDB	Drawing	Drawing	DFDB	Round IDCS	Q/V		Keep Size	DFDB	Drawing	DFDB	ACGIH or DFDB	Σ
			Hood: ACGIH, VS-80-19*	Appendix C, Figure C-1											0.25	
			Duct	CD11-1				N/A	N/A	N/A	6	4380	38	[Round Dia]		1.76
1	3	2	90° Flat-back Elbow	CD3-11	860	90	0.072								0.08	
			Capped wye with elbow: Db=6 in., Dc=6 in.	ED5-6											0.61	
			Wye, main: Ds=6 in., Dc=7.5 in., Db=4.5in.	ED5-1											-0.13	
														1.15	0.81	0.93
Section 1 Total																2.69
			Hood: ACGIH (2010), VS-80-11[b] (Tapered Takeoff)	Appendix C, Figure C-2											0.40	
			Duct	CD11-1				4000		4.79	4.5	4527	20	[Round Dia]		1.33
			90° Flat-back Elbow	CD3-11											0.09	
2	3	1	90° Flat-back Elbow	CD3-11	500	90	0.072								0.09	
			45° Die Stamped Elbow	CD3-3											0.12	
			Wye, branch: Ds=6 in., Dc=7.5 in., Db=4.5in.	ED5-1											0.34	
														1.22	1.04	1.27
Section 2 Total																2.60

Designing the Duct System

Balancing with Airflow

Example – Revisiting the Spreadsheet Calculate Sizes and Pressure Losses Sections 1 and 2, SI

Constant Velocity Duct Design Example - Balancing

Keep sizes, increase flow rate

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Section	Parent	Brother	Fitting Description	ASHRAE Fitting Code	Air Qty, aL/s	Temp., °C	Density, Kg/m³	Minimum Velocity, m/s (Table 2-1)	Maximum Duct Area (m²)	Maximum Duct Dia., D_e, mm.	Duct Size D (W x H, A x a), mm	Actual Velocity, m/s	Duct Length, m	Velocity Pressure, pv, Pa	Loss Coef-ficient CO	Δp_t, Pa
				Source												
				DFDB	Drawing	Drawing	DFDB	Round IDCS	Q/V		Keep Size	DFDB	Drawing	DFDB	ACGIH or DFDB	Σ
1	3	2	Hood: ACGIH, VS-80-19ᵃ	Appendix C, Figure C-1	405	32	0.072								0.25	
			Duct	CD11-1				N/A	N/A	N/A	152	22.3	11.6	[Round Dia]		458.1
			90° Flat-back Elbow	CD3-11											0.08	
			Capped wye with elbow: Db=152 mm, Dc=152	ED5-6											0.61	
			Wye, main: Ds=152 mm., Dc=191 mm., Db=114 mm	ED5-1											-0.13	
														300	0.81	[illegible]
Section 1 Total																701.1
2	3	1	Hood: ACGIH (2010), VS-80-11ᵇ (Tapered Takeoff)	Appendix C, Figure C-2	236	32	1.147								0.40	
			Duct	CD11-1				N/A	N/A	N/A	114.0	23.1	6.1	[Round Dia]		353
			90° Flat-back Elbow	CD3-11											0.09	
			90° Flat-back Elbow	CD3-11											0.09	
			45° Die Stamped Elbow	CD3-3											0.12	
			Wye, branch: Ds=152 mm, Dc=191 mm, Db=114 mm	ED5-1											0.34	
														306	1.04	318.2
Section 2 Total																671.2

Designing the Duct System

Balancing with Airflow

Example – Spreadsheet Calculates Sizes and Pressure Losses (I-P) Sections 3, Collector and 6 (revised for balancing)

3	5	4	Duct	CD11-1	1360	90	0.072	4000		7.90	7.5	4443	30	[Round Dia]		1.08
														1.18	0	0.00
Section 3 Total																1.08
--	--	--	Collector													3
6	Fan	--	Duct	CD11-1, size at 0.2 in. water/100 ft, ε = 0.0004 ft						--	13	1475	15	[Round Dia]		0.034
			Bellmouth (collector to duct): D1=18 in., Ho=120 in., Wo =72in., bellmouth radius=4	ER2-1, Loss Coefficient based on V_1	1360	90	0.072								0.03	
			Transition to fan inlet: D1=13 ¼ in., Do=18 in., L=24 in. (θ = 12°)	ED4-1											0.17	
														0.131	0.20	0.03
Section 6 Total																0.06

Path Total Pressure Loss:

Terminal	Path	Path Total Pressure Losses (in. water)	Path Total Pressure (in. of water)	Imbalance (in. of water)
Hood	1-3-Collector-6	2.69+1.08 +3.00+0.06	6.83	0.00
Hood	2-3-Collector-6	2.60+1.08+3.00+0.06	6.74	0.09

1.36% dif

Designing the Duct System

Balancing with Airflow

Example – Spreadsheet Calculates Sizes and Pressure Losses (SI)
Sections 3, Collector and 6 (revised for balancing)

3	6	6	Duct	CD11-1	641	32	1.147	N/A	N/A	N/A	191	22.4	9.1	[Round Dia]		272.2
														301	0	0.00
Section 3 Total ...																**272.2**
--	--	--	Collector ...													**746.5**
6	Fan	--	Duct	CD11-1, size at 1.64 Pam, ε = .12 mm	641	32	1.147	.		--	332	7.4	4.6	[Round Dia]		8.5
			Bellmouth (collector to duct): D1=457 mm., Ho=3048mm, Wo =1829mm, bellmouth radius=100 mm	ER2-1, Loss Coefficient based on V_1											0.03	
			Transition to fan inlet: D1=337 mm, Do=457 mm, L=610 in. (θ = 12°)	ED4-1											0.17	
														33	0.20	6.6
Section 6 Total ...																**15.1**

Path Total Pressure Loss:

Terminal	Path	Path Total Pressure Losses (in. water)	Path Total Pressure (Pa)	Imbalance (Pa)
Hood	1-3-Collector-6	701.1 +272.2+746.5 +15.1	1734.9	0.0
Hood	2-3-Collector-6	671.2 +272.2+746.5 +15.1	1705.0	29.9

1.72% dif

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses, I-P

Imbalance Corrected

Path
1-3-Collector-6
2-3-Collector-6

Original

	Path Total Pressure (in. of water)	Imbalance (in. of water)
	6.23	0.35
	6.57	0

5.3% dif

More Balanced

	Path Total Pressure (in. of water)	Imbalance (in. of water)
	6.83	0.00
	6.74	0.09

1.36% dif

Designing the Duct System

Example – Spreadsheet Calculate Sizes and Pressure Losses, SI

Imbalance Corrected

Original

Path	Path Total Pressure (Pa)	Imbalance (Pa)
1-3-Collector-6	1585.4	85.5
2-3-Collector-6	1670.9	0

5.1% dif

More Balanced

Path	Path Total Pressure (Pa)	Imbalance (Pa)
1-3-Collector-6	1734.9	0.0
2-3-Collector-6	1705.0	29.9

1.72% dif

Summary

- ✓ Equal Friction Designs for 1000 to 2000 fpm (5 – 10 m/s) Should be Used to Size Sections not Carrying Fumes or Particulates
- ✓ Constant (Transport) Velocity Should be Used to Size Other Sections
- ✓ Get Hood Loss Coefficients from the Industrial Ventilation Manual from ACGIH
- ✓ Efficient Fittings Should be Used
- ✓ Consider Increasing Airflow in Non-Design Legs to Help Balance the System. Don’t use Dampers or Blast Gates for Balancing
- ✓ Smaller Duct Sizes or Less Efficient Fittings can also be Used After the Initial Design to help Balance the non-design legs, which should Lower First Cost

Questions?

Thank You

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Questions?

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