

CHAPTER 21

DUCT DESIGN

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COMMERCIAL, industrial, and residential air duct system design must consider (1) space availability, (2) space air diffusion, (3) noise levels, (4) air distribution system (duct and equipment), (5) duct heat gains and losses, (6) balancing, (7) fire and smoke control, (8) initial investment cost, and (9) system operating cost.

Deficiencies in duct design can result in systems that operate incorrectly or are expensive to own and operate. Poor design or lack of system sealing can produce inadequate airflow rates at the terminals, leading to discomfort, loss of productivity, and even adverse health effects. Lack of sound attenuation may lead to objectionable noise levels. Proper duct insulation eliminates excessive heat gain or loss.

In this chapter, system design and calculation of a system's frictional and dynamic resistance to airflow are considered. Chapter 18 of the 2008 *ASHRAE Handbook—HVAC Systems and Equipment* examines duct construction and presents construction standards for residential, commercial, and industrial HVAC and exhaust systems.

BERNOULLI EQUATION

The Bernoulli equation can be developed by equating the forces on an element of a stream tube in a frictionless fluid flow to the rate of momentum change. On integrating this relationship for steady flow, the following expression (Osborne 1966) results:

$$\frac{v^2}{2g_c} + \int \frac{dP}{\rho} + \frac{gz}{g_c} = \text{constant, ft} \cdot \text{lb}_f / \text{lb}_m \quad (1)$$

where

- v = streamline (local) velocity, fps
- g_c = dimensional constant, $32.2 \text{ lb}_m \cdot \text{ft} / \text{lb}_f \cdot \text{s}^2$
- P = absolute pressure, $\text{lb}_f / \text{ft}^2$
- ρ = density, $\text{lb}_m / \text{ft}^3$
- g = acceleration caused by gravity, ft / s^2
- z = elevation, ft

Assuming constant fluid density in the system, Equation (1) reduces to

$$\frac{v^2}{2g_c} + \frac{P}{\rho} + \frac{gz}{g_c} = \text{constant, ft} \cdot \text{lb}_f / \text{lb}_m \quad (2)$$

Although Equation (2) was derived for steady, ideal frictionless flow along a stream tube, it can be extended to analyze flow through ducts in real systems. In terms of pressure, the relationship for fluid resistance between two sections is

$$\frac{\rho_1 V_1^2}{2g_c} + P_1 + \frac{g}{g_c} \rho_1 z_1 = \frac{\rho_2 V_2^2}{2g_c} + P_2 + \frac{g}{g_c} \rho_2 z_2 + \Delta p_{t,1-2} \quad (3)$$

where

V = average duct velocity, fps

$\Delta p_{t,1-2}$ = total pressure loss caused by friction and dynamic losses between sections 1 and 2, $\text{lb}_f / \text{ft}^2$

In Equation (3), V (section average velocity) replaces v (streamline velocity) because experimentally determined loss coefficients allow for errors in calculating $v^2/2g_c$ (velocity pressure) across streamlines.

On the left side of Equation (3), add and subtract p_{z1} ; on the right side, add and subtract p_{z2} , where p_{z1} and p_{z2} are the values of atmospheric air at heights z_1 and z_2 . Thus,

$$\begin{aligned} \frac{\rho_1 V_1^2}{2g_c} + P_1 + (p_{z1} - p_{z1}) + \frac{g}{g_c} \rho_1 z_1 \\ = \frac{\rho_2 V_2^2}{2g_c} + P_2 + (p_{z2} - p_{z2}) + \frac{g}{g_c} \rho_2 z_2 + \Delta p_{t,1-2} \end{aligned} \quad (4)$$

Atmospheric pressure at any elevation (p_{z1} and p_{z2}) expressed in terms of the atmospheric pressure p_a at the same datum elevation is given by

$$p_{z1} = p_a - \frac{g}{g_c} \rho_a z_1 \quad (5)$$

$$p_{z2} = p_a - \frac{g}{g_c} \rho_a z_2 \quad (6)$$

Substituting Equations (5) and (6) into Equation (4) and simplifying yields the total pressure change between sections 1 and 2. Assume no temperature change between sections 1 and 2 (no heat exchanger within the section); therefore, $\rho_1 = \rho_2$. When a heat exchanger is located in the section, the average of the inlet and outlet temperatures is generally used. Let $\rho = \rho_1 = \rho_2$. ($P_1 - p_{z1}$) and ($P_2 - p_{z2}$) are gage pressures at elevations z_1 and z_2 .

$$\Delta p_{t,1-2} = \left(p_{s,1} + \frac{\rho V_1^2}{2} \right) - \left(p_{s,2} + \frac{\rho V_2^2}{2} \right) + g(\rho_a - \rho)(z_2 - z_1) \quad (7a)$$

$$\Delta p_{t,1-2} = \Delta p_t + \Delta p_{se} \quad (7b)$$

$$\Delta p_t = \Delta p_{t,1-2} + \Delta p_{se} \quad (7c)$$

where

$p_{s,1}$ = static pressure, gage at elevation z_1 , $\text{lb}_f / \text{ft}^2$

The preparation of this chapter is assigned to TC 5.2, Duct Design.

$p_{s,2}$ = static pressure, gage at elevation z_2 , lb_f/ft^2

V_1 = average velocity at section 1, fps

V_2 = average velocity at section 2, fps

ρ_a = density of ambient air, lb_m/ft^3

ρ = density of air or gas in duct, lb_m/ft^3

Δp_{se} = thermal gravity effect, lb_f/ft^2

Δp_t = total pressure change between sections 1 and 2, lb_f/ft^2

$\Delta p_{t,1-2}$ = total pressure loss caused by friction and dynamic losses between sections 1 and 2, lb_f/ft^2

HEAD AND PRESSURE

The terms **head** and **pressure** are often used interchangeably; however, head is the height of a fluid column supported by fluid flow, whereas pressure is the normal force per unit area. For liquids, it is convenient to measure head in terms of the flowing fluid. With a gas or air, however, it is customary to measure pressure on a column of liquid.

Static Pressure

The term $pg_c/\rho g$ is static head; p is static pressure.

Velocity Pressure

The term $V^2/2g$ refers to velocity head, and $\rho V^2/2g_c$ refers to velocity pressure. Although velocity head is independent of fluid density, velocity pressure [Equation (8)] is not.

$$p_v = \rho(V/1097)^2 \quad (8)$$

where

p_v = velocity pressure, in. of water

V = fluid mean velocity, fpm

1097 = conversion factor to in. of water

For air at standard conditions ($0.075 \text{ lb}_m/\text{ft}^3$), Equation (8) becomes

$$p_v = (V/4005)^2 \quad (9)$$

where $4005 = (1097^2/0.075)^{1/2}$. Velocity is calculated by

$$V = Q/A \quad (10)$$

where

Q = airflow rate, cfm

A = cross-sectional area of duct, ft^2

Total Pressure

Total pressure is the sum of static pressure and velocity pressure:

$$p_t = p_s + \rho(V/1097)^2 \quad (11)$$

or

$$p_t = p_s + p_v \quad (12)$$

where

p_t = total pressure, in. of water

p_s = static pressure, in. of water

Pressure Measurement

The range, precision, and limitations of instruments for measuring pressure and velocity are discussed in [Chapter 36](#). The manometer is a simple and useful means for measuring partial vacuum and low pressure. Static, velocity, and total pressures in a duct system relative to atmospheric pressure can be measured with a pitot tube connected to a manometer. Pitot tube construction and locations for traversing round and rectangular ducts are presented in [Chapter 36](#).

SYSTEM ANALYSIS

The total pressure change caused by friction, fittings, equipment, and net **thermal gravity effect (stack effect)** for each section of a duct system is calculated by the following equation:

$$\Delta p_{t_i} = \Delta p_{f_i} + \sum_{j=1}^m \Delta p_{ij} + \sum_{k=1}^n \Delta p_{ik} - \sum_{r=1}^{\lambda} \Delta p_{se_{ir}} \quad (13)$$

for $i = 1, 2, \dots, n_{up} + n_{dn}$

where

Δp_{t_i} = net total pressure change for i -section, in. of water

Δp_{f_i} = pressure loss due to friction for i -section, in. of water

Δp_{ij} = total pressure loss due to j -fittings, including fan system effect (FSE), for i -section, in. of water

Δp_{ik} = pressure loss due to k -equipment for i -section, in. of water

$\Delta p_{se_{ir}}$ = thermal gravity effect due to r -stacks for i -section, in. of water

m = number of fittings within i -section

n = number of equipment within i -section

λ = number of stacks within i -section

n_{up} = number of duct sections upstream of fan (exhaust/return air subsystems)

n_{dn} = number of duct sections downstream of fan (supply air subsystems)

From Equation (7), the thermal gravity effect for each nonhorizontal duct with a density other than that of ambient air is determined by the following equation:

$$\Delta p_{se} = 0.192(\rho_a - \rho)(z_2 - z_1) \quad (14)$$

where

Δp_{se} = thermal gravity effect, in. of water

z_1 and z_2 = elevation from datum in direction of airflow ([Figure 1](#)), ft

ρ_a = density of ambient air, lb_m/ft^3

ρ = density of air or gas within duct, lb_m/ft^3

0.192 = conversion factor to in. of water

Example 1. For [Figure 1](#), calculate the thermal gravity effect for two cases: (a) air cooled to -30°F , and (b) air heated to 1000°F . Density of air at -30°F is $0.0924 \text{ lb}_m/\text{ft}^3$ and at 1000°F is $0.0271 \text{ lb}_m/\text{ft}^3$. Density of ambient air is $0.075 \text{ lb}_m/\text{ft}^3$. Stack height is 40 ft.

Solution:

$$\Delta p_{se} = 0.192(\rho_a - \rho)z$$

(a) For $\rho > \rho_a$ ([Figure 1A](#)),

$$\Delta p_{se} = 0.192(0.075 - 0.0924)40 = -0.13 \text{ in. of water}$$

(b) For $\rho < \rho_a$ ([Figure 1B](#)),

$$\Delta p_{se} = 0.192(0.075 - 0.0271)40 = +0.37 \text{ in. of water}$$

Example 2. Calculate the thermal gravity effect for the two-stack system shown in [Figure 2](#), where the air is 250°F and stack heights are 50 and 100 ft. Density of 250°F air is $0.0558 \text{ lb}_m/\text{ft}^3$; ambient air is $0.075 \text{ lb}_m/\text{ft}^3$.

Solution:

$$\Delta p_{se} = 0.192(0.075 - 0.0558)(100 - 50) = 0.18 \text{ in. of water}$$

For the system shown in [Figure 3](#), the direction of air movement created by the thermal gravity effect depends on the initiating force (e.g., fans, wind, opening and closing doors, turning equipment on and off). If for any reason air starts to enter the left stack ([Figure 3A](#)), it creates a buoyancy effect in the right stack. On the other hand, if flow starts to enter the right stack ([Figure 3B](#)), it creates a buoyancy effect in the left stack. In both cases, the produced thermal gravity effect is stable and depends on stack height and magnitude

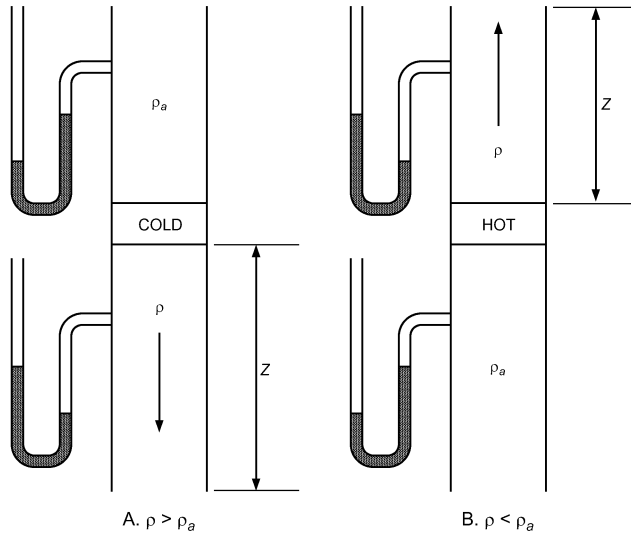


Fig. 1 Thermal Gravity Effect for Example 1

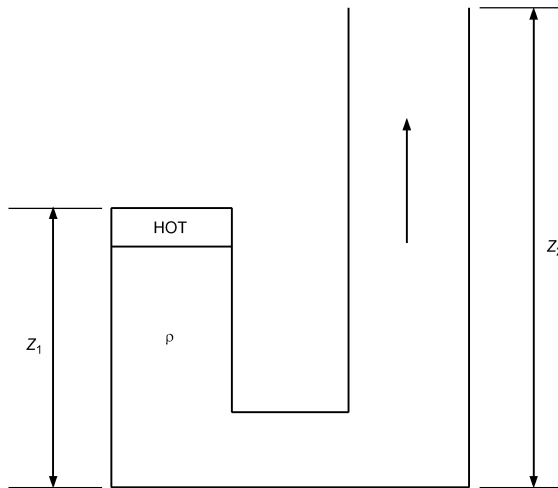


Fig. 2 Multiple Stacks for Example 2

of heating. The starting direction of flow is important when using natural convection for ventilation.

To determine the fan total pressure requirement for a system, use the following equation:

$$P_t = \sum_{i \in F_{up}} \Delta p_{t_i} + \sum_{i \in F_{dn}} \Delta p_{t_i} \quad \text{for } i = 1, 2, \dots, n_{up} + n_{dn} \quad (15)$$

where

F_{up} and F_{dn} = sets of duct sections upstream and downstream of fan
 P_t = fan total pressure, in. of water
 ε = symbol that ties duct sections into system paths from exhaust/return air terminals to supply terminals

Figure 4 illustrates the use of Equation (15). This system has three supply and two return terminals consisting of nine sections connected in six paths: 1-3-4-9-7-5, 1-3-4-9-7-6, 1-3-4-9-8, 2-4-9-7-5, 2-4-9-7-6, and 2-4-9-8. Sections 1 and 3 are unequal area; thus, they are assigned separate numbers in accordance with the rules for identifying sections (see step 4 in the section on HVAC Duct Design Procedures). To determine the fan pressure requirement, apply the following six equations, derived from Equation (15).

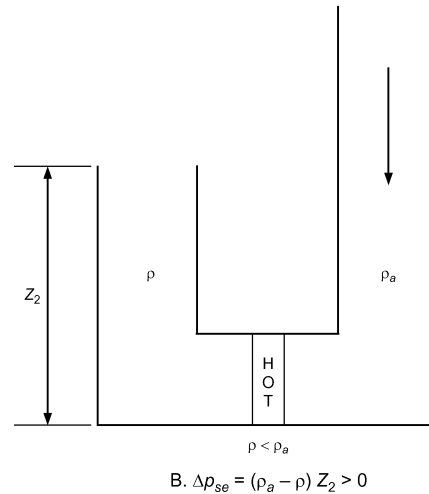
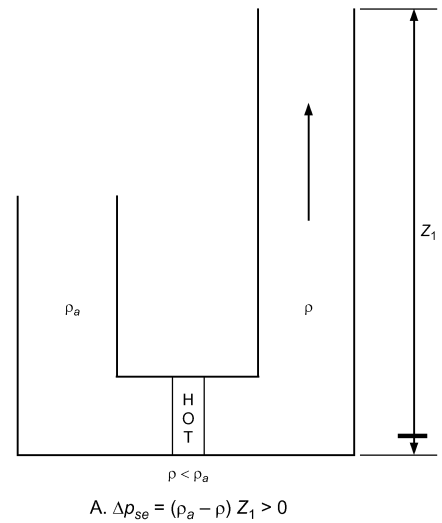


Fig. 3 Multiple Stack Analysis

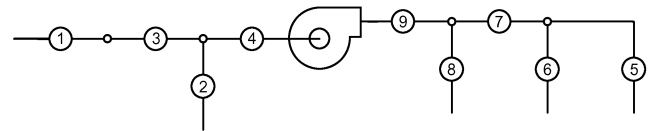


Fig. 4 Illustrative 6-Path, 9-Section System

These equations must be satisfied to attain pressure balancing for design airflow. Relying entirely on dampers is not economical and may create objectionable flow-generated noise.

$$\begin{cases} P_t = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5 \\ P_t = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_6 \\ P_t = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_8 \\ P_t = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5 \\ P_t = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_6 \\ P_t = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_8 \end{cases} \quad (16)$$

Example 3. For Figures 5A and 5C, calculate the thermal gravity effect and fan total pressure required when the air is cooled to -30°F . The heat exchanger and ductwork (section 1 to 2) total pressure losses are 0.70 and

0.28 in. of water respectively. Density of -30°F air is $0.0924 \text{ lb}_m/\text{ft}^3$; ambient air is $0.075 \text{ lb}_m/\text{ft}^3$. Elevations are 70 and 10 ft.

Solution:

(a) For Figure 5A (downward flow),

$$\begin{aligned}\Delta p_{se} &= 0.192(\rho_a - \rho)(z_2 - z_1) \\ &= 0.192(0.075 - 0.0924)(10 - 70) \\ &= 0.20 \text{ in. of water}\end{aligned}$$

$$\begin{aligned}P_t &= \Delta p_{t,3-2} - \Delta p_{se} \\ &= (0.70 + 0.28) - (0.20) \\ &= 0.78 \text{ in. of water}\end{aligned}$$

(b) For Figure 5C (upward flow),

$$\begin{aligned}\Delta p_{se} &= 0.192(\rho_a - \rho)(z_2 - z_1) \\ &= 0.192(0.075 - 0.0924)(70 - 10) \\ &= -0.20 \text{ in. of water}\end{aligned}$$

$$\begin{aligned}P_t &= \Delta p_{t,3-2} - \Delta p_{se} \\ &= (0.70 + 0.28) - (-0.20) \\ &= 1.18 \text{ in. of water}\end{aligned}$$

Example 4. For Figures 5B and 5D, calculate the thermal gravity effect and fan total pressure required when air is heated to 250°F . Heat exchanger and ductwork (section 1 to 2) total pressure losses are 0.70 and 0.28 in. of water, respectively. Density of 250°F air is $0.0558 \text{ lb}_m/\text{ft}^3$; ambient air is $0.075 \text{ lb}_m/\text{ft}^3$. Elevations are 70 and 10 ft.

Solution:

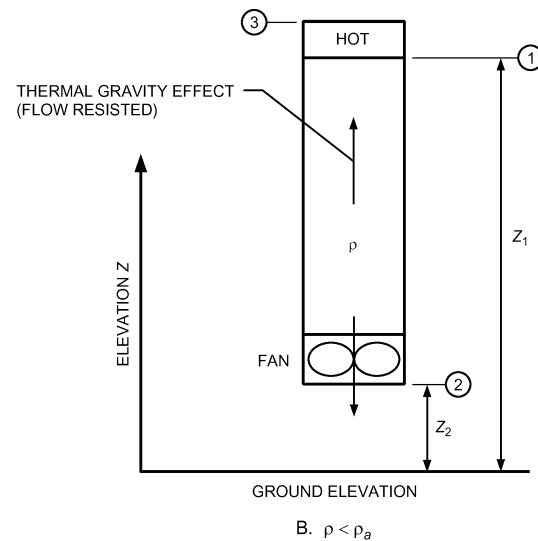
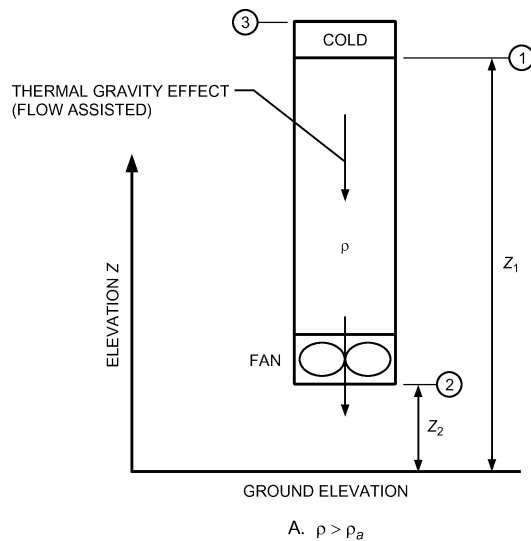
(a) For Figure 5B (downward flow),

$$\begin{aligned}\Delta p_{se} &= 0.192(\rho_a - \rho)(z_2 - z_1) \\ &= 0.192(0.075 - 0.0558)(10 - 70) \\ &= -0.22 \text{ in. of water}\end{aligned}$$

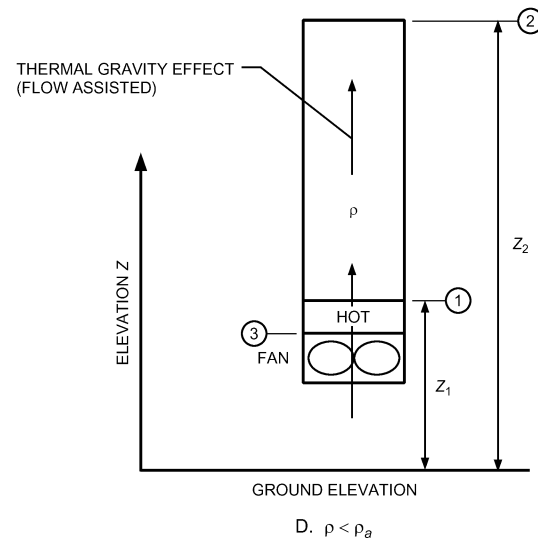
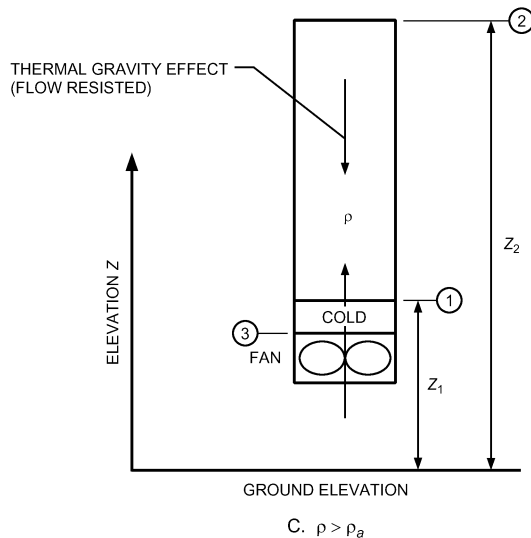
$$\begin{aligned}P_t &= \Delta p_{t,3-2} - \Delta p_{se} \\ &= (0.70 + 0.28) - (-0.22) \\ &= 1.20 \text{ in. of water}\end{aligned}$$

(b) For Figure 5D (upward flow),

$$\begin{aligned}\Delta p_{se} &= 0.192(\rho_a - \rho)(z_2 - z_1) \\ &= 0.192(0.075 - 0.0558)(70 - 10) \\ &= 0.22 \text{ in. of water}\end{aligned}$$



DOWNWARD FLOW



UPWARD FLOW

Fig. 5 Single Stack with Fan for Examples 3 and 4

$$P_t = \Delta p_{t,3-2} - \Delta p_{se}$$
$$= (0.70 + 0.28) - (0.22)$$
$$= 0.76 \text{ in. of water}$$

Example 5. Calculate the thermal gravity effect for each section of the system in Figure 6 and the system's net thermal gravity effect. Density of ambient air is 0.075 lb_m/ft³, and the lengths are as follows: z₁ = 50 ft, z₂ = 90 ft, z₄ = 95 ft, z₅ = 25 ft, and z₉ = 200 ft. Pressure required at section 3 is -0.1 in. of water. Write the equation to determine the fan total pressure requirement.

Solution: The following table summarizes the thermal gravity effect for each section of the system as calculated by Equation (14). The net

thermal gravity effect for the system is 0.52 in. of water. To select a fan, use the following equation:

$$P_t = 0.1 + \Delta p_{t,1-7} + \Delta p_{t,8-9} - \Delta p_{se} = 0.1 + \Delta p_{t,1-7}$$
$$+ \Delta p_{t,8-9} - 0.52 = \Delta p_{t,1-7} + \Delta p_{t,8-9} - 0.42$$

Path (x-x')	Temp., °F	ρ, lb _m /ft ³	Δz (z _{x'} - z _x), ft	Δp (ρ _a - ρ _{x-x'}), lb _m /ft ³	Δp _{se} , in. of water [Eq. (14)]
1-2	1500	0.0202	(90 - 50)	+0.0548	+0.42
3-4	1000	0.0271	0	+0.0479	0
4-5	1000	0.0271	(25 - 95)	+0.0479	-0.64
6-7	250	0.0558	0	+0.0192	0
8-9	250	0.0558	(200 - 0)	+0.0192	+0.74
Net Thermal Gravity Effect					0.52

PRESSURE CHANGES IN SYSTEM

Figure 7 shows total and static pressure changes in a fan/duct system consisting of a fan with both supply and return air ductwork. Also shown are total and static pressure gradients referenced to atmospheric pressure.

For all constant-area sections, total and static pressure losses are equal. At diverging transitions, velocity pressure decreases, absolute total pressure decreases, and absolute static pressure can increase. The static pressure increase at these sections is known as **static regain**.

At converging transitions, velocity pressure increases in the direction of airflow, and absolute total and absolute static pressures decrease.

At the exit, total pressure loss depends on the shape of the fitting and the flow characteristics. Exit loss coefficients C_o can be greater than, less than, or equal to one. Total and static pressure grade lines for the various coefficients are shown in Figure 7. Note that, for a loss coefficient less than one, static pressure upstream of the exit is less than atmospheric pressure (negative). Static pressure just upstream of the discharge fitting can be calculated by subtracting the upstream velocity pressure from the upstream total pressure.

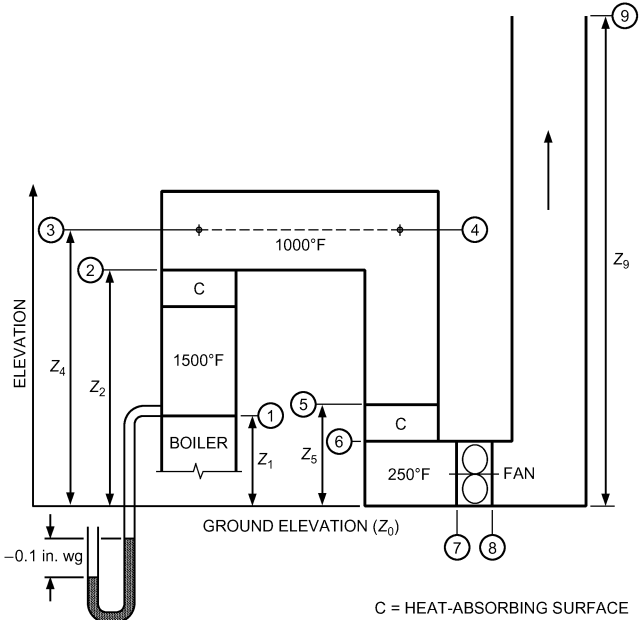


Fig. 6 Triple Stack System for Example 5

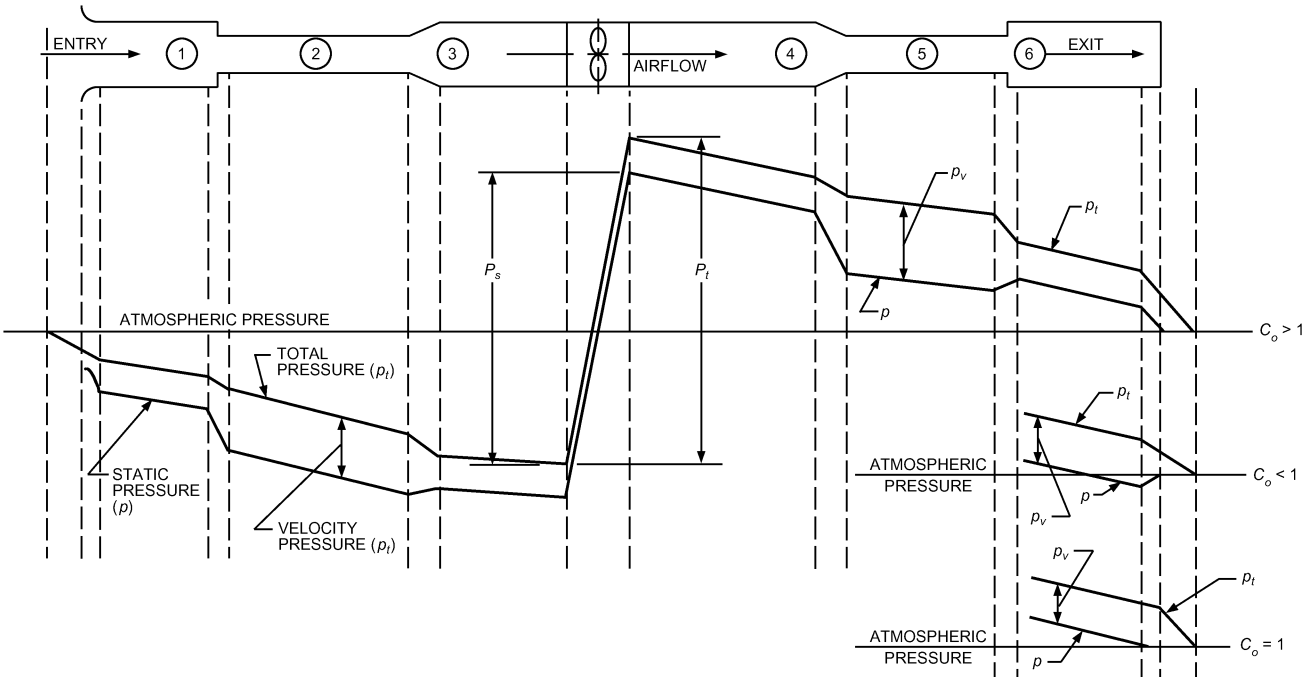


Fig. 7 Pressure Changes During Flow in Ducts

At section 1, total pressure loss depends on the shape of the entry. Total pressure immediately downstream of the entrance equals the difference between the upstream pressure, which is zero (atmospheric pressure), and loss through the fitting. Static pressure of ambient air is zero; several diameters downstream, static pressure is negative, equal to the sum of the total pressure (negative) and the velocity pressure (always positive).

System resistance to airflow is noted by the total pressure grade line in Figure 7. Sections 3 and 4 include fan system effect pressure losses. To obtain the fan static pressure requirement for fan selection where fan total pressure is known, use

$$P_s = P_t - p_{v,o} \quad (17)$$

where

P_s = fan static pressure, in. of water

P_t = fan total pressure, in. of water

$p_{v,o}$ = fan outlet velocity pressure, in. of water

FLUID RESISTANCE

Duct system losses are the irreversible transformation of mechanical energy into heat. The two types of losses are (1) friction losses and (2) dynamic losses.

FRICTION LOSSES

Friction losses are due to fluid viscosity and result from momentum exchange between molecules (in laminar flow) or between individual particles of adjacent fluid layers moving at different velocities (in turbulent flow). Friction losses occur along the entire duct length.

Darcy and Colebrook Equations

For fluid flow in conduits, friction loss can be calculated by the Darcy equation:

$$\Delta p_f = \frac{12fL}{D_h} \rho \left(\frac{V}{1097} \right)^2 \quad (18)$$

where

Δp_f = friction losses in terms of total pressure, in. of water

f = friction factor, dimensionless

L = duct length, ft

D_h = hydraulic diameter [Equation (24)], in.

V = velocity, fpm

ρ = density, lb_m/ft³

In the region of laminar flow (Reynolds numbers less than 2000), the friction factor is a function of Reynolds number only.

For completely turbulent flow, the friction factor depends on Reynolds number, duct surface roughness, and internal protuberances (e.g., joints). Between the bounding limits of hydraulically smooth behavior and fully rough behavior is a transitional roughness zone where the friction factor depends on both roughness and Reynolds number. In this transitionally rough, turbulent zone, the friction factor f is calculated by Colebrook's equation (Colebrook 1938-1939). This transition curve merges asymptotically into the curves representing laminar and completely turbulent flow. Because Colebrook's equation cannot be solved explicitly for f , use iterative techniques (Behl 1971).

$$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{\varepsilon}{3.7D_h} + \frac{2.51}{\text{Re}\sqrt{f}} \right) \quad (19)$$

where

ε = material absolute roughness factor, ft

Re = Reynolds number

Reynolds number (Re) may be calculated by using the following equation.

$$\text{Re} = \frac{D_h V}{720\nu} \quad (20)$$

where ν = kinematic viscosity, ft²/s.

For standard air and temperature between 40 and 100°F, Re can be calculated by

$$\text{Re} = 8.50 D_h V \quad (21)$$

Roughness Factors

Roughness factors ε listed in Table 1 are recommended for use with Equation (19). These values include not only material, but also duct construction, joint type, and joint spacing (Griggs and Khodabakhsh-Sharifabad 1992). Idelchik et al. (1994) summarize roughness factors for 80 materials, including metal tubes; conduits made from concrete and cement; and wood, plywood, and glass tubes.

Swim (1978) conducted tests on duct liners of varying densities, surface treatments, transverse joints (workmanship), and methods of attachment to sheet metal ducts. Results suggested using $\varepsilon = 0.015$ ft for spray-coated liners and $\varepsilon = 0.005$ ft for liners with a facing material adhered onto the air side. In both cases, the roughness factor includes resistance offered by mechanical fasteners, and assumes good joints. Liner density does not significantly influence flow resistance.

Figure 8 or Equation (22) (Abushakra et al. 2002, 2004; Culp and Cantrill 2009) provides pressure loss correction factors for compressed flexible ducts ranging in size from 6 to 16 in. Flexible ducts exhibit considerable variation in pressure loss, which can be in the ± 15 to 25% range, because of differences in manufacturing, materials, test setup (compression over the full length of duct), inner liner nonuniformities, installation, and draw-through or blow-through

Table 1 Duct Roughness Factors

Duct Material	Roughness Category	Absolute Roughness ε , ft
Uncoated carbon steel, clean (Moody 1944) (0.00015 ft)	Smooth	0.0001
PVC plastic pipe (Swim 1982) (0.00003 to 0.00015 ft)		
Aluminum (Hutchinson 1953) 0.000015 to 0.0002 ft)		
Galvanized steel, longitudinal seams, 4 ft joints (Griggs et al. 1987) (0.00016 to 0.00032 ft)	Medium-smooth	0.0003
Galvanized steel, continuously rolled, spiral seams, 10 ft joints (Jones 1979) (0.0002 to 0.0004 ft)		
Galvanized steel, spiral seam with 1, 2, and 3 ribs, 12 ft joints (Griggs et al. 1987) (0.00029 to 0.00038 ft)		
Galvanized steel, longitudinal seams, 2.5 ft joints (Wright 1945) (0.0005 ft)	Average	0.0005
Galvanized steel, spiral, corrugated, 10 ft joints (Kulkarni et al. 2009) (0.0024 ft)	Medium-rough	0.003
Fibrous glass duct, rigid		
Fibrous glass duct liner, air side with facing material (Swim 1978) (0.005 ft)		
Flexible duct, fabric and wire, fully extended		
Fibrous glass duct liner, air side spray coated (Swim 1978) (0.015 ft)	Rough	0.01
Flexible duct, metallic (0.004 to 0.007 ft when fully extended)		
Concrete (Moody 1944) (0.001 to 0.01 ft)		

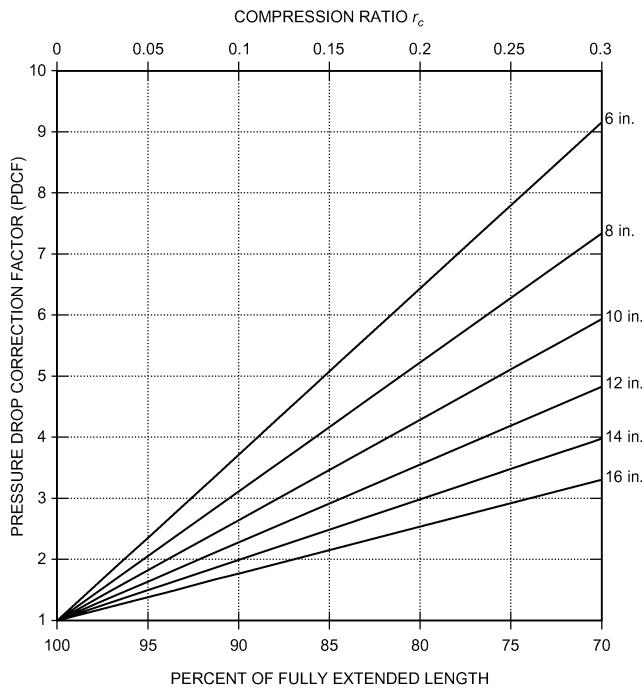


Fig. 8 Pressure Loss Correction Factor for Flexible Duct Not Fully Extended

applications. Pressure drop correction factors should be applied to medium-rough ducts ($\epsilon = 0.003$ ft); they can be obtained by multiplying the values from the friction chart for galvanized ducts (Figure 9) by 1.55, where ($\epsilon = 0.0003$ ft).

For commercial systems, flexible ducts should be

- Limited to connections between duct branches and diffusers or variable-air-volume (VAV) terminal units
- No more than 5 ft in length, fully stretched
- Installed without any radial compression (kinks)
- Not used in lieu of fittings

For 6 to 16 in. ducts that are 70% extended, pressure losses can be three to nine times greater than those for a fully extended flexible duct of the same diameter.

$$\text{PDCF} = 1 + 58r_c e^{-0.126D} \quad (22)$$

with

$$r_c = 1 - (L/L_{FE}) \quad (23)$$

where

PDCF = pressure drop correction factor
 r_c = compression ratio, dimensionless
 D = flexible duct diameter, in.
 L = installed duct length, ft
 L_{FE} = duct length fully extended, ft

Friction Chart

Fluid resistance caused by friction in round ducts can be determined by the friction chart (Figure 9). This chart is based on standard air flowing through round galvanized ducts with beaded slip couplings on 48 in. centers, equivalent to an absolute roughness of 0.0003 ft.

Changes in barometric pressure, temperature, and humidity affect air density, air viscosity, and Reynolds number. No corrections to Figure 9 are needed for (1) duct materials with a medium-smooth roughness factor, (2) temperature variations of $\pm 30^\circ\text{F}$ from

70°F , (3) elevations to 1500 ft, and (4) duct pressures from -20 to $+20$ in. of water relative to ambient pressure. These individual variations in temperature, elevation, and duct pressure result in duct losses within $\pm 5\%$ of the standard air friction chart.

For duct materials not categorized as medium-smooth in Table 1, and for variations in temperature, barometric pressure (elevation), and duct pressures (outside the range listed), calculate friction loss in a duct by the Colebrook and Darcy equations [Equations (19) and (18), respectively].

Noncircular Ducts

A momentum analysis can relate average wall shear stress to pressure drop per unit length for fully developed turbulent flow in a passage of arbitrary shape but uniform longitudinal cross-sectional area. This analysis leads to the definition of **hydraulic diameter**:

$$D_h = 4A/P \quad (24)$$

where

D_h = hydraulic diameter, in.
 A = duct area, in^2
 P = perimeter of cross section, in.

Although hydraulic diameter is often used to correlate noncircular data, exact solutions for laminar flow in noncircular passages show that this causes some inconsistencies. No exact solutions exist for turbulent flow. Tests over a limited range of turbulent flow indicated that fluid resistance is the same for equal lengths of duct for equal mean velocities of flow if the ducts have the same ratio of cross-sectional area to perimeter. From experiments using round, square, and rectangular ducts having essentially the same hydraulic diameter, Huebscher (1948) found that each, for most purposes, had the same flow resistance at equal mean velocities. Tests by Griggs and Khodabakhsh-Sharifabad (1992) also indicated that experimental rectangular duct data for airflow over the range typical of HVAC systems can be correlated satisfactorily using Equation (19) together with hydraulic diameter, particularly when a realistic experimental uncertainty is accepted. These tests support using hydraulic diameter to correlate noncircular duct data.

Rectangular Ducts. Huebscher (1948) developed the relationship between rectangular and round ducts that is used to determine size equivalency based on equal flow, resistance, and length. This relationship, Equation (25), is the basis for Table 2.

$$D_e = \frac{1.30(ab)^{0.625}}{(a+b)^{0.250}} \quad (25)$$

where

D_e = circular equivalent of rectangular duct for equal length, fluid resistance, and airflow, in.
 a = length one side of duct, in.
 b = length adjacent side of duct, in.

To determine equivalent round duct diameter, use Table 2. Equations (18) and (19) must be used to determine pressure loss.

Flat Oval Ducts. To convert round ducts to flat oval sizes, use Table 3, which is based on Equation (26) (Heyt and Diaz 1975), the circular equivalent of a flat oval duct for equal airflow, resistance, and length. Equations (18) and (19) must be used to determine friction loss.

$$D_e = \frac{1.55AR^{0.625}}{P^{0.250}} \quad (26)$$

where AR is the cross-sectional area of flat oval duct defined as

$$AR = (\pi a^2/4) + a(A - a) \quad (27)$$

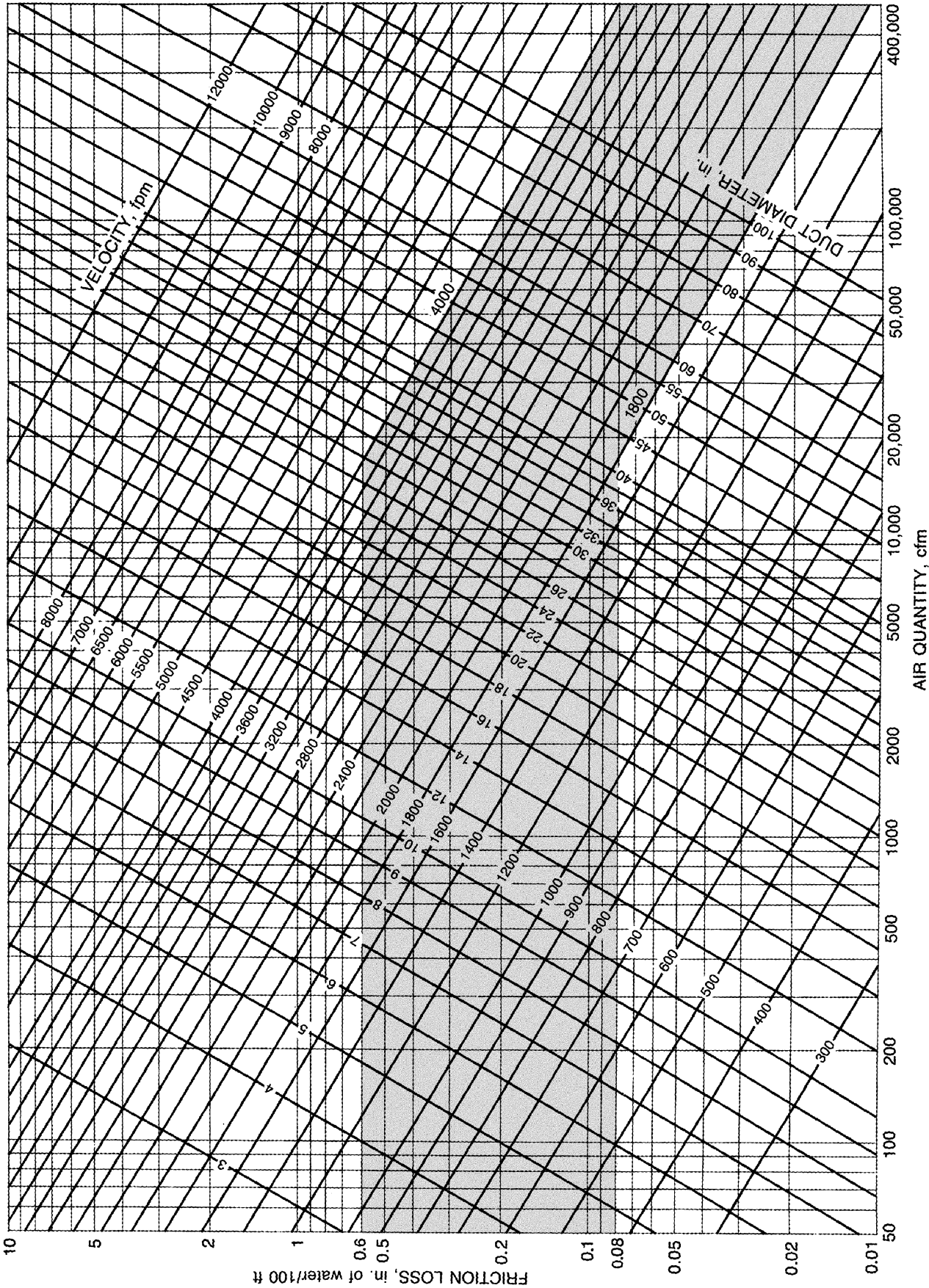


Fig. 9 Friction Chart for Round Duct ($\rho = 0.075 \text{ lb}_m/\text{ft}^3$ and $\varepsilon = 0.0003 \text{ ft}$)

and the perimeter P is calculated by

$$P = \pi a + 2(A - a) \quad (28)$$

where

- P = perimeter of flat oval duct, in.
- A = major axis of flat oval duct, in.
- a = minor axis of flat oval duct, in.

DYNAMIC LOSSES

Dynamic losses result from flow disturbances caused by duct-mounted equipment and fittings (e.g., entries, exits, elbows, transitions, and junctions) that change the airflow path's direction and/or area. Idelchik et al. (1994) discuss parameters affecting fluid resistance of fittings and presents local loss coefficients in three forms: tables, curves, and equations.

Local Loss Coefficients

The dimensionless coefficient C is used for fluid resistance, because this coefficient has the same value in dynamically similar streams (i.e., streams with geometrically similar stretches, equal Reynolds numbers, and equal values of other criteria necessary for dynamic similarity). The fluid resistance coefficient represents the ratio of total pressure loss to velocity pressure at the referenced cross section:

$$C = \frac{\Delta p_j}{\rho(V/1097)^2} = \frac{\Delta p_j}{p_v} \quad (29)$$

where

- C = local loss coefficient, dimensionless
- Δp_j = total pressure loss, in. of water
- ρ = density, lb_m/ft³
- V = velocity, fpm
- p_v = velocity pressure, in. of water

Dynamic losses occur along a duct length and cannot be separated from friction losses. For ease of calculation, dynamic losses are assumed to be concentrated at a section (local) and exclude friction. Frictional losses must be considered only for relatively long fittings. Generally, fitting friction losses are accounted for by measuring duct lengths from the centerline of one fitting to that of the next fitting. For fittings closely coupled (less than six hydraulic diameters apart), the flow pattern entering subsequent fittings differs from the flow pattern used to determine loss coefficients. Adequate data for these situations are unavailable.

For all fittings, except junctions, calculate the total pressure loss Δp_j at a section by

$$\Delta p_j = C_o p_{v,o} \quad (30)$$

where the subscript o is the cross section at which the velocity pressure is referenced. Dynamic loss is based on the actual velocity in the duct, not the velocity in an equivalent circular duct. For the cross section to reference a fitting loss coefficient, see step 4 in the section on HVAC Duct Design Procedures. Where necessary (e.g., unequal-area fittings), convert a loss coefficient from section o to section i using Equation (31), where V is the velocity at the respective sections.

$$C_i = \frac{C_o}{(V_i/V_o)^2} \quad (31)$$

For converging and diverging flow junctions, total pressure losses through the straight (main) section are calculated as

$$\Delta p_j = C_{c,s} p_{v,c} \quad (32)$$

For total pressure losses through the branch section,

$$\Delta p_j = C_{c,b} p_{v,c} \quad (33)$$

where $p_{v,c}$ is the velocity pressure at the common section c , and $C_{c,s}$ and $C_{c,b}$ are loss coefficients for the straight (main) and branch flow paths, respectively, each referenced to the velocity pressure at section c . To convert junction local loss coefficients referenced to straight and branch velocity pressures, use the following equation:

$$C_i = \frac{C_{c,i}}{(V_i/V_c)^2} \quad (34)$$

where

- C_i = local loss coefficient referenced to section being calculated (see subscripts), dimensionless
- $C_{c,i}$ = straight ($C_{c,s}$) or branch ($C_{c,b}$) local loss coefficient referenced to dynamic pressure at common section, dimensionless
- V_i = velocity at section to which C_i is being referenced, fpm
- V_c = velocity at common section, fpm

Subscripts:

- b = branch
- s = straight (main) section
- c = common section

The junction of two parallel streams moving at different velocities is characterized by turbulent mixing of the streams, accompanied by pressure losses. In the course of this mixing, momentum is exchanged between particles moving at different velocities, resulting in equalization of the velocity distributions in the common stream. The jet with higher velocity loses part of its kinetic energy by transmitting it to the slower jet. The loss in total pressure before and after mixing is always large and positive for the higher-velocity jet, and increases with an increase in the amount of energy transmitted to the lower-velocity jet. Consequently, the local loss coefficient [Equation (29)] is always positive. Energy stored in the lower-velocity jet increases because of mixing. The loss in total pressure and the local loss coefficient can, therefore, also have negative values for the lower velocity jet (Idelchik et al. 1994).

Duct Fitting Database

A duct fitting database that includes more than 220 round, flat oval, and rectangular fittings is available from ASHRAE (2009).

The fittings are numbered (coded) as shown in Table 4. Entries and converging junctions are only in the exhaust/return portion of systems. Exits and diverging junctions are only in supply systems. Equal-area elbows, obstructions, and duct-mounted equipment are common to both supply and exhaust systems. Transitions and unequal-area elbows can be either supply or exhaust fittings. Fitting ED5-1 (see the section on Fitting Loss Coefficients) is an Exhaust fitting with a round shape (Diameter). The number 5 indicates that the fitting is a junction, and 1 is its sequential number. Fittings SR31 and ER3-1 are Supply and Exhaust fittings, respectively. The R indicates that the fitting is Rectangular, and the 3 identifies the fitting as an elbow. Note that the cross-sectional areas at sections 0 and 1 are not equal (see the section on Fitting Loss Coefficients). Otherwise, the elbow would be a Common fitting such as CR3-6. Additional fittings are reproduced in the section on Fitting Loss Coefficients to support the example design problems (see Table 10 for Example 6; see Table 12 for Example 7).

Bends in Flexible Duct

Abushakra et al. (2002) show that loss coefficients for bends in flexible ductwork vary widely from condition to condition, with no uniform or consistent trends. Loss coefficients range from a low of 0.87 to a high of 3.27. Flexible duct elbows should not be used in lieu of rigid elbows.

Table 2 Equivalent Rectangular Duct Dimensions

Circular Duct Diameter, in.	Length of One Side of Rectangular Duct a , in.																			
	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30	32	34	36
	Length Adjacent Side of Rectangular Duct b , in.																			
5	5																			
5.5	6	5																		
6	8	6																		
6.5	9	7	6																	
7	11	8	7																	
7.5	13	10	8	7																
8	15	11	9	8																
8.5	17	13	10	9																
9	20	15	12	10	8															
9.5	22	17	13	11	9															
10	25	19	15	12	10	9														
10.5	29	21	16	14	12	10														
11	32	23	18	15	13	11	10													
11.5		26	20	17	14	12	11													
12		29	22	18	15	13	12													
12.5		32	24	20	17	15	13													
13		35	27	22	18	16	14	12												
13.5		38	29	24	20	17	15	13												
14			32	26	22	19	17	14												
14.5			35	28	24	20	18	15												
15			38	30	25	22	19	16	14											
16			45	36	30	25	22	18	15											
17				41	34	29	25	20	17	16										
18				47	39	33	29	23	19	17										
19				54	44	38	33	26	22	19	18									
20					50	43	37	29	24	21	19									
21					57	48	41	33	27	23	20									
22					64	54	46	36	30	26	23	20								
23						60	51	40	33	28	25	22								
24						66	57	44	36	31	27	24	22							
25							63	49	40	34	29	26	24							
26							69	54	44	37	32	28	26	24						
27							76	59	48	40	35	31	28	25						
28								64	52	43	38	33	30	27	26					
29								70	56	47	41	36	32	29	27					
30								76	61	51	44	39	35	31	29	28				
31								82	66	55	47	41	37	34	31	29				
32								89	71	59	51	44	40	36	33	31				
33								96	76	64	54	48	42	38	35	33	30			
34									82	68	58	51	45	41	37	35	32			
35									88	73	62	54	48	44	40	37	34	32		
36									95	78	67	58	51	46	42	39	36	34		
37									101	83	71	62	55	49	45	41	38	36	34	
38									108	89	76	66	58	52	47	44	40	38	36	
39										95	80	70	62	55	50	46	43	40	37	36
40										101	85	74	65	58	53	49	45	42	39	37
41										107	91	78	69	62	56	51	47	44	41	39
42										114	96	83	73	65	59	54	50	46	44	41
43										120	102	88	77	69	62	57	53	49	46	43
44											107	93	81	73	66	60	55	51	48	45
45											113	98	86	76	69	63	58	54	50	47
46											120	103	90	80	72	66	61	56	53	49
47											126	108	95	84	76	69	64	59	55	52
48											133	114	100	89	80	73	67	62	58	54
49											140	120	105	93	84	76	70	65	60	56
50											147	126	110	98	88	80	73	68	63	59
51												132	115	102	92	83	76	71	66	61
52												139	121	107	96	87	80	74	69	64
53												145	127	112	100	91	83	77	71	67
54												152	133	117	105	95	87	80	74	70
55													139	123	110	99	91	84	78	72
56													145	128	114	104	95	87	81	75
57													151	134	119	108	98	91	84	78
58													158	139	124	112	102	94	87	81
59													165	145	130	117	107	98	91	85
60													172	151	135	122	111	102	94	88

Table 3 Equivalent Flat Oval Duct Dimensions

Circular Duct Diameter, in.	Minor Axis <i>a</i> , in.													Circular Duct Diameter, in.	Minor Axis <i>a</i> , in.																			
	3	4	5	6	7	8	9	10	11	12	14	16	8		9	10	11	12	14	16	18	20	22	24										
	Major Axis <i>A</i> , in.														Major Axis <i>A</i> , in.																			
5	8													19	46	—	34	—	28	23	21													
5.5	9	7												20	50	—	38	—	31	27	24	21												
6	11	9												21	58	—	43	—	34	28	25	23												
6.5	12	10	8											22	65	—	48	—	37	31	29	26												
7	15	12	10	8										23	71	—	52	—	42	34	30	27												
7.5	19	13	—	9										24	77	—	57	—	45	38	33	29	26											
8	22	15	11	—										25	63			—	50	41	36	32	29											
8.5	18		13	11	10										26	70			—	56	45	38	34	31										
9	20		14	12	—	10										27	76			—	59	49	41	37	34									
9.5	21		18	14	12	—										28				65	52	46	40	36										
10	19			15	13	11										29				72	58	49	43	39	35									
10.5	21			17	15	13	12										30				78	61	54	46	40	38								
11	19				16	14	—	12										31				81	67	57	49	44	39	37						
11.5	20				18	16	14	—										32				71	60	53	47	42	40							
12	23				20	17	15	13										33				77	66	56	51	46	41							
12.5	25				21	—	15			14										34				69	59	55	47	44						
13	28				23	19	17	16	—			14										35				76	65	58	50	46				
13.5	30				—	21	18	—			16			—										36				79	68	61	53	49		
14	33				—	22	20	18	17	15										37				71			64	57	52					
14.5	36				—	24	22	19	—			17										38				78			67	60	55			
15	39				—	27	23	21	19	18										40							77	69	62					
16	45				—	30	—	24	22	20	17										42							75			68			
17	52				—	35	—	27	24	21	19										44							82			74			
18	59				—	39	—	30	—	25	22	19																						

Table 4 Duct Fitting Codes

Fitting Function	Geometry	Category	Sequential Number
S: Supply	D: round (Diameter)	1. Entries	1,2,3... <i>n</i>
		2. Exits	
E: Exhaust/Return	R: Rectangular	3. Elbows	
		4. Transitions	
C: Common (supply and return)	F: Flat oval	5. Junctions	
		6. Obstructions	
		7. Fan and system interactions	
		8. Duct-mounted equipment	
		9. Dampers	
		10. Hoods	

DUCTWORK SECTIONAL LOSSES

Darcy-Weisbach Equation

Total pressure loss in a duct section is calculated by combining Equations (18) and (29) in terms of Δp , where ΣC is the summation of local loss coefficients in the duct section. Each fitting loss coefficient must be referenced to that section's velocity pressure.

$$\Delta p = \left(\frac{12 f L}{D_h} + \Sigma C \right) \rho \left(\frac{V}{1097} \right)^2 \quad (35)$$

FAN/SYSTEM INTERFACE

Fan Inlet and Outlet Conditions

Fan performance data measured in the field may show lower performance capacity than manufacturers' ratings. The most common causes of deficient performance of the fan/system combination are improper outlet connections, nonuniform inlet flow, and swirl at the fan inlet. These conditions alter the fan's aerodynamic

characteristics so that its full flow potential is not realized. One bad connection can reduce fan performance far below its rating. No data have been published that account for the effects of fan inlet and outlet flexible vibration connectors.

Normally, a fan is tested with open inlets and a section of straight duct attached to the outlet (ASHRAE *Standard* 51). This setup results in uniform flow into the fan and efficient static pressure recovery on the fan outlet. If good inlet and outlet conditions are not provided in the actual installation, the performance of the fan suffers. To select and apply the fan properly, these effects must be considered, and the pressure requirements of the fan, as calculated by standard duct design procedures, must be increased.

Figure 10 illustrates deficient fan/system performance. System pressure losses have been determined accurately, and a fan has been selected for operation at point 1. However, no allowance has been made for the effect of system connections to the fan on fan performance. To compensate, a fan system effect must be added to the calculated system pressure losses to determine the actual system curve. The point of intersection between the fan performance curve and the actual system curve is point 4. The actual flow volume is, therefore, deficient by the difference from 1 to 4. To achieve design flow volume, a fan system effect pressure loss equal to the pressure difference between points 1 and 2 should be added to the calculated system pressure losses, and the fan should be selected to operate at point 2.

Fan System Effect Coefficients

The system effect concept was formulated by Farquhar (1973) and Meyer (1973); the magnitudes of the system effect, called **system effect factors**, were determined experimentally by the Air Movement and Control Association (AMCA 2007a; Brown 1973; Clarke et al. 1978). The system effect factors, converted to local loss coefficients, are in the *ASHRAE Duct Fitting Database* (2009) for both centrifugal and axial fans. Fan system effect coefficients are only an approximation. Fans of different types and even fans of the same type, but supplied by different manufacturers, do not

necessarily react to a system in the same way. Therefore, judgment based on experience must be applied to any design.

Fan Outlet Conditions. Fans intended primarily for duct systems are usually tested with an outlet duct in place (ASHRAE *Standard 51*). Figure 11 shows the changes in velocity profiles at various

distances from the fan outlet. For 100% recovery, the duct, including transition, must meet the requirements for 100% effective duct length [L_e (Figure 11)], which is calculated as follows:

For $V_o > 2500$ fpm,

$$L_e = \frac{V_o \sqrt{A_o}}{10,600} \quad (36)$$

For $V_o \leq 2500$ fpm,

$$L_e = \frac{\sqrt{A_o}}{4.3} \quad (37)$$

where

V_o = duct velocity, fpm

L_e = effective duct length, ft

A_o = duct area, in²

As illustrated by Fitting SR7-1 in the section on Fitting Loss Coefficients, centrifugal fans should not abruptly discharge to the atmosphere. A diffuser design should be selected from Fitting SR7-2 (see the section on Fitting Loss Coefficients) or SR7-3 [see ASHRAE (2009)].

Fan Inlet Conditions. For rated performance, air must enter the fan uniformly over the inlet area in an axial direction without prerotation. Nonuniform flow into the inlet is the most common cause of reduced fan performance. Such inlet conditions are not equivalent to a simple increase in system resistance; therefore, they cannot be treated as a percentage decrease in the flow and pressure from the fan. A poor inlet condition results in an entirely new fan performance. An elbow at the fan inlet, for example Fitting ED7-2 (see the

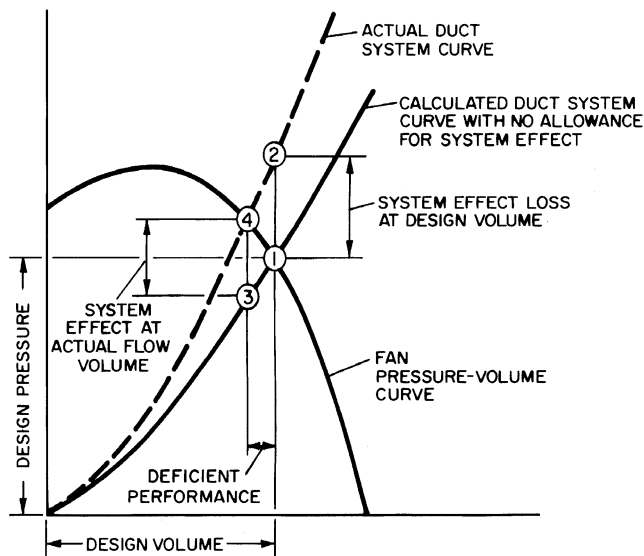


Fig. 10 Deficient System Performance with System Effect Ignored

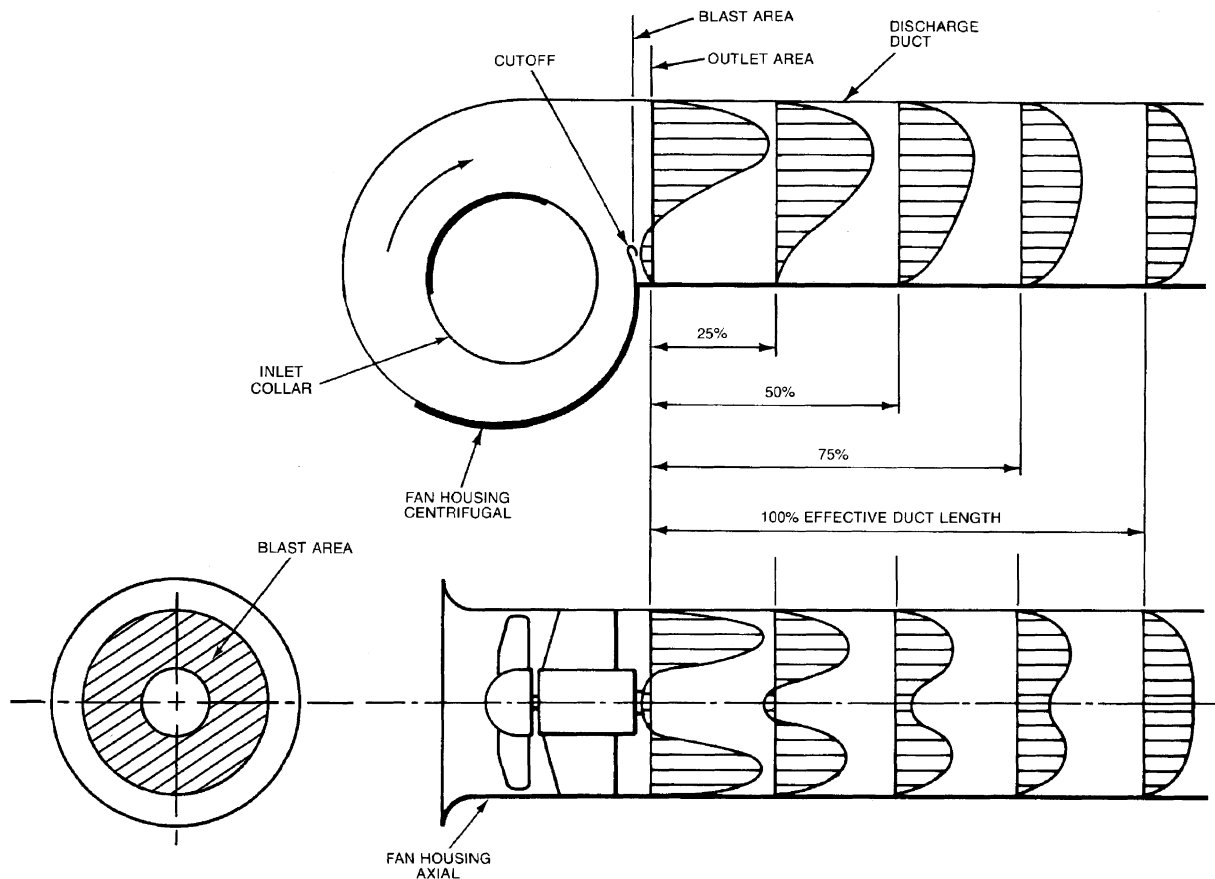


Fig. 11 Establishment of Uniform Velocity Profile in Straight Fan Outlet Duct
(Adapted by permission from AMCA Publication 201)

section on Fitting Loss Coefficients), causes turbulence and uneven flow into the fan impeller. Losses from the fan system effect can be eliminated by including an adequate length of straight duct between the elbow and the fan inlet.

The ideal inlet condition allows air to enter axially and uniformly without spin. A spin in the same direction as the impeller rotation reduces the pressure/volume curve by an amount dependent on the vortex's intensity. A counterrotating vortex at the inlet slightly increases the pressure/volume curve, but the power is increased substantially.

Inlet spin may arise from many different approach conditions, and sometimes the cause is not obvious. Inlet spin can be avoided by providing an adequate length of straight duct between the elbow and the fan inlet. Figure 12 illustrates some common duct connections that cause inlet spin and includes recommendations for correcting spin.

Fans within plenums and cabinets or next to walls should be located so that air may flow unobstructed into the inlets. Fan performance is reduced if the space between the fan inlet and the enclosure is too restrictive. System effect coefficients for fans in an enclosure or adjacent to walls are listed under Fitting ED7-1 (see the section on Fitting Loss Coefficients). How the airstream enters an enclosure in relation to the fan inlets also affects fan performance. Plenum or enclosure inlets or walls that are not symmetrical with the fan inlets cause uneven flow and/or inlet spin.

Testing, Adjusting, and Balancing Considerations

Fan system effects (FSEs) are not only to be used in conjunction with the system resistance characteristics in the fan selection process, but are also applied in the calculations of the results of testing, adjusting, and balancing (TAB) field tests to allow direct comparison to design calculations and/or fan performance data. Fan inlet swirl and the effect on system performance of poor fan inlet and outlet ductwork connections cannot be measured directly. Poor inlet flow patterns affect fan performance within the impeller wheel (centrifugal fan) or wheel rotor impeller (axial fan), while the fan outlet system effect is flow instability and turbulence within the fan discharge ductwork.

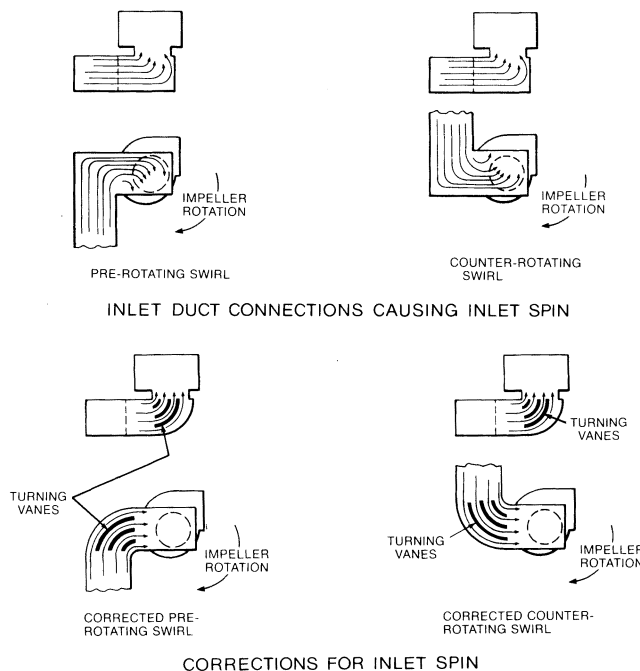


Fig. 12 Inlet Duct Connections Causing Inlet Spin and Corrections for Inlet Spin

(Adapted by permission from AMCA Publication 201)

The static pressure at the fan inlet and the static pressure at the fan outlet may be measured directly in some systems. In most cases, static pressure measurements for use in determining fan total (or static) pressure will not be made directly at the fan inlet and outlet, but at locations a relatively short distance from the fan inlet and downstream from the fan outlet. To calculate fan total pressure for this case from field measurements, use Equation (38), where Δp_{x-y} is the summation of calculated total pressure losses between the fan inlet and outlet sections noted. Plane 3 is used to determine airflow rate. If necessary, use Equation (17) to calculate fan static pressure knowing fan total pressure. For locating measurement planes and calculation procedures, consult AMCA Publication 203 (AMCA 2007b).

$$P_t = (p_{s,5} + p_{v,5}) + \Delta p_{2-5} + \text{FSE}_2 + (p_{s,4} + p_{v,4}) + \Delta p_{4-1} + \text{FSE}_1 + \text{FSE}_{1,\text{sw}} \quad (38)$$

where

P_t = fan total pressure, in. of water

p_s = static pressure, in. of water

p_v = velocity pressure, in. of water

FSE = fan system effect, in. of water

Δp_{x-y} = summarization of total pressure losses between planes x and y , in. of water

Subscripts [numerical subscripts same as used by AMCA (2007b)]:

1 = fan inlet

2 = fan outlet

3 = plane of airflow measurement

4 = plane of static pressure measurement upstream of fan

5 = plane of static pressure measurement downstream of fan

sw = swirl

DUCT SYSTEM DESIGN

DESIGN CONSIDERATIONS

Space Pressure Relationships

Space pressure is determined by fan location and duct system arrangement. For example, a supply fan that pumps air into a space increases space pressure; an exhaust fan reduces space pressure. If both supply and exhaust fans are used, space pressure depends on the relative capacity of the fans. Space pressure is positive if supply exceeds exhaust and negative if exhaust exceeds supply (Osborne 1966). System pressure variations caused by wind can be minimized or eliminated by careful selection of intake air and exhaust vent locations (see Chapter 24).

Fire and Smoke Management

Because duct systems can convey smoke, hot gases, and fire from one area to another and can accelerate a fire within the system, fire protection is an essential part of air-conditioning and ventilation system design. Generally, fire safety codes require compliance with the standards of national organizations. NFPA Standard 90A examines fire safety requirements for (1) ducts, connectors, and appurtenances; (2) plenums and corridors; (3) air outlets, air inlets, and fresh air intakes; (4) air filters; (5) fans; (6) electric wiring and equipment; (7) air-cooling and -heating equipment; (8) building construction, including protection of penetrations; and (9) controls, including smoke control.

Fire safety codes often refer to the testing and labeling practices of nationally recognized laboratories, such as Factory Mutual and Underwriters Laboratories (UL). UL's annual *Building Materials Directory* lists fire and smoke dampers that have been tested and meet the requirements of UL Standards 555 and 555S. This directory also summarizes maximum allowable sizes for individual dampers and assemblies of these dampers. Fire dampers are 1.5 h or 3 h fire-rated. Smoke dampers are classified by (1) temperature degradation [ambient air or high temperature (250°F minimum)] and

(2) leakage at 1 and 4 in. of water pressure difference (8 and 12 in. of water classification optional). Smoke dampers are tested under conditions of maximum airflow. UL's annual *Fire Resistance Directory* lists fire resistances of floor/roof and ceiling assemblies with and without ceiling fire dampers.

For a more detailed presentation of fire protection, see the NFPA (2008) *Fire Protection Handbook*, Chapter 52 of the 2007 *ASHRAE Handbook—HVAC Applications*, and Klote and Milke (2002).

Duct Insulation

In all new construction (except low-rise residential buildings), air-handling ducts and plenums that are part of an HVAC air distribution system should be thermally insulated in accordance with ASHRAE *Standard* 90.1. Duct insulation for new low-rise residential buildings should comply with ASHRAE *Standard* 90.2. Existing buildings should meet requirements of ASHRAE *Standard* 100. In all cases, thermal insulation should meet local code requirements. Insulation thicknesses in these standards are minimum values; economic and thermal considerations may justify higher insulation levels. Additional insulation, vapor retarders, or both may be required to limit vapor transmission and condensation.

Duct heat gains or losses must be known to calculate supply air quantities, supply air temperatures, and coil loads. To estimate duct heat transfer and entering or leaving air temperatures, refer to [Chapter 23](#).

Duct System Leakage

It is recommended that all transverse joints, longitudinal seams, and ductwork penetrations be sealed. **Longitudinal seams** are joints oriented in the direction of airflow. **Duct wall penetrations** are openings made by screws, non-self-sealing fasteners, pipe, tubing, rods, and wire. All other connections are considered **transverse joints**, which are connections of two duct or fitting elements oriented perpendicular to flow (e.g., spin-ins, taps, branch connections, duct connections to equipment). System (ductwork and equipment) leakage should be tested to verify the installing contractor's workmanship and sealing practices.

Leakage in all unsealed ducts varies considerably with the fabricating machinery used, material thickness, assembly methods, and installation workmanship. For sealed ducts, a wide variety of sealing methods and products exists. Sealed and unsealed duct leakage tests (AISI/SMACNA 1972; ASHRAE/SMACNA/TIMA 1985; Swim and Griggs 1995) confirmed that longitudinal seam, transverse joint, and assembled duct leakage can be represented by Equation (39) and that, for the same construction, leakage is not significantly different in negative and positive modes. [Table 5](#) presents a range of leakage rates for longitudinal seams commonly used in metal duct construction. Longitudinal seam leakage for unsealed or unwelded metal ducts is about 10 to 15% of total duct leakage.

$$Q = C \Delta p_n^N \quad (39)$$

where

Q = duct leakage rate, cfm

C = constant reflecting area characteristics of leakage path

Δp_s = static pressure differential from duct interior to exterior, in. of water

N = exponent relating turbulent or laminar flow in leakage path

The AISI/ASHRAE/SMACNA/TIMA data showed that duct leakage (equipment not included) is best predicted by duct surface area and pressure, because surface area highlights the effect of system size. Duct leakage were grouped into a geometric series of **leakage classes** C_L ([Figure 13](#)) based on Equation (40), where the exponent N is assumed to be 0.65. [Table 6](#) shows leakage classes for commonly used duct construction and sealing practices (equipment leakage excluded).

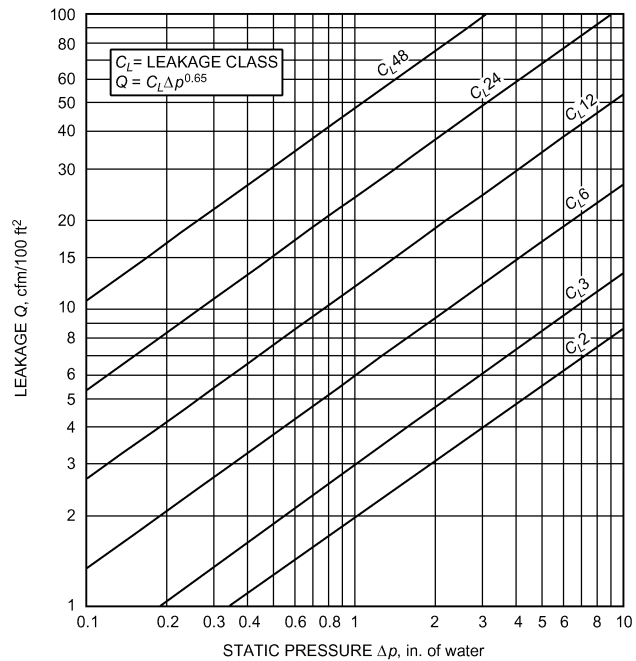


Fig. 13 Duct Leakage Classifications

Table 5 Unsealed Longitudinal Seam Leakage, Metal Ducts

Type of Duct/Seam	Leakage, cfm per ft Seam Length*	
	Range	Average
Rectangular		
Pittsburgh lock		
26 gage	0.01 to 0.02	0.0164
22 gage	0.001 to 0.002	0.0016
Button punch snaplock		
26 gage	0.03 to 0.15	0.0795
22 gage	NA (1 test)	0.0032
Round		
Spiral (26 gage)	NA (1 test)	0.015
Snaplock	0.04 to 0.14	0.11
Grooved	0.11 to 0.18	0.12

*Leakage rate is at 1 in. of water static pressure.

$$C_L = Q / \Delta p_n^{0.65} \quad (40)$$

where

Q = leakage rate, cfm/100 ft² (surface area)

C_L = leakage class, cfm per 100 ft duct surface at 1 in. of water static pressure

Effects of equipment leakage (e.g., through dampers, access doors, VAV boxes, diffusers) should be anticipated. Ductwork should not be expected to compensate for equipment leakage. Terminal units may leak 1 to 2% of their maximum flow. Use [Table 6](#) to calculate allowable ductwork leakage for a system. Leakage classes listed in [Table 6](#) are for a specific duct type, not a system with a variety of duct types. When several pressure classifications or shapes occur in a system, ductwork in each class or shape should be evaluated independently to find an aggregate leakage for the system. System leakage (ductwork plus equipment) values for use in specifications should be in terms of cfm at the pressure(s) leakage was determined. The estimated percent leakage for any section of ductwork can be determined from [Table 7](#) (equipment leakage not included).

Limited performance standards for metal duct sealants and tapes exist. For guidance in their selection and use, refer to SMACNA's

Table 6 Duct Leakage Classification^a

Duct Type	Predicted Leakage Class C_L [Eq. (40)]	
	Sealed ^{b,c}	Unsealed ^c
Metal (flexible excluded)		
Round and flat oval	3	30 (6 to 70)
Rectangular	6	48 (12 to 110)
Flexible		
Metal, aluminum	8	30 (12 to 54)
Nonmetal	12	30 (4 to 54)
Fibrous glass		
Round	3	NA
Rectangular	6	NA

^aLeakage classes here are averages based on tests conducted by AISI/SMACNA (1972), ASHRAE/SMACNA/TIMA (1985), and Swim and Griggs (1995).

^b“Sealed” leakage classes assume that, for metal ducts, all transverse joints, seams, and openings in duct wall are sealed.

^cLeakage classes anticipate about 25 joints per 100 linear feet of duct. For systems with a high fitting-to-straight-duct ratio, greater leakage occurs in both sealed and unsealed conditions.

Table 7 Leakage as Percentage of Airflow^{a,b}

Leakage Class	System cfm per ft ² Duct Surface ^c	Static Pressure, in. of water					
		0.5	1	2	3	4	6
48	2	15	24	38	49	59	77
	2.5	12	19	30	39	47	62
	3	10	16	25	33	39	51
	4	7.7	12	19	25	30	38
	5	6.1	9.6	15	20	24	31
24	2	7.7	12	19	25	30	38
	2.5	6.1	9.6	15	20	24	31
	3	5.1	8.0	13	16	20	26
	4	3.8	6.0	9.4	12	15	19
	5	3.1	4.8	7.5	9.8	12	15
12	2	3.8	6	9.4	12	15	19
	2.5	3.1	4.8	7.5	9.8	12	15
	3	2.6	4.0	6.3	8.2	9.8	13
	4	1.9	3.0	4.7	6.1	7.4	9.6
	5	1.5	2.4	3.8	4.9	5.9	7.7
6	2	1.9	3	4.7	6.1	7.4	9.6
	2.5	1.5	2.4	3.8	4.9	5.9	7.7
	3	1.3	2.0	3.1	4.1	4.9	6.4
	4	1.0	1.5	2.4	3.1	3.7	4.8
	5	0.8	1.2	1.9	2.4	3.0	3.8
3	2	1.0	1.5	2.4	3.1	3.7	4.8
	2.5	0.8	1.2	1.9	2.4	3.0	3.8
	3	0.6	1.0	1.6	2.0	2.5	3.2
	4	0.5	0.8	1.3	1.6	2.0	2.6
	5	0.4	0.6	0.9	1.2	1.5	1.9

^aAdapted with permission from *HVAC Air Duct Leakage Test Manual* (SMACNA 1985, Appendix A).

^bPercentage applies to airflow entering a section of duct operating at an assumed pressure equal to average of upstream and downstream pressures.

^cRatios in this column are typical of fan volumetric flow rate divided by total system surface. Portions of systems may vary from these averages.

HVAC Duct Construction Standards (2005). Fibrous glass ducts and their closure systems are covered by UL *Standards* 181 and 181A. For fibrous glass duct construction standards, consult NAIMA (2002) and SMACNA (2003). Flexible duct performance and installation standards are covered by UL *Standards* 181 and 181B and ADC (2003). Soldered or welded duct construction is necessary where sealants are not suitable. Sealants used on exterior ducts must be resistant to weather, temperature cycles, sunlight, and ozone.

Table 8 Typical Design Velocities for HVAC Components

Duct Element	Face Velocity, fpm
Louvers ^a	
Intake	
7000 cfm and greater	400
Less than 7000 cfm	See Figure 14
Exhaust	
5000 cfm and greater	500
Less than 5000 cfm	See Figure 14
Filters ^b	
Panel filters	
Viscous impingement	200 to 800
Dry-type, extended-surface	
Flat (low efficiency)	Duct velocity
Pleated media (intermediate efficiency)	Up to 750
HEPA	250
Renewable media filters	
Moving-curtain viscous impingement	500
Moving-curtain dry media	200
Electronic air cleaners	
Ionizing type	150 to 350
Heating Coils ^c	
Steam and hot water	500 to 1000 200 min., 1500 max.
Electric	
Open wire	Refer to mfg. data
Finned tubular	Refer to mfg. data
Dehumidifying Coils ^d	400 to 500
Air Washers ^e	
Spray type	Refer to mfg. data
Cell type	Refer to mfg. data
High-velocity spray type	1200 to 1800

^aBased on assumptions presented in text.

^bAbstracted from Ch. 28, 2008 *ASHRAE Handbook—HVAC Systems and Equipment*.

^cAbstracted from Ch. 26, 2008 *ASHRAE Handbook—HVAC Systems and Equipment*.

^dAbstracted from Ch. 22, 2008 *ASHRAE Handbook—HVAC Systems and Equipment*.

^eAbstracted from Ch. 40, 2008 *ASHRAE Handbook—HVAC Systems and Equipment*.

Shaft and compartment pressure changes affect duct leakage and are important to health and safety in the design and operation of contaminant and smoke control systems. Shafts should not be used for supply, return, and/or exhaust air without accounting for their leakage rates. Airflow around buildings, building component leakage, and the distribution of inside and outside pressures over the height of a building, including shafts, are discussed in [Chapters 16 and 24](#).

System Component Design Velocities

[Table 8](#) summarizes face velocities for HVAC components in built-up systems. In most cases, the values are abstracted from pertinent chapters in the 2008 *ASHRAE Handbook—HVAC Systems and Equipment*; final selection of components should be based on data in these chapters or, preferably, from manufacturers.

Use [Figure 14](#) for preliminary sizing of air intake and exhaust louvers. For air quantities greater than 7000 cfm per louver, the air intake gross louver openings are based on 400 fpm; for exhaust louvers, 500 fpm is used for air quantities of 5000 cfm per louver and greater. For smaller air quantities, refer to [Figure 14](#). These criteria are presented on a per-louver basis (i.e., each louver in a bank of louvers) to include each louver frame. Representative production-run louvers were used in establishing [Figure 14](#), and all data used were based on AMCA *Standard* 500-L tests. For louvers larger than 16 ft², the free areas are greater than 45%; for louvers less than 16 ft², free areas are less than 45%. Unless specific louver data are analyzed, no louver should have a face area less than 4 ft². If debris can collect on the screen of an intake louver, or if louvers are located

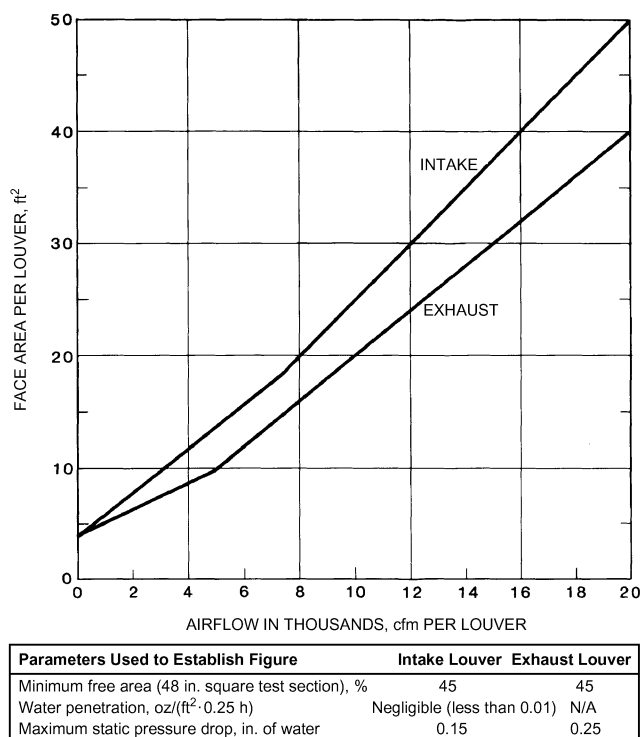


Fig. 14 Criteria for Louver Sizing

at grade with adjacent pedestrian traffic, louver face velocity should not exceed 100 fpm.

Louvers require special treatment because the blade shapes, angles, and spacing cause significant variations in louver-free area and performance (pressure drop and water penetration). Selection and analysis should be based on test data obtained from the manufacturer in accordance with AMCA *Standard 500-L*, which presents both pressure drop and water penetration test procedures and a uniform method for calculating the free area of a louver. Tests are conducted on a 48 in. square louver with the frame mounted flush in the wall. For water penetration tests, rainfall is 4 in./h, no wind, and the water flow down the wall is 0.25 gpm per linear foot of louver width.

AMCA *Standard 500-L* also includes a method for measuring water rejection performance of louvers subjected to simulated rain and wind pressures. These louvers are tested at a rainfall of 3 in./h falling on the louver's face with a predetermined wind velocity directed at the face of the louver (typically 29.1 or 44.7 mph). Effectiveness ratings are assigned at various airflow rates through the louver.

System and Duct Noise

The major sources of noise from air-conditioning systems are diffusers, grilles, fans, ducts, fittings, and vibrations. Chapter 47 of the 2007 ASHRAE Handbook—HVAC Applications discusses sound control for each of these sources, as well as methods for calculating required sound attenuation. Sound control for terminal devices consists of selecting devices that meet the design goal under all operating conditions and installing them properly so that no additional sound is generated. The sound power output of a fan is determined by the type of fan, airflow, and pressure. Sound control in the duct system requires proper duct layout, sizing, and provision for installing duct attenuators, if required. Noise generated by a system increases with both duct velocity and system pressure.

Testing and Balancing

Each air duct system should be tested, adjusted, and balanced. Detailed procedures are given in Chapter 37 of the 2007 ASHRAE Handbook—HVAC Applications. To properly determine fan total (or static) pressure from field measurements taking into account fan system effect, see the section on Fan/System Interface. Equation (38) allows direct comparison of system resistance to design calculations and/or fan performance data. It is important that system effect magnitudes be known prior to testing. If necessary, use Equation (17) to calculate fan static pressure knowing fan total pressure [Equation (38)]. For TAB calculation procedures of numerous fan/system configurations encountered in the field, refer to AMCA (2007b).

DUCT DESIGN METHODS

Duct design methods for HVAC systems and for exhaust systems conveying vapors, gases, and smoke are the equal-friction method, the static regain method, and the T-method. The section on Industrial Exhaust System Duct Design presents the design criteria and procedures for exhaust systems conveying particulates. Equal friction and static regain are nonoptimizing methods, and the T-method is a practical optimization method introduced by Tsal et al. (1988).

To ensure that system designs are acoustically acceptable, noise generation should be analyzed and sound attenuators and/or acoustically lined duct provided where necessary.

Equal-Friction Method

In the equal-friction method, ducts are sized for a constant pressure loss per unit length. The shaded area of the friction chart (see Figure 9) is the suggested range of friction rate and air velocity. When energy cost is high and installed ductwork cost is low, a low-friction-rate design is more economical. For low energy cost and high duct cost, a higher friction rate is more economical. After initial sizing, calculate total pressure loss for all duct sections, and then resize sections to balance pressure losses at each junction.

Static Regain Method

This design method is only applicable to supply air systems. The objective is to obtain the same static pressure at diverging flow junctions by changing downstream duct sizes. This design objective can be developed by rearranging Equation (7a) and setting $p_{s,2}$ equal to $p_{s,1}$ (neglecting thermal gravity effect term). This means that the change in static pressure from one section to another is zero, which is satisfied when the change in total pressure is equal to the change in velocity pressure. Thus,

$$p_{s,1} - p_{s,2} = \Delta p_{t,1-2} - \left[\frac{\rho V_1^2}{2g_c} - \frac{\rho V_2^2}{2g_c} \right] \quad (41)$$

and

$$\Delta p_{t,1-2} = \frac{\rho V_1^2}{2g_c} - \frac{\rho V_2^2}{2g_c} \quad (42)$$

where $\Delta p_{t,1-2}$ is total pressure loss from upstream of junction 1 to upstream of junction 2. Junction 2 can be a terminal section, where the total pressure is zero. For each main section, the straight-through and branch sections immediately downstream of the main duct section are determined by iteration of that section's size until Equation (42) is satisfied. However, there could be cases when the straight or branch sections need to be larger than the upstream section to satisfy Equation (42). Fittings in the 2009 ASHRAE Duct Fitting Database have not been tested under these conditions, and making downstream sections larger than upstream sections is not practical. The largest straight-through or branch size should be limited to that of the upstream section. The imbalance that occurs is resolved during total-pressure balancing of the system.

To start system design, a maximum velocity is selected for the root section (duct section downstream of a fan). In Figure 16, section 19 is the root for the supply air subsystem. The shaded area on the friction chart (see Figure 9) is the suggested range of air velocity. When energy cost is high and installed ductwork cost is low, a lower initial velocity is more economical. For low energy cost and high duct cost, a higher velocity is more economical.

Because terminal sections often require additional static pressure to operate VAV terminal boxes properly, that static pressure requirement is added into the section after it is sized using static regain. Otherwise, the downstream section could be larger than the upstream section. For calculating duct sizes, the total pressure losses of grilles, registers, diffusers, or constant-volume (CV) terminal boxes should be included in the sizing iterations.

Total Pressure Balancing. After completing duct sizing by the static regain method, any residual unbalance can be reduced or eliminated by calculating the system's total pressure (pressure required in the critical paths) and changing duct sizes or fittings in other paths to increase the paths' total pressure to approximate what is needed in the critical paths.

T-Method

T-method optimization (Tsal et al. 1988) is a dynamic programming procedure based on Bellman's (1957) tee-staging idea, except that phase-level vector tracing is eliminated by optimizing locally at each stage. This modification reduces the number of calculations, but requires iteration.

Ductwork sizes are determined by minimizing the objective function:

$$E = E_p(\text{PWEF}) + E_s \quad (43)$$

where

E = present-worth owning and operating cost

E_p = first-year energy cost

E_s = initial cost

PWEF = present worth escalation factor (Smith 1968), dimensionless

The objective function includes both initial system cost and present worth of energy. Hours of operation, annual escalation and interest rates, and amortization period are also required for optimization.

The following constraints are necessary for duct optimization (Tsal and Adler 1987):

- *Continuity.* For each node, flow in equals flow out.
- *Pressure balancing.* Total pressure loss in each path must equal fan total pressure; or, in effect, at any junction, total pressure loss for all paths is the same.
- *Nominal duct size.* Ducts are constructed in discrete, nominal sizes. Each diameter of a round duct or height and width of a rectangular duct is rounded to the nearest increment, usually 1 or 2 in. If a lower nominal size is selected, initial cost decreases, but pressure loss increases and may exceed the fan pressure. If a higher nominal size is selected, the opposite is true: initial cost increases, but section pressure loss decreases. However, this lower pressure at one section may allow smaller ducts to be selected for sections that follow. Therefore, optimization must consider size rounding.
- *Air velocity restriction.* Maximum allowable velocity is an acoustic limitation (ductwork regenerated noise).
- *Construction restriction.* Architectural limits may restrict duct sizes. If air velocity or construction constraints are violated during an iteration, a duct size must be calculated. Pressure loss calculated for this preselected duct size is considered a fixed loss.

T-method simulation, developed by Tsal et al. (1990), determines the flow in each duct section of an existing system with a known operating fan performance curve. The simulation version of the T-method converges very efficiently. Usually three iterations are sufficient to obtain a solution with a high degree of accuracy.

Many HVAC problems require duct system simulation. In addition to the following concerns that can be clarified by simulation, the T-method is an excellent design tool for simulating flow distribution within a system with various modes of operation.

- Flow distribution in a VAV system caused by terminal box flow diversity
- Airflow redistribution caused by HVAC system additions and/or modifications
- System airflow analysis for partially occupied buildings
- Necessity to replace fans and/or motors when retrofitting an air distribution system
- Multiple-fan system operating condition when one or more fans shut down
- Pressure differences between adjacent confined spaces in a nuclear facility when a design basis accident (DBA) occurs (Farajian et al. 1992)
- Smoke management system performance during a fire, when some fire/smoke dampers close and others remain open

Availability. Software for T-method optimization is under development to identify optimum duct design, considering energy, operation, and construction costs.

BALANCING DAMPERS

Constant-Volume (CV) Systems

Dampers should be provided throughout CV systems. Systems designed using the inherently non-self-balancing equal-friction method should have balancing dampers at each branch throughout the system, unless sections are resized to balance pressure losses at each junction. Self-balancing design methods, such as static regain and the T-method, produce fairly well-balanced systems and theoretically do not need balancing dampers; however, because of the accuracy limitations of fitting data (loss coefficients), use of fittings for which no data are available, and effects of close-coupled fittings, dampers should be provided.

Variable-Air-Volume (VAV) Systems

VAV systems in balance at design loads will not be in balance at part-load conditions, because there is no single critical path in VAV systems. The critical path is dynamic and continually changing as loads on a building change. In general, balancing dampers are not needed for systems designed by the static regain or T-method, because these design methods are self-balancing at design loads and VAV boxes compensate for inaccuracy in fitting data or data inaccuracy caused by close-coupled fittings (at design loads) and system pressure variation (at part loads). Balancing dampers, however, are required for systems designed using the non-self-balancing equal-friction method. For systems designed using any method, dampers should not be installed in the inlets to VAV boxes.

For any design method, VAV terminal units may have upstream static pressures higher than for which the box is rated, thus possibly introducing noise into occupied spaces. In these cases, control algorithms can poll the VAV boxes and drive the duct static pressure to the minimum set point required to keep at least one unit at starvation (open) at any given time. Upstream static pressure should always be kept at a minimum that is easy for the VAV box to control. Because there may be large differences in static pressure at riser takeoffs serving many floors from a single air handler, manual dampers should be provided at each floor takeoff so that testing, adjusting, and balancing (TAB) contractors can field-adjust them after construction. Alternatively, these takeoff dampers could also be dynamically controlled to adjust the downstream static pressure applied to the VAV boxes, while simultaneously driving the air handler to the lowest possible static pressure set point.

Silencers downstream of VAV terminal units should not be necessary if the VAV box damper is operating at nearly open conditions.

Their use in this location should be based on careful acoustical analysis, because silencers add total pressure to the system and therefore create more system noise by causing air handlers to operate at higher speeds for a given airflow.

HVAC DUCT DESIGN PROCEDURES

The general procedure for HVAC system duct design is as follows:

1. Study the building plans, and arrange supply and return outlets to provide proper distribution of air in each space. Adjust calculated air quantities for duct heat gains or losses and duct leakage. Also, adjust supply, return, and/or exhaust air quantities to meet space pressurization requirements.
2. Select outlet sizes from manufacturers' data (see Chapter 20).
3. Sketch the duct system, connecting supply outlets and return intakes with the air-handling units/air conditioners. Use rigid round ducts, minimize the number of fittings, and avoid close-coupled fittings because little is known about the resulting loss coefficients. If space is restricted and a properly designed
4. Divide the system into sections and number each section. A duct system should be divided at all points where flow, size, or shape changes. Assign fittings to the section toward the supply and return (or exhaust) terminals. The following examples are for the fittings identified for Example 6 (Figure 15), and system section numbers assigned (Figure 16). For converging flow fitting 3, assign the straight-through flow to section 1 (toward terminal 1), and the branch to section 2 (toward terminal 4). For diverging flow fitting 24, assign the straight-through flow to section 13 (toward terminals 26 and 29) and the branch to section 10

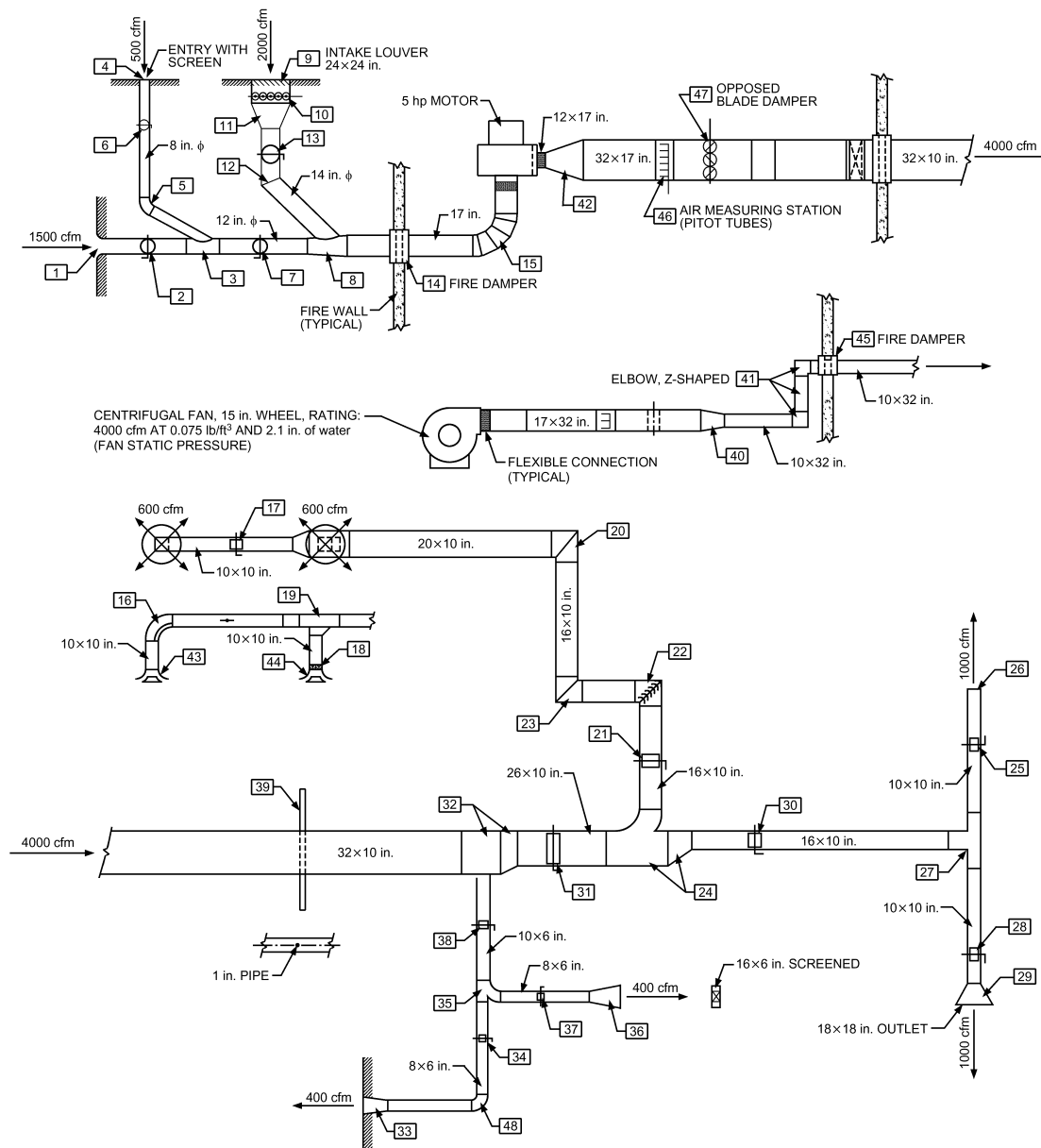


Fig. 15 Schematic for Example 6

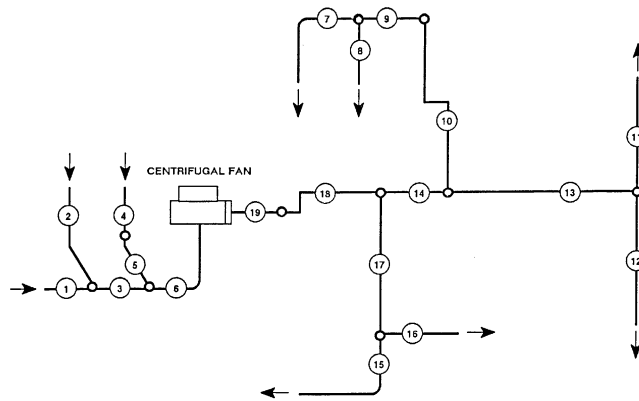


Fig. 16 System Schematic with Section Numbers for Example 6

- (toward terminals 43 and 44). For transition fitting 11, assign the fitting to upstream section 4 [toward terminal 9 (intake louver)]. For fitting 20, assign the unequal area elbow to downstream section 9 (toward diffusers 43 and 44). The fan outlet diffuser, fitting 42, is assigned to section 19 (again, toward the supply duct terminals).
5. Size ducts by the selected design method. Calculate system total pressure loss; then select the fan (refer to Chapter 20 of the 2008 *ASHRAE Handbook—HVAC Systems and Equipment*).
6. Lay out the system in detail. If duct routing and fittings vary significantly from the original design, recalculate pressure losses. Reselect the fan if necessary.
7. Resize duct sections to approximately balance pressures at each junction.
8. Analyze the design for objectionable noise levels, and specify lined duct, double-wall duct, and sound attenuators as necessary. Refer to the section on System and Duct Noise.

Example 6. For the system illustrated by Figures 15 and 16, size the ductwork by the equal-friction method, and pressure-balance the system by changing duct sizes (use 1 in. increments). Determine system resistance and total pressure unbalance at junctions. Airflow quantities are actual values adjusted for heat gains or losses, and ductwork is sealed (assume no leakage), galvanized steel ducts with transverse joints on 4 ft centers ($\epsilon = 0.0003$ ft). Air is at standard conditions ($0.075 \text{ lb}_m/\text{ft}^3$ density).

Because Figure 15 is intended to illustrate calculation procedures, its duct layout is not typical of any real duct system. The layout includes fittings from the local loss coefficient tables, with emphasis on converging and diverging tees and various types of entries and discharges. The supply system is constructed of rectangular ductwork; the return system, round ductwork.

Solution: See Figure 16 for section numbers assigned to the system. Duct sections are sized within the suggested range of friction rate shown on the friction chart (see Figure 9). Tables 9 and 10 give total pressure loss calculations and the supporting summary of loss coefficients by sections. Straight-duct friction factor and pressure loss were calculated by Equations (18) and (19). Fitting loss coefficients are from the 2009 *ASHRAE Duct Fitting Database*. Loss coefficients were calculated automatically by the database program (not by manual interpolation). Pressure loss values in Table 9 for diffusers (fittings 43 and 44), louver (fitting 9), and air-measuring station (fitting 46) are manufacturers' data.

Pressure unbalance at junctions is shown in Figure 17, the total pressure grade line for the system. System resistance P_t is 2.89 in. of water. Noise levels and the need for sound attenuation were not evaluated. To calculate the fan static pressure, use Equation (17):

$$P_s = 2.89 - 0.50 = 2.39 \text{ in. of water}$$

where 0.50 in. of water is the fan outlet velocity pressure.

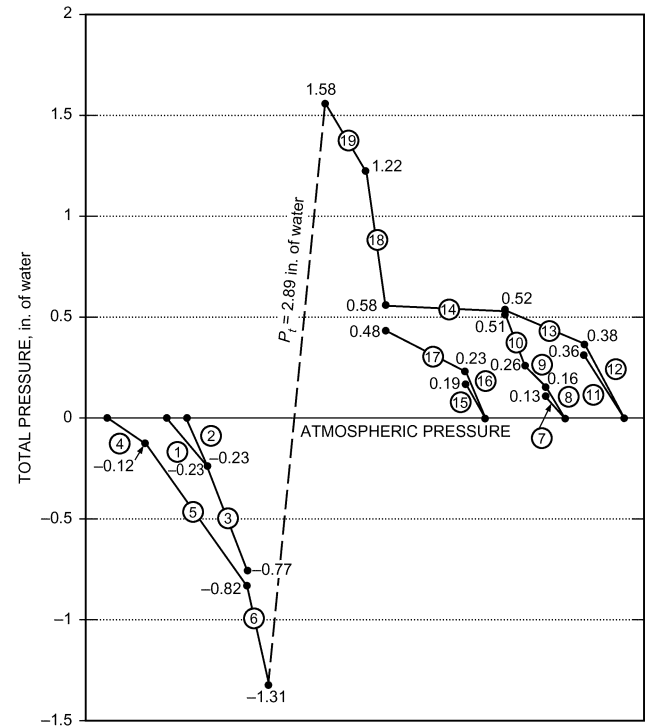


Fig. 17 Total Pressure Grade Line for Example 6

INDUSTRIAL EXHAUST SYSTEM DUCT DESIGN

Chapter 30 of the 2007 *ASHRAE Handbook—HVAC Applications* discusses design criteria, including hood design, for industrial exhaust systems. Exhaust systems conveying vapors, gases, and smoke can be designed by the equal-friction or T-method. Systems conveying particulates are designed by the constant velocity method at duct velocities adequate to convey particles to the system air cleaner. For contaminant transport velocities, see Table 2 in Chapter 30 of the 2007 *ASHRAE Handbook—HVAC Applications*.

Two pressure-balancing methods can be considered when designing industrial exhaust systems. One method uses balancing devices (e.g., dampers, blast gates) to obtain design airflow through each hood. The other approach balances systems by adding resistance to ductwork sections (i.e., changing duct size, selecting different fittings, and increasing airflow). This self-balancing method is preferred, especially for systems conveying abrasive materials. Where potentially explosive or radioactive materials are conveyed, the prebalanced system is mandatory because contaminants could accumulate at the balancing devices. To balance systems by increasing airflow, use Equation (44) which assumes that all ductwork has the same diameter and that fitting loss coefficients, including main and branch tee coefficients, are constant.

$$Q_c = Q_d(P_h/P_l)^{0.5} \quad (44)$$

where

Q_c = airflow rate required to increase P_l to P_h , cfm

Q_d = total airflow rate through low-resistance duct run, cfm

P_h = absolute value of pressure loss in high-resistance ductwork section(s), in. of water

P_l = absolute value of pressure loss in low-resistance ductwork section(s), in. of water

For systems conveying particulates, use elbows with a large centerline radius-to-diameter ratio (r/D), greater than 1.5 whenever possible. If r/D is 1.5 or less, abrasion in dust-handling systems can

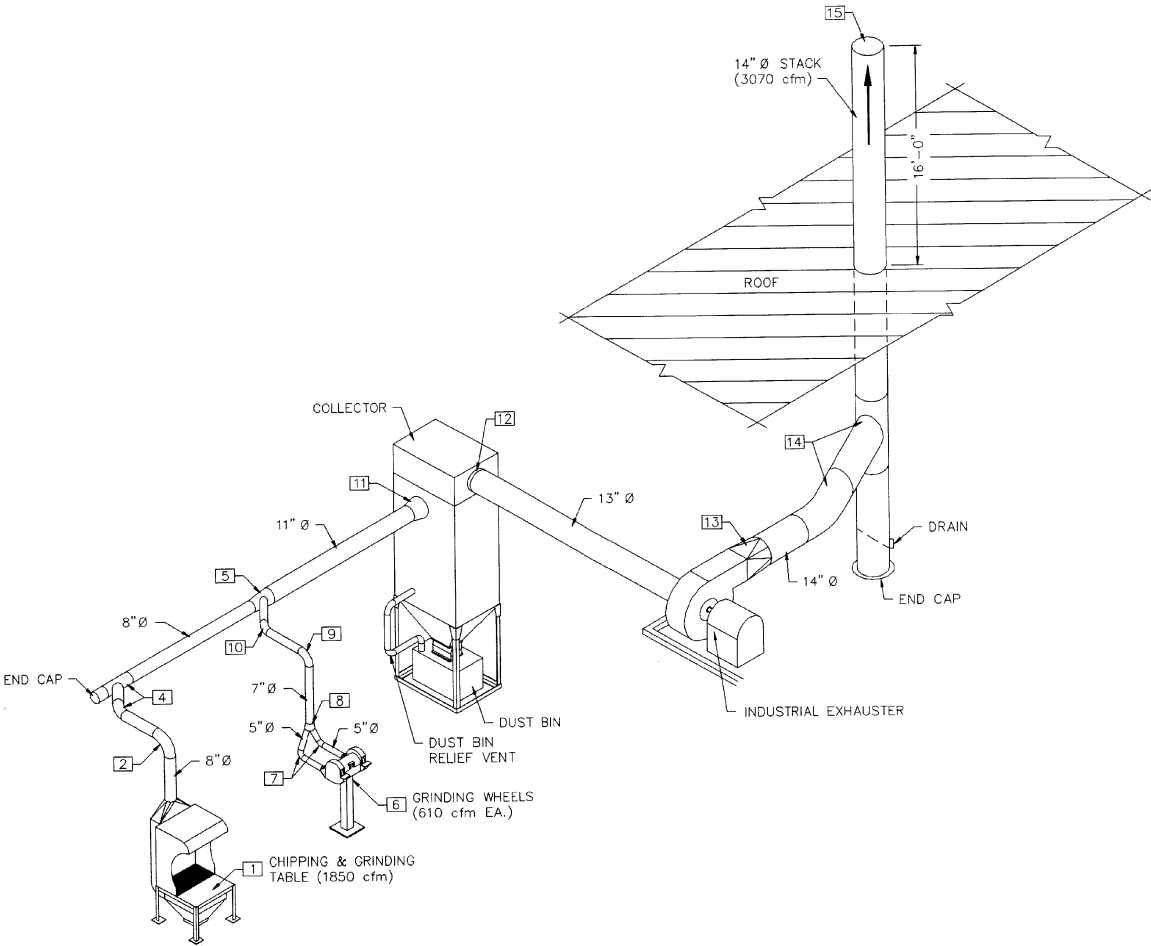


Fig. 18 Metalworking Exhaust System for Example 7

reduce the life of elbows. Elbows are often made of seven or more gores, especially in large diameters. For converging flow fittings, a 30° entry angle is recommended to minimize energy losses and abrasion in dust-handling systems. For the entry loss coefficients of hoods and equipment for specific operations, see Chapter 30 of the 2007 ASHRAE Handbook—HVAC Applications and ACGIH (2007).

Example 7. For the metalworking exhaust system in Figures 18 and 19, size the ductwork and calculate fan static pressure requirement for an industrial exhaust designed to convey granular materials. Pressure-balance the system by changing duct sizes and adjusting airflow rates. Minimum particulate transport velocity for the chipping and grinding table ducts (sections 1 and 5, Figure 19) is 4000 fpm. For ducts associated with the grinder wheels (sections 2, 3, 4, and 5), minimum duct velocity is 4500 fpm. Ductwork is galvanized steel, with absolute roughness of 0.0003 ft. Assume that air is standard and that duct and fittings are available in the following sizes: 3 to 9.5 in. diameters in 0.5 in. increments, 10 to 37 in. diameters in 1 in. increments, and 38 to 90 in. diameters in 2 in. increments.

The building is one story, and the design wind velocity is 20 mph. For the stack, use design J shown in Figure 2 in Chapter 44 of the 2007 ASHRAE Handbook—HVAC Applications for complete rain protection; stack height, determined by calculations from Chapter 44, is 16 ft above the roof. This height is based on minimized stack downwash; therefore, the stack discharge velocity must exceed 1.5 times the design wind velocity.

Solution: The following table summarizes initial duct sizes and transport velocities for contaminated ducts upstream of the collector. The 4474 fpm velocity in sections 2 and 3 is acceptable because the transport velocity is not significantly lower than 4500 fpm. For the next

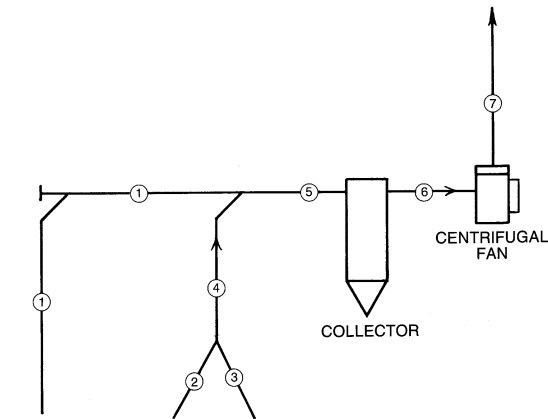


Fig. 19 System Schematic with Section Numbers for Example 7

available duct size (4.5 in. diameter), the duct velocity is 5523 fpm, significantly higher than 4500 fpm.

Duct Section	Design Airflow, cfm	Transport Velocity, fpm	Duct Diameter, in.	Duct Velocity, fpm
1	1800	4000	9	4074
2, 3	610 each	4500	5	4474
4	1220	4500	7	4565
5	3020	4500	11	4576

Design calculations up through the junction after sections 1 and 4 are summarized as follows:

Design No.	D_1 , in.	Δp_1 , in. of water	Δp_{2+4} , in. of water	Imbalance, $\Delta p_1 - \Delta p_{2+4}$
1	9	1.46	3.09	-1.63
2	8.5	2.00	3.08	-1.08
3	8	2.79	3.00	-0.21
4	7.5	3.92	2.88	+1.04

$Q_1 = 1800$ cfm

$Q_2 = 610$ cfm; $D_2 = 5$ in. dia.

$Q_3 = 610$ cfm; $D_3 = 5$ in. dia.

$Q_4 = 1220$ cfm; $D_4 = 7$ in. dia.

For (initial) design 1, the imbalance between section 1 and section 2 (or 3) is 1.63 in. of water, with section 1 requiring additional resistance. Decreasing section 1 duct diameter by 0.5 in. increments results in the least imbalance, 0.21 in. of water, when the duct diameter is 8 in. (design 3). Because section 1 requires additional resistance, estimate the new airflow rate using Equation (44):

$$Q_{c,1} = (1800)(3.00/2.79)^{0.5} = 1870 \text{ cfm}$$

At 1870 cfm flow in section 1, 0.13 in. of water imbalance remains at the junction of sections 1 and 4. By trial-and-error solution, balance is attained when the flow in section 1 is 1850 cfm. The duct between the collector and fan inlet is 13 in. round to match the fan inlet (12.75 in. diameter). To minimize downwash, the stack discharge velocity must exceed 2640 fpm, 1.5 times the design wind velocity (20 mph) as stated in the problem definition. Therefore, the stack is 14 in. round, and the stack discharge velocity is 2872 fpm.

Table 11 summarizes the system losses by sections. The straight duct friction factor and pressure loss were calculated by Equations (18) and (19). Table 12 lists fitting loss coefficients and input parameters necessary to determine the loss coefficients. The fitting loss coefficients are from the 2009 ASHRAE Duct Fitting Database. The fitting loss coefficient tables are included in the section on Fitting Loss Coefficients for illustration but cannot be obtained exactly by manual interpolation because the coefficients were calculated by the duct fitting database algorithms (more significant figures). Figure 20 shows a pressure grade line of the system. Fan total pressure, calculated by Equation (15), is 7.89 in. of water. To calculate the fan static pressure, use Equation (17):

$$P_s = 7.89 - 0.81 = 7.1 \text{ in. of water}$$

where 0.81 in. of water is the fan outlet velocity pressure. The fan airflow rate is 3070 cfm, and its outlet area is 0.853 ft^3 (10.125 by 12.125 in.). Therefore, the fan outlet velocity is 3600 fpm.

Hood suction for the chipping and grinding table hood is 2.2 in. of water, calculated by Equation (5) from Chapter 30 of the 2007 ASHRAE Handbook—HVAC Applications [$P_{s,h} = (1 + 0.25)(1.74) = 2.2$ in. of water, where 0.25 is hood entry loss coefficient C_o , and 1.74 is duct velocity pressure P_v a few diameters downstream from the hood]. Similarly, hood suction for each grinder wheel is 1.7 in. of water:

$$P_{2,3} = (1 + 0.4)(1.24) = 1.7 \text{ in. of water}$$

where 0.4 is the hood entry loss coefficient, and 1.24 in. of water is the duct velocity pressure.

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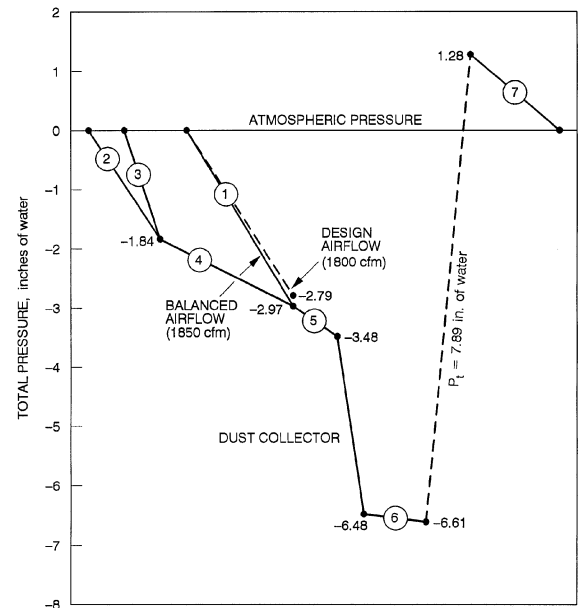


Fig. 20 Total Pressure Grade Line for Example 7

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Table 9 Total Pressure Loss Calculations by Sections for Example 6

Duct Section ^a	Fitting No. ^b	Duct Element	Airflow, cfm	Duct Size (Equivalent Round)	Velocity, fpm	Velocity Pressure, in. of water	Duct Length, ^c ft	Summary of Fitting Loss Coefficients ^d	Duct Pressure Loss/100 ft, ^e in. of water	Total Pressure Loss, in. of water	Section Pressure Loss, in. of water
1	—	Duct	1500	12 in. ϕ	1910	—	15	—	0.40	0.06	
	—	Fittings	1500	—	1910	0.23	—	0.74	—	0.17	0.23
2	—	Duct	500	8 in. ϕ	1432	—	60	—	0.39	0.23	
	—	Fittings	500	—	1432	0.13	—	0.03	—	0.00	0.23
3	—	Duct	2000	12 in. ϕ	2546	—	20	—	0.69	0.14	
	—	Fittings	2000	—	2546	0.40	—	1.00	—	0.40	0.54
4	—	Duct	2000	24 $\times$ 24 in. (26.2)	500	—	5	—	0.01	0.00	
	—	Fittings	2000	—	500	0.02	—	0.90	—	0.02	
	9	Louver	2000	24 $\times$ 24 in.	—	—	—	—	—	0.10 ^f	0.12
5	—	Duct	2000	14 in. ϕ	1871	—	55	—	0.32	0.18	
	—	Fittings	2000	—	1871	0.22	—	2.37	—	0.52	0.70
6	—	Duct	4000	17 in. ϕ	2538	—	30	—	0.45	0.14	
	—	Fittings	4000	—	2538	0.40	—	0.87	—	0.35	0.49
7	—	Duct	600	10 $\times$ 10 in. (10.9)	864	—	14	—	0.12	0.02	
	—	Fittings	600	—	864	0.05	—	0.26	—	0.01	
	43	Diffuser	600	10 $\times$ 10 in.	—	—	—	—	—	0.10 ^f	0.13
8	—	Duct	600	10 $\times$ 10 in. (10.9)	864	—	4	—	0.12	0.00	
	—	Fittings	600	—	864	0.05	—	1.10	—	0.06	
	44	Diffuser	600	10 $\times$ 10 in.	—	—	—	—	—	0.10 ^f	0.16
9	—	Duct	1200	20 $\times$ 10 in. (15.2)	864	—	25	—	0.08	0.02	
	—	Fittings	1200	—	864	0.05	—	1.67	—	0.08	0.10
10	—	Duct	1200	16 $\times$ 10 in. (13.7)	1080	—	45	—	0.13	0.06	
	—	Fittings	1200	—	1080	0.07	—	2.65	—	0.19	0.25
11	—	Duct	1000	10 $\times$ 10 in. (10.9)	1440	—	10	—	0.30	0.03	
	—	Fittings	1000	—	1440	0.13	—	2.53	—	0.33	0.36
12	—	Duct	1000	10 $\times$ 10 in. (10.9)	1440	—	22	—	0.30	0.07	
	—	Fittings	1000	—	1440	0.13	—	2.42	—	0.31	0.38
13	—	Duct	2000	16 $\times$ 10 in. (13.7)	1800	—	35	—	0.35	0.12	
	—	Fittings	2000	—	1800	0.20	—	0.11	—	0.02	0.14
14	—	Duct	3200	26 $\times$ 10 in. (17.1)	1772	—	15	—	0.28	0.04	
	—	Fittings	3200	—	1772	0.20	—	0.12	—	0.02	0.06
15	—	Duct	400	8 $\times$ 6 in. (7.6)	1200	—	40	—	0.34	0.14	
	—	Fittings	400	—	1200	0.09	—	0.56	—	0.05	0.19
16	—	Duct	400	8 $\times$ 6 in. (7.6)	1200	—	20	—	0.34	0.07	
	—	Fittings	400	—	1200	0.09	—	1.74	—	0.16	0.23
17	—	Duct	800	10 $\times$ 6 in. (8.4)	1920	—	22	—	0.72	0.16	
	—	Fittings	800	—	1920	0.23	—	0.40	—	0.09	0.25
18	—	Duct	4000	32 $\times$ 10 in. (18.8)	1800	—	23	—	0.27	0.06	
	—	Fittings	4000	—	1800	0.20	—	2.91	—	0.58	0.64
19	—	Duct	4000	32 $\times$ 17 in. (25.2)	1059	—	12	—	0.06	0.00	
	—	Fittings	4000	—	1059	0.07	—	4.37	—	0.31	
46	—	Air-measuring station	4000	—	—	—	—	—	—	0.05 ^f	

^aSee Figure 16.

^bSee Figure 15.

^cDuct lengths are to fitting centerlines.

^dSee Table 10.

^eDuct pressure based on 0.0003 ft absolute roughness factor.

^fPressure drop based on manufacturers' data.

Table 10 Loss Coefficient Summary by Sections for Example 6

Duct Section	Fitting Number	Type of Fitting	ASHRAE Fitting No.*	Parameters	Loss Coefficient
1	1	Entry	ED1-3		0.03
	2	Damper	CD9-1	$\theta = 0^\circ$	0.60
	3	Wye (30°), main	ED5-1	$A_s/A_c = 1.0, A_b/A_c = 0.444, Q_s/Q_c = 0.75$	0.11 (C_s)
Summation of Section 1 loss coefficients.....					0.74
2	4	Entry	ED1-1	$L = 0, t = 0.064$ in. (16 gage)	0.50
	4	Screen	CD6-1	$n = 0.60, A_1/A_o = 1$	0.97
	5	Elbow	CD3-7	45°, $r/D = 1.5$, pleated	0.21
	6	Damper	CD9-1	$\theta = 0^\circ$	0.60
	3	Wye (30°), branch	ED5-1	$A_s/A_c = 1.0, A_b/A_c = 0.444, Q_b/Q_c = 0.25$	-2.25 (C_b)
Summation of Section 2 loss coefficients.....					0.03
3	7	Damper	CD9-1	$\theta = 0^\circ$	0.60
	8	Wye (45°), main	ED5-2	$A_s/A_c = 0.498, A_b/A_c = 0.678, Q_s/Q_c = 0.5$	0.40 (C_s)
Summation of Section 3 loss coefficients.....					1.00

*2009 ASHRAE Duct Fitting Database data for fittings reprinted in section on Fitting Loss Coefficients.

Table 10 Loss Coefficient Summary by Sections for Example 6 (Concluded)

Duct Section	Fitting Number	Type of Fitting	ASHRAE Fitting No.*	Parameters	Loss Coefficient
4	10	Damper	CR9-4	$\theta = 0^\circ$	0.18
	11	Transition	ER4-3	$L = 30 \text{ in.}, A_o/A_1 = 3.74, \theta = 19^\circ$	0.72
	Summation of Section 4 loss coefficients.....				0.90
5	12	Elbow	CD3-17	45° , mitered	0.71
	13	Damper	CD9-1	$\theta = 0^\circ$	0.60
	8	Wye (45°), branch	ED5-2	$Q_b/Q_c = 0.5, A_s/A_c = 0.498, A_b/A_c = 0.678$	1.06 (C_b)
	Summation of Section 5 loss coefficients.....				2.37
6	14	Fire damper	CD9-3	Curtain type, Type C	0.12
	15	Elbow	CD3-9	90° , 5 gore, $r/D = 1.5$	0.15
	—	Fan and system interaction	ED7-2	90° elbow, 4 gore, $r/D = 1.5, L = 34 \text{ in.}$	0.60
	Summation of Section 6 loss coefficients.....				0.87
7	16	Elbow	CR3-3	$90^\circ, r/W = 0.70$, 1 splitter vane	0.14
	17	Damper	CR9-1	$\theta = 0^\circ, H/W = 1.0$	0.08
	19	Tee, main	SR5-13	$Q_s/Q_c = 0.5, A_s/A_c = 0.50$	0.04 (C_s)
	Summation of Section 7 loss coefficients.....				0.26
8	19	Tee, branch	SR5-13	$Q_b/Q_c = 0.5, A_b/A_c = 0.50$	0.73 (C_b)
	18	Damper	CR9-3	$\theta = 0^\circ$	0.37
	Summation of Section 8 loss coefficients.....				1.10
9	20	Elbow	SR3-1	90° , mitered, $H/W_1 = 0.625, W_o/W_1 = 1.25$	1.67
	Summation of Section 9 loss coefficients.....				1.67
10	21	Damper	CR9-1	$\theta = 0^\circ, H/W = 0.625$	0.08
	22	Elbow	CR3-9	90° , single-thickness vanes, 1.5 in. vane spacing	0.11
	23	Elbow	CR3-6	$\theta = 90^\circ$, mitered, $H/W = 0.625$	1.25
	24	Tee, branch	SR5-1	$r/W_b = 1.0, Q_b/Q_c = 0.375, A_s/A_c = 0.615, A_b/A_c = 0.615$	1.21 (C_b)
	Summation of Section 10 loss coefficients.....				2.65
11	25	Damper	CR9-1	$\theta = 0^\circ, H/W = 1.0$	0.08
	26	Exit	SR2-1	$H/W = 1.0, \text{Re} = 122,700$	1.00
	27	Bullhead tee w/o vanes	SR5-15	$Q_{b1}/Q_c = 0.5, A_{b1}/A_c = 0.625$	1.45 (C_b)
	Summation of Section 11 loss coefficients.....				2.53
12	28	Damper	CR9-1	$\theta = 0^\circ, H/W = 1.0$	0.08
	29	Exit	SR2-5	$\theta = 30^\circ, A_1/A_o = 3.86, \text{Re} = 122,700, L = 18 \text{ in.}$	0.89
	27	Bullhead tee w/o vanes	SR5-15	$Q_{b2}/Q_c = 0.5, A_{b2}/A_c = 0.625$	1.45 (C_b)
	Summation of Section 12 loss coefficients.....				2.42
13	30	Damper	CR9-1	$\theta = 0^\circ, H/W = 0.71$	0.08
	24	Tee, main	SR5-1	$r/W_b = 1.0, Q_s/Q_c = 0.625, A_s/A_c = 0.615, A_b/A_c = 0.615$	0.03 (C_s)
	Summation of Section 13 loss coefficients.....				0.11
14	31	Damper	CR9-1	$\theta = 0^\circ, H/W = 0.38$	0.08
	32	Tee, main	SR5-13	$Q_s/Q_c = 0.8, A_s/A_c = 0.813$	0.04 (C_s)
	Summation of Section 14 loss coefficients.....				0.12
15	48	Elbow	CR3-1	$\theta = 90^\circ, r/W = 1.5, H/W = 0.75$	0.19
	33	Exit	SR2-6	$L = 18 \text{ in.}, D_h = 6.86$	0.28
	34	Damper	CR9-1	$\theta = 0^\circ, H/W = 0.75$	0.08
	35	Tee, main	SR5-1	$r/W_b = 1.0, Q_s/Q_c = 0.5, A_s/A_c = 0.80, A_b/A_c = 0.80$	0.01 (C_s)
	Summation of Section 15 loss coefficients.....				0.56
16	36	Exit	SR2-3	$\theta = 20^\circ, L = 18 \text{ in.}, A_1/A_o = 2.0, \text{Re} = 70,000$	0.63
	36	Screen	CR6-1	$n = 0.8, A_1/A_o = 2.0$	0.08
	37	Damper	CR9-1	$\theta = 0^\circ, H/W = 0.75$	0.08
	35	Tee, branch	SR5-1	$r/W_b = 1.0, Q_b/Q_c = 0.5, A_s/A_c = 0.80, A_b/A_c = 0.80$	0.95 (C_b)
	Summation of Section 16 loss coefficients.....				1.74
17	38	Damper	CR9-1	$\theta = 0^\circ, H/W = 0.6$	0.08
	32	Tee, branch	SR5-13	$Q_b/Q_c = 0.2, A_b/A_c = 0.187$	0.32 (C_b)
	Summation of Section 17 loss coefficients.....				0.40
18	39	Obstruction, pipe	CR6-4	$\text{Re} = 15,000, y = 0, d = 1 \text{ in.}, S_m/A_o = 0.1, y/H = 0$	0.17
	40	Transition	SR4-1	$\theta = 22^\circ, A_o/A_1 = 0.588, L = 18 \text{ in.}$	0.04
	41	Elbows, Z-shaped	CR3-17	$L = 42 \text{ in.}, L/W = 4.2, H/W = 3.2, \text{Re} = 240,000$	2.51
	45	Fire damper	CR9-6	Curtain type, Type B	0.19
	Summation of Section 18 loss coefficients.....				2.91
19	42	Diffuser, fan	SR7-17	$\theta_1 = 28^\circ, L = 40 \text{ in.}, A_o/A_1 = 2.67, C_1 = 0.59$	4.19 (C_o)
	47	Damper	CR9-4	$\theta = 0^\circ$	0.18
	Summation of Section 19 loss coefficients.....				4.37

*2009 ASHRAE Duct Fitting Database data for fittings reprinted in section on Fitting Loss Coefficients

Table 11 Total Pressure Loss Calculations by Sections for Example 7

Duct Section ^a	Duct Element	Airflow, cfm	Duct Size	Velocity, fpm	Velocity Pressure, in. of water	Duct Length, ^b ft	Summary of Fitting Loss Coefficients ^c	Duct Pressure Loss/100 ft, in. of water ^d	Total Pressure Loss, in. of water	Section Pressure Loss, in. of water
1	Duct	1850	8 in. ϕ	5300	—	23.7	—	4.64	1.10	
	Fittings	1850		5300	1.75	—	1.07	—	1.87	2.97
2, 3	Duct	610	5 in. ϕ	4474	—	8.5	—	5.96	0.51	
	Fittings	610		4474	1.25	—	1.06	—	1.33	1.84
4	Duct	1220	7 in. ϕ	4565	—	11.5	—	4.09	0.47	
	Fittings	1220		4565	1.30	—	0.51	—	0.66	1.13
5	Duct	3070	11 in. ϕ	4652	—	8.5	—	2.44	0.21	
	Fittings	3070		4652	1.35	—	0.22	—	0.30	0.51
—	Collector, ^e fabric	3070	—	—	—	—	—	—	3.0	3.0
6	Duct	3070	13 in. ϕ	3331	—	10.5	—	1.05	0.11	
	Fittings	3070		3331	0.69	—	0.03	—	0.02	0.13
7	Duct	3070	14 in. ϕ	2872	—	50	—	0.72	0.36	
	Fittings	3070		2872	0.51	—	1.80	—	0.92	1.28

^aSee Figure 15.^bDuct lengths are to fitting centerlines.^cSee Table 12.^dDuct pressure based on a 0.0003 ft absolute roughness factor.^eCollector manufacturers set fabric bag cleaning mechanism to actuate at a pressure difference of 3.0 in. of water between inlet and outlet plenums. Pressure difference across clean media is approximately 1.5 in. of water.

Table 12 Loss Coefficient Summary by Sections for Example 7

Duct Section	Fitting Number	Type of Fitting	ASHRAE Fitting No. ^a	Parameters	Loss Coefficient
1	1	Hood ^b	—	Hood face area: 3 by 4 ft	0.25
	2	Elbow	CD3-10	90°, 7 gore, $r/D = 2.5$	0.11
	4	Capped wye (45°), with 45° elbow	ED5-6	$A_b/A_c = 1$	0.61 (C_b)
	5	Wye (30°), main	ED5-1	$Q_s/Q_c = 0.60$, $A_s/A_c = 0.529$, $A_b/A_c = 0.405$	0.10 (C_s)
Summation of Section 1 loss coefficients					1.07
2,3	6	Hood ^c	—	Type hood: For double wheels, dia. = 22 in. each, wheel width = 4 in. each; type takeoff: tapered	0.40
	7	Elbow	CD3-12	90°, 3 gore, $r/D = 1.5$	0.34
	8	Symmetrical wye (60°)	ED5-9	$Q_b/Q_c = 0.5$, $A_{b1}/A_c = 0.51$, $A_{b2}/A_c = 0.51$	0.32 (C_b)
Summation of Sections 2 and 3 loss coefficients					1.06
4	9	Elbow	CD3-10	90°, 7 gore, $r/D = 2.5$	0.11
	10	Elbow	CD3-13	60°, 3 gore, $r/D = 1.5$	0.19
	5	Wye (30°), branch	ED5-1	$Q_b/Q_c = 0.40$, $A_s/A_c = 0.529$, $A_b/A_c = 0.405$	0.21 (C_b)
Summation of Section 4 loss coefficients					0.51
5	11	Exit, conical diffuser to collector	ED2-1	$L = 24$ in., $L/D_o = 2.0$, $A_1/A_o \approx 16$	0.22
Summation of Section 5 loss coefficients					0.22
6	12	Entry, bellmouth from collector	ER2-1	$r/D_1 = 0.23$, $r = 3$ in., $C_o = 3.30$	0.03 (C_1)
Summation of Section 6 loss coefficients					0.03
7	13	Diffuser, fan outlet ^d	SD4-2	Fan outlet size: 10.125 by 12.125 in.; $L = 18$ in.	0.19
	14	Capped wye (45°), with 45° elbow	ED5-6	$A_b/A_c = 1$	0.61 (C_b)
	15	Stackhead	SD2-6	$D_e/D = 1$	1.0
Summation of Section 7 loss coefficients					1.80

^aASHRAE Duct Fitting Database (2009) data for fittings reprinted in the section on Fitting Loss Coefficients.^bFrom *Industrial Ventilation* (ACGIH 2007, Figure VS-80-19).^cFrom *Industrial Ventilation* (ACGIH 2007, Figure VS-80-11).^dFan specified: Industrial exhaustor for granular materials: 21 in. wheel diameter, 12.75 in. inlet diameter, 10.125 by 12.125 in. outlet, 7.5 hp motor.

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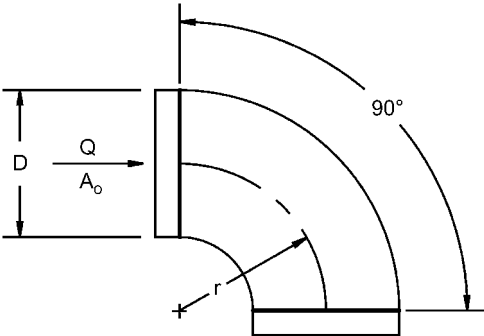
FITTING LOSS COEFFICIENTS

Fittings to support Examples 6 and 7 and some of the more common fittings are reprinted here.
For the complete fitting database see the *ASHRAE Duct Fitting Database* (ASHRAE 2009).

ROUND FITTINGS

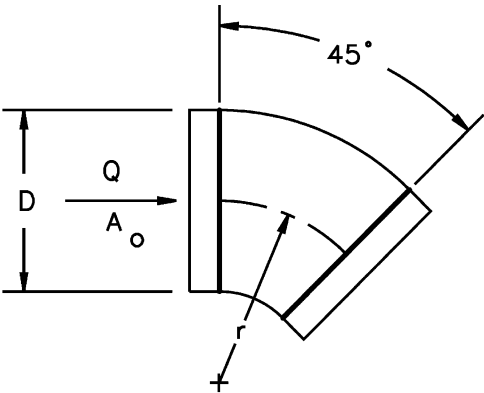
CD3-1 Elbow, Die Stamped, 90 Degree, $r/D = 1.5$

<i>D</i> , in.	3	4	5	6	7	8	9	10
<i>C_o</i>	0.30	0.21	0.16	0.14	0.12	0.11	0.11	0.11



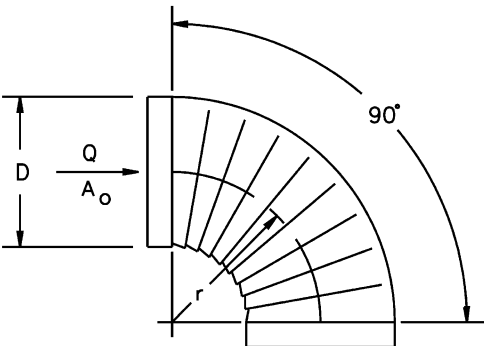
CD3-3 Elbow, Die Stamped, 45 Degree, $r/D = 1.5$

<i>D</i> , in.	3	4	5	6	7	8	9	10
<i>C_o</i>	0.18	0.13	0.10	0.08	0.07	0.07	0.07	0.07



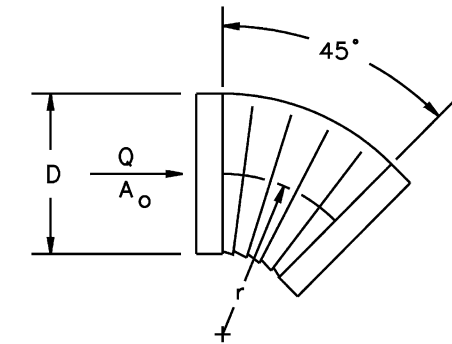
CD3-5 Elbow, Pleated, 90 Degree, $r/D = 1.5$

<i>D</i> , in.	4	6	8	10	12	14	16
<i>C_o</i>	0.57	0.43	0.34	0.28	0.26	0.25	0.25



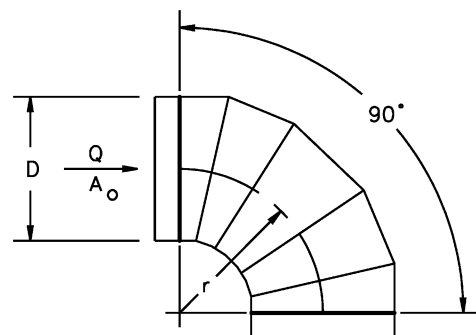
CD3-7 Elbow, Pleated, 45 Degree, $r/D = 1.5$

<i>D</i> , in.	4	6	8	10	12	14	16
<i>C_o</i>	0.34	0.26	0.21	0.17	0.16	0.15	0.15

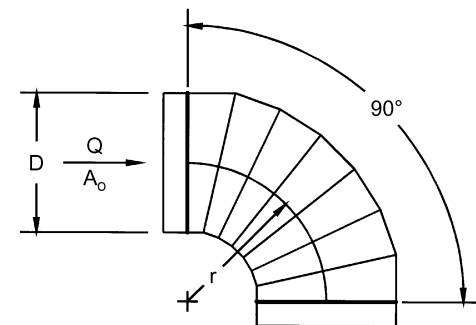


CD3-9 Elbow, 5 Gore, 90 Degree, $r/D = 1.5$

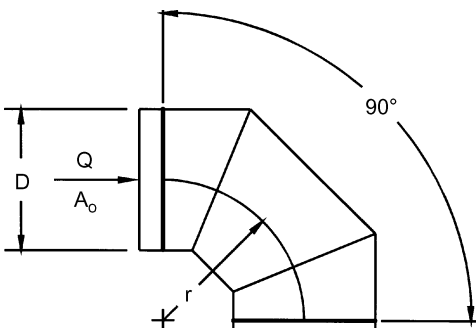
D , in.	3	6	9	12	15	18	21	24	27	30	60
C_o	0.51	0.28	0.21	0.18	0.16	0.15	0.14	0.13	0.12	0.12	0.12


CD3-10 Elbow, 7 Gore, 90 Degree, $r/D = 2.5$

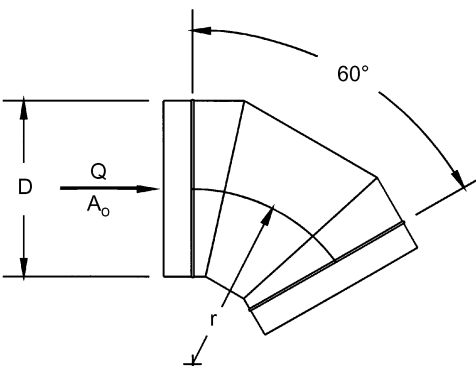
D , in.	3	6	9	12	15	18	27	60
C_o	0.16	0.12	0.10	0.08	0.07	0.06	0.05	0.03


CD3-12 Elbow, 3 Gore, 90 Degree, $r/D = 0.75$ to 2.0

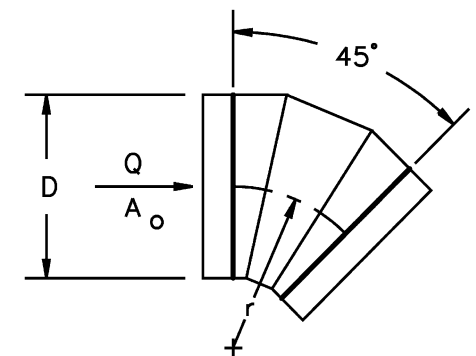
r/D	0.75	1.00	1.50	2.00
C_o	0.54	0.42	0.34	0.33


CD3-13 Elbow, 3 Gore, 60 Degree, $r/D = 1.5$

D , in.	3	6	9	12	15	18	21	24	27	30	60
C_o	0.40	0.21	0.16	0.14	0.12	0.12	0.11	0.10	0.09	0.09	0.09

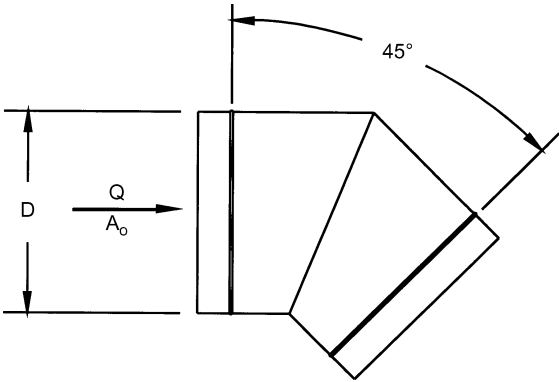

CD3-14 Elbow, 3 Gore, 45 Degree, $r/D = 1.5$

D , in.	3	6	9	12	15	18	21	24	27	30	60
C_o	0.31	0.17	0.13	0.11	0.11	0.09	0.08	0.08	0.07	0.07	0.07



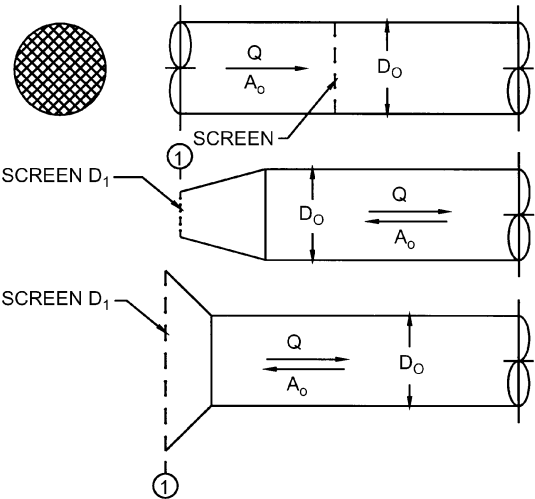
CD3-17 Elbow, Mitered, 45 Degree

D, in.	3	6	9	12	15	18	21	24	27	60
C _o	0.87	0.79	0.74	0.72	0.71	0.70	0.69	0.68	0.68	0.67



CD6-1 Screen (Only)

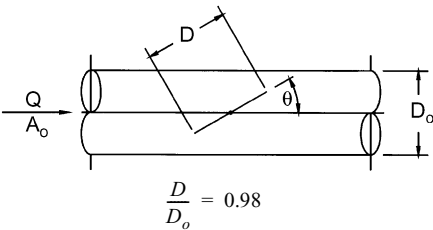
C _o Values													
n													
A ₁ /A _o	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.90	1.00
0.2	155.00	102.50	75.00	55.00	41.25	31.50	24.25	18.75	14.50	11.00	8.00	3.50	0.0
0.3	68.89	45.56	33.33	24.44	18.33	14.00	10.78	8.33	6.44	4.89	3.56	1.56	0.0
0.4	38.75	25.63	18.75	13.75	10.31	7.88	6.06	4.69	3.63	2.75	2.00	0.88	0.0
0.5	24.80	16.40	12.00	8.80	6.60	5.04	3.88	3.00	2.32	1.76	1.28	0.56	0.0
0.6	17.22	11.39	8.33	6.11	4.58	3.50	2.69	2.08	1.61	1.22	0.89	0.39	0.0
0.7	12.65	8.37	6.12	4.49	3.37	2.57	1.98	1.53	1.18	0.90	0.65	0.29	0.0
0.8	9.69	6.40	4.69	3.44	2.58	1.97	1.52	1.17	0.91	0.69	0.50	0.22	0.0
0.9	7.65	5.06	3.70	2.72	2.04	1.56	1.20	0.93	0.72	0.54	0.40	0.17	0.0
1.0	6.20	4.10	3.00	2.20	1.65	1.26	0.97	0.75	0.58	0.44	0.32	0.14	0.0
1.2	4.31	2.85	2.08	1.53	1.15	0.88	0.67	0.52	0.40	0.31	0.22	0.10	0.0
1.4	3.16	2.09	1.53	1.12	0.84	0.64	0.49	0.38	0.30	0.22	0.16	0.07	0.0
1.6	2.42	1.60	1.17	0.86	0.64	0.49	0.38	0.29	0.23	0.17	0.13	0.05	0.0
1.8	1.91	1.27	0.93	0.68	0.51	0.39	0.30	0.23	0.18	0.14	0.10	0.04	0.0
2.0	1.55	1.03	0.75	0.55	0.41	0.32	0.24	0.19	0.15	0.11	0.08	0.04	0.0
2.5	0.99	0.66	0.48	0.35	0.26	0.20	0.16	0.12	0.09	0.07	0.05	0.02	0.0
3.0	0.69	0.46	0.33	0.24	0.18	0.14	0.11	0.08	0.06	0.05	0.04	0.02	0.0
4.0	0.39	0.26	0.19	0.14	0.10	0.08	0.06	0.05	0.04	0.03	0.02	0.01	0.0
6.0	0.17	0.11	0.08	0.06	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.0



n = free area ratio of screen
A_o = area of duct
A₁ = cross-sectional area of duct or fitting where screen is located

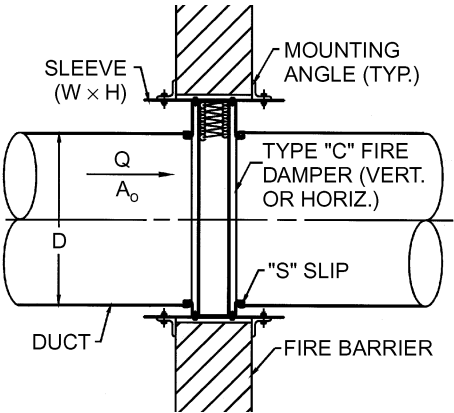
CD9-1 Damper, Butterfly

θ	0	10	20	30	40	50	60	70	75	90
C _o	0.60	0.85	1.70	4.0	9.4	24	67	215	400	9999



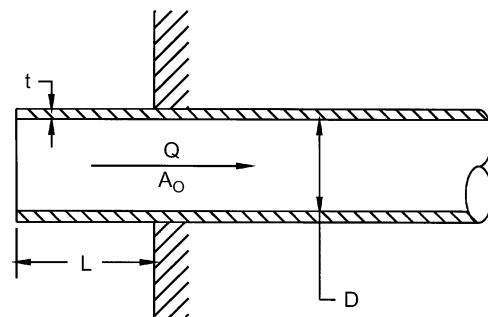
CD9-3 Fire Damper, Curtain Type, Type C, Horizontal Duct

C_o = 0.12



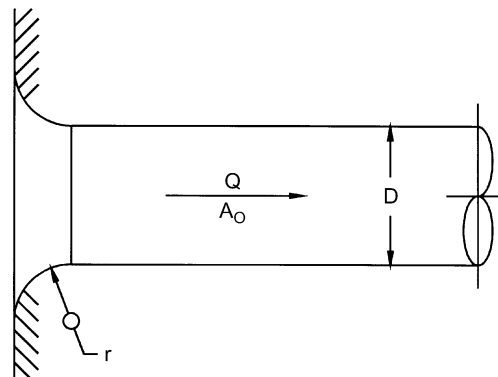
ED1-1 Duct Mounted in Wall

t/D	C_o Values								
	L/D								
	0.0	0.002	0.01	0.05	0.10	0.20	0.30	0.50	10.0
0.00	0.50	0.57	0.68	0.80	0.86	0.92	0.97	1.00	1.00
0.02	0.50	0.51	0.52	0.55	0.60	0.66	0.69	0.72	0.72
0.05	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
10.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50



ED1-3 Bellmouth, with Wall

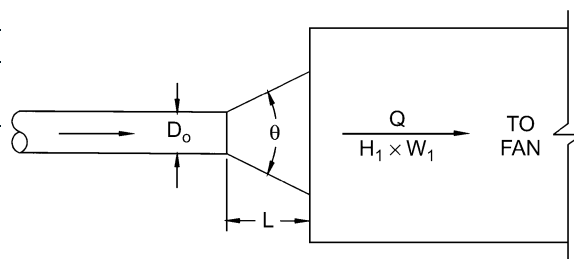
r/D	0.0	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.16	0.20	10.0
C_o	0.50	0.44	0.37	0.31	0.26	0.22	0.20	0.15	0.12	0.09	0.06	0.03	0.03



ED2-1 Conical Diffuser, Round to Plenum, Exhaust/Return Systems

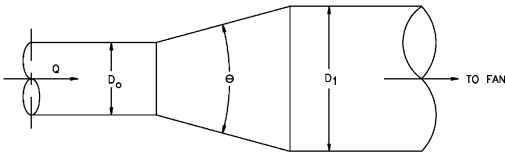
A_1/A_o	C_o Values										
	L/D_o										
	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.5	0.03	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.10	0.11	0.13
2.0	0.08	0.06	0.04	0.04	0.04	0.05	0.05	0.06	0.08	0.09	0.10
2.5	0.13	0.09	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.09
3.0	0.17	0.12	0.09	0.07	0.07	0.06	0.06	0.07	0.07	0.08	0.08
4.0	0.23	0.17	0.12	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.08
6.0	0.30	0.22	0.16	0.13	0.12	0.10	0.10	0.09	0.09	0.09	0.08
8.0	0.34	0.26	0.18	0.15	0.13	0.12	0.11	0.10	0.09	0.09	0.09
10.0	0.36	0.28	0.20	0.16	0.14	0.13	0.12	0.11	0.10	0.09	0.09
14.0	0.39	0.30	0.22	0.18	0.16	0.14	0.13	0.12	0.10	0.10	0.10
20.0	0.41	0.32	0.24	0.20	0.17	0.15	0.14	0.12	0.11	0.11	0.10
1000.0	0.41	0.32	0.24	0.20	0.17	0.15	0.14	0.12	0.11	0.11	0.10

Optimum Angle θ , degrees											
A_1/A_o	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0
1.0	0	0	0	0	0	0	0	0	0	0	0
1.5	17	10	6.5	4.5	3.5	2.8	2.2	1.7	1.2	1.0	0.8
2.0	21	14	8.5	6.2	5.0	4.3	3.8	3.0	2.3	2.0	1.6
2.5	25	16	10	7.4	6.0	5.4	4.8	4.0	3.5	3.0	2.5
3.0	27	17	11	8.5	7.0	6.1	5.6	4.8	4.2	3.8	3.2
4.0	29	20	13	9.8	8.0	7.2	6.6	5.8	5.2	4.8	4.4
6.0	31	21	14	11	9.4	8.2	7.4	6.2	5.6	5.2	4.7
8.0	32	22	15	12	10	8.8	8.0	6.6	5.8	5.4	5.0
33	33	23	15	12	11	9.4	8.4	7.0	6.2	5.5	5.2
14.0	33	24	16	13	11	9.6	8.7	7.3	6.3	5.6	5.4
20.0	34	24	16	13	11	9.8	9.0	7.5	6.5	6.0	5.6
1000.0	34	24	16	13	11	9.8	9.0	7.5	6.5	6.0	5.6



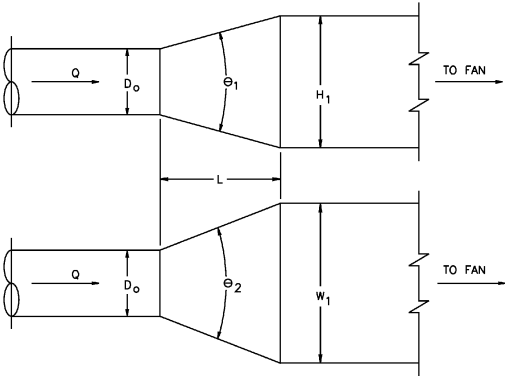
ED4-1 Transition, Round to Round, Exhaust/Return Systems

A_o/A_1	C_θ Values												
	θ												
	0	3	5	10	15	20	30	45	60	90	120	150	180
0.063	0.0	0.18	0.18	0.20	0.29	0.38	0.60	0.84	0.88	0.88	0.88	0.88	0.88
0.10	0.0	0.20	0.18	0.20	0.27	0.38	0.59	0.76	0.80	0.83	0.84	0.83	0.83
0.167	0.0	0.18	0.17	0.18	0.25	0.33	0.48	0.66	0.77	0.74	0.73	0.73	0.72
0.25	0.0	0.20	0.17	0.16	0.21	0.30	0.46	0.61	0.68	0.64	0.63	0.62	0.62
0.50	0.0	0.15	0.13	0.11	0.13	0.19	0.32	0.33	0.33	0.32	0.31	0.30	0.30
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.0	0.30	0.26	0.21	0.19	0.19	0.19	0.23	0.27	0.51	0.73	0.90	0.95
4.00	0.0	1.60	1.14	0.75	0.70	0.70	0.70	0.90	1.09	2.78	4.29	5.63	6.53
6.00	0.0	3.89	3.02	1.73	1.58	1.58	1.58	2.12	2.66	6.62	10.01	13.03	15.12
10.00	0.0	11.80	9.30	5.30	5.00	5.00	5.00	6.45	7.90	19.00	28.50	36.70	42.70

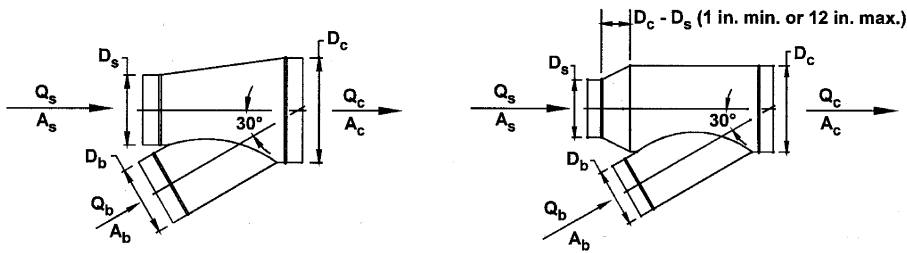


ED4-2 Transition, Round to Rectangular, Exhaust/Return Systems

A_o/A_1	C_θ Values												
	θ												
	0	3	5	10	15	20	30	45	60	90	120	150	180
0.063	0.0	0.17	0.19	0.30	0.46	0.53	0.64	0.77	0.88	0.95	0.95	0.94	0.93
0.10	0.0	0.17	0.19	0.30	0.45	0.53	0.64	0.75	0.84	0.89	0.89	0.89	0.88
0.167	0.0	0.18	0.19	0.30	0.44	0.53	0.63	0.72	0.78	0.79	0.79	0.79	0.79
0.25	0.0	0.16	0.18	0.25	0.36	0.45	0.52	0.58	0.62	0.64	0.64	0.64	0.64
0.50	0.0	0.14	0.14	0.15	0.22	0.25	0.30	0.33	0.33	0.33	0.32	0.31	0.30
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.0	0.30	0.27	0.26	0.28	0.25	0.19	0.23	0.27	0.52	0.75	0.91	0.95
4.00	0.0	1.60	1.14	0.84	0.85	0.86	0.76	0.90	1.09	2.78	4.30	5.65	6.55
6.00	0.0	3.89	3.04	1.84	1.77	1.78	1.73	2.18	2.67	6.67	10.07	13.09	15.18
10.00	0.0	11.80	9.31	5.40	5.18	5.15	5.05	6.44	7.94	19.06	28.55	36.75	42.75



ED5-1 Wye, 30 Degree, Converging



		C_b Values								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-13.25	-1.80	0.01	0.55	0.75	0.84	0.88	0.91	0.97
	0.2	-56.10	-10.12	-2.80	-0.63	0.19	0.53	0.69	0.75	0.78
	0.3	-127.28	-23.81	-7.31	-2.44	-0.59	0.19	0.52	0.66	0.70
	0.4	-226.84	-42.88	-13.55	-4.89	-1.61	-0.22	0.38	0.62	0.68
	0.5	-354.79	-67.34	-21.52	-7.98	-2.86	-0.69	0.24	0.61	0.70
	0.6	-511.13	-97.21	-31.22	-11.73	-4.35	-1.23	0.11	0.64	0.77
	0.7	-695.87	-132.47	-42.66	-16.13	-6.08	-1.84	0.00	0.71	0.89
	0.8	-909.01	-173.14	-55.83	-21.17	-8.05	-2.51	-0.12	0.82	1.05
	0.9	-1151.	-219.20	-70.73	-26.87	-10.27	-3.25	-0.22	0.97	1.26
	1.0	-1420.	-270.66	-87.36	-33.21	-12.72	-4.05	-0.31	1.15	1.51

ED5-1 Wye, 30 Degree, Converging (Continued)

		C_b Values (Continued)								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.2	0.1	-5.30	-0.24	0.54	0.77	0.85	0.88	0.90	0.93	0.98
	0.2	-24.17	-3.78	-0.60	0.30	0.64	0.77	0.83	0.88	0.98
	0.3	-55.88	-9.77	-2.57	-0.50	0.25	0.55	0.67	0.70	0.71
	0.4	-99.93	-17.94	-5.13	-1.45	-0.11	0.42	0.62	0.68	0.68
	0.5	-156.51	-28.40	-8.37	-2.62	-0.52	0.30	0.62	0.71	0.69
	0.6	-225.62	-41.13	-12.30	-4.01	-0.99	0.20	0.66	0.78	0.75
	0.7	-307.26	-56.14	-16.90	-5.61	-1.51	0.11	0.73	0.90	0.86
	0.8	-401.44	-73.44	-22.18	-7.44	-2.08	0.04	0.84	1.06	1.01
	0.9	-508.15	-93.02	-28.15	-9.49	-2.71	-0.03	0.99	1.27	1.20
	1.0	-627.39	-114.89	-34.80	-11.77	-3.39	-0.08	1.18	1.52	1.43
0.3	0.1	-2.77	0.26	0.71	0.83	0.88	0.90	0.91	0.93	0.99
	0.2	-13.97	-1.77	0.08	0.59	0.77	0.84	0.88	0.92	1.06
	0.3	-33.06	-5.33	-1.09	0.10	0.51	0.66	0.71	0.72	0.74
	0.4	-59.43	-10.08	-2.52	-0.41	0.32	0.59	0.67	0.68	0.66
	0.5	-93.24	-16.11	-4.30	-1.00	0.14	0.56	0.69	0.70	0.66
	0.6	-134.51	-23.45	-6.44	-1.68	-0.03	0.57	0.76	0.77	0.70
	0.7	-183.25	-32.08	-8.93	-2.45	-0.21	0.61	0.87	0.88	0.79
	0.8	-239.47	-42.01	-11.77	-3.32	-0.38	0.69	1.02	1.03	0.91
	0.9	-303.16	-53.25	-14.97	-4.27	-0.56	0.80	1.21	1.23	1.07
	1.0	-374.32	-65.79	-18.53	-5.32	-0.73	0.94	1.45	1.47	1.27
0.4	0.1	-1.58	0.48	0.78	0.86	0.89	0.90	0.91	0.93	0.99
	0.2	-9.20	-0.85	0.39	0.71	0.82	0.87	0.90	0.94	1.09
	0.3	-22.31	-3.24	-0.38	0.39	0.64	0.73	0.76	0.78	0.85
	0.4	-40.52	-6.48	-1.37	0.02	0.48	0.64	0.67	0.66	0.65
	0.5	-63.71	-10.50	-2.50	-0.33	0.40	0.63	0.69	0.67	0.63
	0.6	-92.00	-15.37	-3.84	-0.71	0.33	0.67	0.75	0.71	0.65
	0.7	-125.40	-21.08	-5.40	-1.13	0.28	0.75	0.85	0.80	0.70
	0.8	-163.90	-27.65	-7.16	-1.59	0.25	0.86	1.00	0.93	0.80
	0.9	-207.52	-35.07	-9.14	-2.09	0.25	1.02	1.18	1.10	0.93
	1.0	-256.25	-43.35	-11.33	-2.63	0.26	1.21	1.42	1.31	1.09
0.5	0.1	-0.94	0.60	0.82	0.87	0.89	0.90	0.91	0.93	0.99
	0.2	-6.62	-0.36	0.54	0.77	0.85	0.88	0.90	0.95	1.11
	0.3	-16.42	-2.11	-0.01	0.54	0.72	0.78	0.80	0.83	0.96
	0.4	-30.26	-4.59	-0.79	0.22	0.54	0.64	0.66	0.64	0.64
	0.5	-47.68	-7.55	-1.61	-0.02	0.48	0.63	0.65	0.62	0.59
	0.6	-68.93	-11.13	-2.56	-0.28	0.45	0.67	0.69	0.65	0.58
	0.7	-94.00	-15.31	-3.65	-0.55	0.44	0.74	0.77	0.71	0.61
	0.8	-122.90	-20.12	-4.88	-0.83	0.46	0.85	0.90	0.81	0.68
	0.9	-155.63	-25.54	-6.25	-1.12	0.51	1.00	1.06	0.94	0.77
	1.0	-192.18	-31.58	-7.77	-1.43	0.59	1.19	1.26	1.12	0.90
0.6	0.1	-0.57	0.66	0.84	0.88	0.89	0.90	0.91	0.93	0.99
	0.2	-5.12	-0.10	0.62	0.79	0.85	0.87	0.90	0.95	1.11
	0.3	-13.00	-1.49	0.18	0.61	0.75	0.79	0.82	0.86	1.02
	0.4	-24.31	-3.55	-0.50	0.30	0.55	0.62	0.63	0.62	0.63
	0.5	-38.41	-5.94	-1.16	0.09	0.48	0.59	0.60	0.57	0.55
	0.6	-55.58	-8.80	-1.92	-0.12	0.45	0.61	0.62	0.57	0.52
	0.7	-75.83	-12.16	-2.79	-0.33	0.44	0.66	0.67	0.60	0.52
	0.8	-99.17	-16.00	-3.76	-0.54	0.46	0.74	0.76	0.67	0.56
	0.9	-125.60	-20.33	-4.83	-0.76	0.51	0.86	0.88	0.77	0.62
	1.0	-155.12	-25.14	-6.02	-0.99	0.58	1.02	1.04	0.90	0.71
0.7	0.1	-0.35	0.70	0.84	0.88	0.89	0.90	0.90	0.92	0.99
	0.2	-4.24	0.05	0.65	0.80	0.85	0.87	0.89	0.94	1.12
	0.3	-11.00	-1.15	0.27	0.63	0.75	0.79	0.82	0.87	1.06
	0.4	-20.82	-3.00	-0.38	0.31	0.52	0.59	0.60	0.59	0.61
	0.5	-32.99	-5.09	-0.98	0.10	0.43	0.53	0.54	0.52	0.51
	0.6	-47.78	-7.58	-1.67	-0.11	0.38	0.52	0.53	0.49	0.45
	0.7	-65.22	-10.50	-2.44	-0.32	0.34	0.53	0.54	0.49	0.43
	0.8	-85.32	-13.83	-3.30	-0.53	0.33	0.58	0.59	0.52	0.43
	0.9	-108.07	-17.58	-4.26	-0.75	0.34	0.66	0.67	0.58	0.46
	1.0	-133.48	-21.76	-5.30	-0.97	0.38	0.76	0.78	0.67	0.51
0.8	0.1	-0.23	0.71	0.84	0.88	0.89	0.89	0.90	0.92	0.98
	0.2	-3.75	0.11	0.65	0.79	0.84	0.86	0.88	0.94	1.12
	0.3	-9.88	-0.99	0.29	0.63	0.74	0.78	0.81	0.87	1.09
	0.4	-18.88	-2.75	-0.36	0.28	0.48	0.55	0.56	0.57	0.61
	0.5	-29.98	-4.71	-0.96	0.04	0.36	0.46	0.47	0.46	0.47
	0.6	-43.46	-7.05	-1.64	-0.20	0.26	0.41	0.43	0.41	0.39
	0.7	-59.34	-9.77	-2.40	-0.44	0.19	0.38	0.41	0.38	0.34
	0.8	-77.64	-12.88	-3.26	-0.69	0.13	0.38	0.42	0.37	0.31
	0.9	-98.35	-16.38	-4.20	-0.95	0.09	0.40	0.45	0.39	0.30
	1.0	-121.48	-20.27	-5.24	-1.23	0.06	0.45	0.51	0.43	0.31

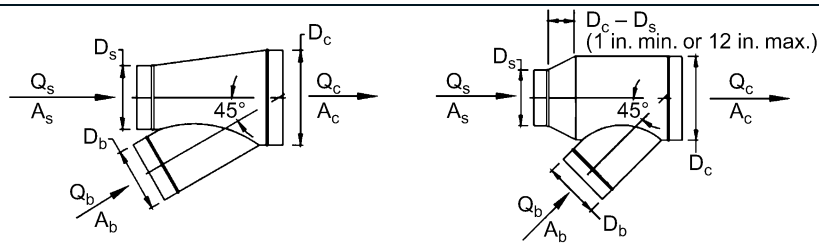
ED5-1 Wye, 30 Degree, Converging (*Continued*)

		<i>C_b Values (Concluded)</i>								
		<i>Q_b/Q_c</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.9	0.1	-0.18	0.72	0.84	0.87	0.88	0.89	0.90	0.92	0.98
	0.2	-3.52	0.12	0.64	0.78	0.82	0.85	0.88	0.93	1.12
	0.3	-9.34	-0.95	0.28	0.60	0.71	0.76	0.80	0.87	1.10
	0.4	-17.96	-2.70	-0.40	0.22	0.43	0.50	0.53	0.54	0.60
	0.5	-28.58	-4.65	-1.05	-0.07	0.26	0.37	0.40	0.41	0.42
	0.6	-41.45	-6.97	-1.77	-0.35	0.12	0.28	0.32	0.32	0.32
	0.7	-56.61	-9.66	-2.58	-0.65	0.00	0.21	0.27	0.26	0.24
	0.8	-74.08	-12.74	-3.49	-0.97	-0.12	0.16	0.23	0.22	0.18
	0.9	-93.84	-16.21	-4.50	-1.30	-0.23	0.13	0.21	0.19	0.14
	1.0	-115.92	-20.06	-5.61	-1.66	-0.34	0.11	0.21	0.18	0.11
1.0	0.1	-0.17	0.71	0.83	0.87	0.88	0.89	0.90	0.92	0.98
	0.2	-3.48	0.10	0.62	0.76	0.81	0.84	0.87	0.92	1.11
	0.3	-9.22	-1.00	0.23	0.56	0.68	0.74	0.78	0.86	1.11
	0.4	-17.76	-2.79	-0.50	0.14	0.37	0.45	0.49	0.52	0.60
	0.5	-28.31	-4.82	-1.21	-0.20	0.15	0.28	0.33	0.35	0.38
	0.6	-41.06	-7.21	-2.01	-0.55	-0.04	0.15	0.22	0.23	0.25
	0.7	-56.09	-9.99	-2.91	-0.92	-0.23	0.03	0.12	0.14	0.15
	0.8	-73.39	-13.17	-3.92	-1.32	-0.41	-0.07	0.04	0.06	0.06
	0.9	-92.98	-16.75	-5.04	-1.75	-0.60	-0.17	-0.03	-0.01	-0.02
	1.0	-114.85	-20.74	-6.28	-2.21	-0.79	-0.26	-0.09	-0.07	-0.09
		<i>C_s Values</i>								
		<i>Q_s/Q_c</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-3.90	-1.07	-0.04	0.66	1.27	1.87	2.47	3.10	3.76
	0.2	-3.76	-0.34	0.52	1.05	1.53	2.02	2.56	3.14	3.77
	0.3	-2.50	0.10	0.76	1.20	1.62	2.08	2.59	3.15	3.77
	0.4	-1.64	0.35	0.88	1.27	1.67	2.11	2.60	3.15	3.77
	0.5	-1.05	0.52	0.96	1.32	1.69	2.12	2.61	3.16	3.77
	0.6	-0.63	0.63	1.02	1.35	1.71	2.13	2.61	3.16	3.77
	0.7	-0.32	0.71	1.06	1.37	1.73	2.14	2.62	3.16	3.77
	0.8	-0.07	0.78	1.09	1.39	1.74	2.15	2.62	3.16	3.77
	0.9	0.13	0.83	1.11	1.40	1.74	2.15	2.62	3.16	3.77
	1.0	0.29	0.87	1.13	1.41	1.75	2.15	2.63	3.17	3.77
0.2	0.1	-14.54	-4.50	-1.82	-0.62	0.05	0.47	0.75	0.95	1.09
	0.2	-16.02	-3.15	-0.80	0.04	0.45	0.69	0.86	0.99	1.10
	0.3	-11.65	-1.94	-0.26	0.32	0.60	0.77	0.90	1.01	1.10
	0.4	-8.56	-1.20	0.05	0.47	0.68	0.82	0.92	1.02	1.11
	0.5	-6.41	-0.71	0.25	0.57	0.73	0.84	0.93	1.02	1.11
	0.6	-4.85	-0.36	0.38	0.63	0.76	0.86	0.94	1.02	1.11
	0.7	-3.68	-0.10	0.48	0.68	0.79	0.87	0.95	1.03	1.11
	0.8	-2.77	0.10	0.56	0.71	0.81	0.88	0.95	1.03	1.11
	0.9	-2.04	0.26	0.62	0.74	0.82	0.89	0.95	1.03	1.11
	1.0	-1.45	0.38	0.66	0.76	0.83	0.89	0.96	1.03	1.11
0.3	0.1	-32.30	-10.04	-4.34	-1.94	-0.73	-0.07	0.30	0.50	0.59
	0.2	-36.37	-7.59	-2.48	-0.79	-0.06	0.29	0.47	0.57	0.61
	0.3	-26.79	-5.07	-1.42	-0.27	0.21	0.42	0.53	0.59	0.61
	0.4	-19.94	-3.49	-0.80	0.02	0.35	0.49	0.56	0.60	0.62
	0.5	-15.18	-2.44	-0.41	0.20	0.43	0.54	0.58	0.61	0.62
	0.6	-11.73	-1.70	-0.13	0.32	0.49	0.56	0.60	0.61	0.62
	0.7	-9.13	-1.14	0.07	0.41	0.53	0.58	0.60	0.61	0.62
	0.8	-7.11	-0.72	0.23	0.48	0.57	0.60	0.61	0.62	0.62
	0.9	-5.49	-0.38	0.35	0.53	0.59	0.61	0.62	0.62	0.62
	1.0	-4.17	-0.11	0.45	0.58	0.61	0.62	0.62	0.62	0.62
0.4	0.1	-57.18	-17.78	-7.80	-3.69	-1.66	-0.59	-0.02	0.26	0.37
	0.2	-64.82	-13.76	-4.74	-1.81	-0.59	-0.02	0.24	0.36	0.39
	0.3	-47.92	-9.38	-2.93	-0.94	-0.16	0.19	0.34	0.39	0.40
	0.4	-35.81	-6.62	-1.88	-0.46	0.07	0.30	0.38	0.41	0.40
	0.5	-27.39	-4.78	-1.20	-0.16	0.22	0.36	0.41	0.42	0.41
	0.6	-21.28	-3.48	-0.73	0.04	0.31	0.41	0.43	0.43	0.41
	0.7	-16.68	-2.51	-0.38	0.20	0.38	0.44	0.45	0.43	0.41
	0.8	-13.10	-1.77	-0.12	0.31	0.44	0.46	0.46	0.44	0.41
	0.9	-10.24	-1.18	0.09	0.40	0.48	0.48	0.46	0.44	0.41
	1.0	-7.90	-0.69	0.26	0.47	0.51	0.50	0.47	0.44	0.41

ED5-1 Wye, 30 Degree, Converging (*Continued*)

		<i>C_s Values (Concluded)</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	<i>Q_b/Q_c</i>								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.5	0.1	-89.21	-27.74	-12.24	-5.89	-2.79	-1.18	-0.33	0.08	0.23
	0.2	-101.39	-21.64	-7.61	-3.07	-1.19	-0.34	0.05	0.22	0.26
	0.3	-75.05	-14.87	-4.83	-1.75	-0.54	-0.03	0.19	0.26	0.27
	0.4	-56.18	-10.59	-3.21	-1.02	-0.20	0.13	0.26	0.29	0.27
	0.5	-43.04	-7.74	-2.16	-0.56	0.02	0.23	0.30	0.30	0.27
	0.6	-33.51	-5.72	-1.43	-0.24	0.16	0.30	0.33	0.31	0.28
	0.7	-26.34	-4.22	-0.90	-0.01	0.27	0.35	0.35	0.32	0.28
	0.8	-20.75	-3.06	-0.49	0.16	0.35	0.39	0.37	0.33	0.28
	0.9	-16.29	-2.14	-0.17	0.30	0.41	0.41	0.38	0.33	0.28
	1.0	-12.64	-1.39	0.10	0.41	0.46	0.44	0.39	0.33	0.28
0.6	0.1	-128.36	-39.93	-17.66	-8.57	-4.15	-1.85	-0.66	-0.09	0.12
	0.2	-146.06	-31.26	-11.09	-4.56	-1.89	-0.68	-0.12	0.10	0.16
	0.3	-108.19	-21.55	-7.12	-2.69	-0.97	-0.24	0.07	0.17	0.17
	0.4	-81.04	-15.40	-4.80	-1.65	-0.48	-0.01	0.17	0.20	0.18
	0.5	-62.13	-11.31	-3.30	-0.99	-0.17	0.13	0.22	0.22	0.18
	0.6	-48.43	-8.41	-2.25	-0.54	0.03	0.22	0.26	0.24	0.18
	0.7	-38.10	-6.25	-1.49	-0.22	0.18	0.29	0.29	0.25	0.19
	0.8	-30.07	-4.59	-0.90	0.03	0.30	0.34	0.31	0.25	0.19
	0.9	-23.64	-3.27	-0.44	0.23	0.39	0.38	0.33	0.26	0.19
	1.0	-18.39	-2.20	-0.06	0.39	0.46	0.42	0.34	0.27	0.19
0.7	0.1	-174.66	-54.33	-24.05	-11.71	-5.72	-2.62	-1.01	-0.25	0.03
	0.2	-198.85	-42.62	-15.17	-6.31	-2.68	-1.04	-0.29	0.01	0.08
	0.3	-147.33	-29.41	-9.78	-3.77	-1.44	-0.45	-0.04	0.10	0.10
	0.4	-110.40	-21.07	-6.64	-2.36	-0.77	-0.14	0.09	0.15	0.11
	0.5	-84.67	-15.50	-4.60	-1.48	-0.36	0.05	0.17	0.17	0.11
	0.6	-66.02	-11.56	-3.19	-0.86	-0.08	0.18	0.23	0.19	0.12
	0.7	-51.97	-8.63	-2.15	-0.42	0.12	0.27	0.27	0.20	0.12
	0.8	-41.04	-6.37	-1.35	-0.08	0.27	0.34	0.29	0.21	0.12
	0.9	-32.30	-4.58	-0.72	0.19	0.39	0.39	0.32	0.22	0.12
	1.0	-25.16	-3.12	-0.21	0.40	0.49	0.43	0.33	0.23	0.13
0.8	0.1	-228.09	-70.95	-31.43	-15.33	-7.52	-3.48	-1.39	-0.40	-0.04
	0.2	-259.75	-55.70	-19.86	-8.29	-3.56	-1.43	-0.46	-0.06	-0.03
	0.3	-192.48	-38.47	-12.84	-4.99	-1.95	-0.66	-0.12	0.05	0.05
	0.4	-144.25	-27.58	-8.74	-3.16	-1.09	-0.26	0.05	0.11	0.06
	0.5	-110.65	-20.32	-6.08	-2.00	-0.55	-0.01	0.15	0.15	0.07
	0.6	-86.30	-15.17	-4.24	-1.20	-0.19	0.15	0.22	0.17	0.08
	0.7	-67.95	-11.34	-2.88	-0.62	0.08	0.27	0.27	0.19	0.08
	0.8	-53.67	-8.40	-1.84	-0.18	0.28	0.36	0.30	0.20	0.08
	0.9	-42.26	-6.05	-1.02	0.16	0.44	0.43	0.33	0.21	0.08
	1.0	-32.93	-4.15	-0.35	0.44	0.56	0.49	0.36	0.22	0.09
0.9	0.1	-288.66	-89.79	-39.78	-19.41	-9.54	-4.43	-1.80	-0.55	-0.09
	0.2	-328.76	-70.51	-25.16	-10.53	-4.54	-1.84	-0.62	-0.12	0.00
	0.3	-243.63	-48.72	-16.28	-6.35	-2.50	-0.87	-0.20	0.03	0.03
	0.4	-182.60	-34.94	-11.09	-4.03	-1.41	-0.37	0.02	0.10	0.04
	0.5	-140.07	-25.75	-7.74	-2.57	-0.74	-0.06	0.15	0.14	0.05
	0.6	-109.25	-19.24	-5.40	-1.56	-0.28	0.15	0.23	0.17	0.05
	0.7	-86.04	-14.40	-3.68	-0.83	0.06	0.30	0.30	0.20	0.06
	0.8	-67.96	-10.66	-2.37	-0.27	0.31	0.41	0.34	0.21	0.06
	0.9	-53.52	-7.70	-1.33	0.17	0.51	0.50	0.38	0.22	0.06
	1.0	-41.71	-5.29	-0.49	0.52	0.67	0.57	0.41	0.23	0.07
1.0	0.1	-356.36	-110.84	-49.12	-23.97	-11.78	-5.48	-2.23	-0.69	-0.12
	0.2	-405.88	-87.06	-31.07	-13.01	-5.62	-2.29	-0.77	-0.16	-0.02
	0.3	-300.78	-60.15	-20.11	-7.85	-3.10	-1.09	-0.26	0.02	0.02
	0.4	-225.44	-43.14	-13.70	-4.99	-1.76	-0.47	0.01	0.11	0.04
	0.5	-172.93	-31.80	-9.56	-3.18	-0.92	-0.09	0.17	0.17	0.05
	0.6	-134.89	-23.76	-6.68	-1.94	-0.35	0.17	0.28	0.20	0.06
	0.7	-106.23	-17.78	-4.56	-1.04	0.06	0.36	0.35	0.23	0.06
	0.8	-83.92	-13.18	-2.93	-0.35	0.37	0.50	0.41	0.25	0.06
	0.9	-66.08	-9.52	-1.65	0.19	0.62	0.61	0.46	0.26	0.07
	1.0	-51.51	-6.54	-0.61	0.63	0.81	0.70	0.49	0.28	0.07

ED5-2 Wye, 45 Degree, Converging

 C_b Values

A_s/A_c	A_b/A_c	Q_b/Q_c								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-13.70	-1.90	-0.02	0.54	0.75	0.85	0.89	0.92	0.96
	0.2	-57.73	-10.44	-2.88	-0.64	0.22	0.59	0.76	0.85	0.94
	0.3	-131.08	-24.63	-7.59	-2.53	-0.60	0.24	0.61	0.79	0.92
	0.4	-233.78	-44.46	-14.15	-5.15	-1.71	-0.23	0.43	0.72	0.88
	0.5	-365.85	-69.96	-22.58	-8.50	-3.12	-0.81	0.21	0.65	0.82
	0.6	-527.21	-101.08	-32.83	-12.55	-4.80	-1.49	-0.02	0.59	0.79
	0.7	-717.81	-137.79	-44.90	-17.28	-6.74	-2.23	-0.23	0.60	0.85
	0.8	-937.72	-180.12	-58.79	-22.73	-8.96	-3.06	-0.45	0.63	0.95
	0.9	-1187.	-228.09	-74.53	-28.88	-11.45	-3.99	-0.69	0.67	1.07
	1.0	-1465.	-281.68	-92.10	-35.74	-14.23	-5.01	-0.94	0.74	1.22
0.2	0.1	-5.52	-0.26	0.56	0.79	0.88	0.92	0.95	0.97	1.05
	0.2	-25.19	-3.97	-0.64	0.32	0.67	0.82	0.90	0.96	1.08
	0.3	-58.03	-10.14	-2.63	-0.45	0.36	0.69	0.84	0.93	1.08
	0.4	-104.08	-18.80	-5.40	-1.51	-0.07	0.52	0.77	0.88	1.01
	0.5	-163.36	-29.97	-8.97	-2.87	-0.62	0.29	0.67	0.80	0.84
	0.6	-235.59	-43.47	-13.22	-4.44	-1.20	0.12	0.65	0.83	0.85
	0.7	-320.90	-59.38	-18.21	-6.25	-1.84	-0.04	0.68	0.91	0.93
	0.8	-419.32	-77.73	-23.95	-8.33	-2.56	-0.22	0.72	1.02	1.02
	0.9	-530.86	-98.50	-30.44	-10.66	-3.36	-0.40	0.79	1.16	1.14
	1.0	-655.51	-121.72	-37.68	-13.26	-4.25	-0.59	0.87	1.33	1.28
0.3	0.1	-2.74	0.32	0.78	0.90	0.94	0.97	0.99	1.02	1.13
	0.2	-14.27	-1.77	0.13	0.66	0.85	0.93	0.97	1.03	1.21
	0.3	-33.62	-5.28	-0.95	0.27	0.70	0.87	0.94	1.01	1.19
	0.4	-60.85	-10.26	-2.48	-0.30	0.47	0.77	0.88	0.93	1.04
	0.5	-95.87	-16.64	-4.44	-1.00	0.21	0.66	0.82	0.84	0.84
	0.6	-138.38	-24.26	-6.68	-1.73	0.01	0.66	0.88	0.91	0.88
	0.7	-188.60	-33.25	-9.32	-2.58	-0.20	0.68	0.98	1.02	0.95
	0.8	-246.54	-43.60	-12.34	-3.54	-0.43	0.72	1.11	1.15	1.03
	0.9	-312.21	-55.33	-15.76	-4.61	-0.68	0.78	1.26	1.31	1.13
	1.0	-385.59	-68.43	-19.56	-5.79	-0.94	0.86	1.45	1.49	1.24
0.4	0.1	-1.32	0.63	0.90	0.96	0.99	1.00	1.02	1.06	1.20
	0.2	-8.77	-0.64	0.54	0.85	0.95	0.99	1.03	1.09	1.31
	0.3	-21.41	-2.85	-0.10	0.63	0.87	0.96	1.00	1.06	1.26
	0.4	-39.30	-6.02	-1.05	0.28	0.72	0.87	0.91	0.92	1.00
	0.5	-62.10	-9.96	-2.16	-0.06	0.63	0.85	0.90	0.88	0.86
	0.6	-89.77	-14.65	-3.42	-0.38	0.61	0.93	0.99	0.95	0.90
	0.7	-122.46	-20.19	-4.88	-0.74	0.61	1.04	1.12	1.06	0.95
	0.8	-160.18	-26.56	-6.55	-1.15	0.62	1.18	1.29	1.19	1.01
	0.9	-202.93	-33.77	-8.44	-1.60	0.64	1.36	1.48	1.35	1.07
	1.0	-250.70	-41.83	-10.54	-2.09	0.68	1.56	1.71	1.53	1.15
0.5	0.1	-0.44	0.83	0.98	1.01	1.02	1.03	1.05	1.10	1.27
	0.2	-5.45	0.04	0.79	0.97	1.02	1.04	1.07	1.14	1.39
	0.3	-14.10	-1.39	0.40	0.84	0.97	1.00	1.02	1.07	1.28
	0.4	-26.48	-3.53	-0.24	0.59	0.83	0.89	0.88	0.85	0.86
	0.5	-41.84	-5.96	-0.80	0.51	0.88	0.97	0.95	0.90	0.87
	0.6	-60.61	-8.90	-1.46	0.43	0.97	1.09	1.06	0.97	0.90
	0.7	-82.80	-12.36	-2.22	0.35	1.09	1.25	1.20	1.08	0.93
	0.8	-108.39	-16.35	-3.09	0.27	1.24	1.45	1.38	1.20	0.96
	0.9	-137.41	-20.86	-4.07	0.19	1.42	1.68	1.59	1.35	0.99
	1.0	-169.84	-25.90	-5.15	0.11	1.63	1.95	1.83	1.52	1.02
0.6	0.1	-0.41	0.83	0.98	1.02	1.03	1.04	1.07	1.13	1.33
	0.2	-5.54	-0.08	0.70	0.91	0.98	1.01	1.05	1.14	1.42
	0.3	-14.48	-1.75	0.13	0.64	0.81	0.88	0.92	0.98	1.19
	0.4	-27.10	-4.14	-0.68	0.26	0.57	0.68	0.71	0.72	0.76
	0.5	-42.84	-6.91	-1.50	-0.02	0.47	0.64	0.68	0.69	0.70
	0.6	-62.07	-10.28	-2.48	-0.34	0.37	0.61	0.67	0.66	0.63
	0.7	-84.79	-14.26	-3.62	-0.71	0.27	0.59	0.67	0.63	0.54
	0.8	-111.02	-18.84	-4.92	-1.12	0.16	0.58	0.67	0.61	0.44
	0.9	-140.76	-24.03	-6.40	-1.57	0.04	0.58	0.68	0.59	0.31
	1.0	-174.01	-29.83	-8.04	-2.07	-0.08	0.58	0.70	0.56	0.15

ED5-2 Wye, 45 Degree, Converging (Continued)

		<i>C_b Values (Concluded)</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	<i>Q_b/Q_c</i>								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.7	0.1	0.03	0.94	1.03	1.05	1.06	1.07	1.10	1.16	1.39
	0.2	-3.96	0.25	0.83	0.97	1.01	1.04	1.08	1.17	1.47
	0.3	-11.07	-1.10	0.34	0.71	0.83	0.87	0.90	0.95	1.13
	0.4	-20.92	-2.92	-0.27	0.43	0.65	0.72	0.73	0.73	0.77
	0.5	-33.20	-5.01	-0.85	0.24	0.59	0.69	0.71	0.69	0.70
	0.6	-48.21	-7.55	-1.55	0.03	0.53	0.68	0.69	0.65	0.61
	0.7	-65.95	-10.56	-2.37	-0.20	0.48	0.68	0.69	0.62	0.49
	0.8	-86.42	-14.01	-3.30	-0.46	0.43	0.68	0.69	0.58	0.35
	0.9	-109.65	-17.93	-4.35	-0.75	0.38	0.70	0.70	0.53	0.18
	1.0	-135.63	-22.32	-5.53	-1.07	0.33	0.72	0.71	0.48	-0.03
0.8	0.1	0.38	1.02	1.08	1.08	1.08	1.09	1.12	1.19	1.44
	0.2	-2.78	0.50	0.91	1.01	1.03	1.05	1.09	1.18	1.49
	0.3	-8.58	-0.65	0.47	0.74	0.82	0.85	0.86	0.89	1.02
	0.4	-16.29	-2.00	0.05	0.56	0.71	0.75	0.74	0.74	0.78
	0.5	-25.98	-3.59	-0.37	0.44	0.68	0.73	0.72	0.69	0.69
	0.6	-37.82	-5.52	-0.87	0.31	0.65	0.72	0.70	0.64	0.58
	0.7	-51.83	-7.79	-1.44	0.17	0.63	0.73	0.69	0.59	0.43
	0.8	-68.01	-10.42	-2.10	0.01	0.62	0.75	0.69	0.53	0.25
	0.9	-86.37	-13.39	-2.84	-0.16	0.61	0.77	0.68	0.47	0.03
	1.0	-106.91	-16.73	-3.68	-0.35	0.61	0.79	0.68	0.38	-0.25
0.9	0.1	0.65	1.10	1.11	1.10	1.10	1.11	1.14	1.22	1.49
	0.2	-1.87	0.68	0.98	1.03	1.05	1.06	1.09	1.18	1.49
	0.3	-6.70	-0.33	0.54	0.74	0.79	0.80	0.80	0.81	0.87
	0.4	-12.69	-1.29	0.29	0.66	0.76	0.77	0.75	0.74	0.78
	0.5	-20.37	-2.48	0.00	0.59	0.74	0.75	0.72	0.69	0.67
	0.6	-29.77	-3.94	-0.34	0.52	0.73	0.75	0.70	0.63	0.54
	0.7	-40.89	-5.66	-0.73	0.45	0.74	0.76	0.68	0.56	0.36
	0.8	-53.74	-7.64	-1.18	0.37	0.76	0.78	0.67	0.48	0.13
	0.9	-68.32	-9.89	-1.69	0.28	0.77	0.80	0.65	0.38	-0.15
	1.0	-84.66	-12.42	-2.27	0.18	0.80	0.83	0.62	0.26	-0.49
1.0	0.1	0.88	1.16	1.14	1.12	1.12	1.13	1.16	1.25	1.54
	0.2	-1.17	0.81	1.02	1.05	1.05	1.06	1.09	1.18	1.48
	0.3	-5.09	-0.02	0.64	0.78	0.81	0.81	0.80	0.80	0.86
	0.4	-9.81	-0.72	0.48	0.74	0.79	0.78	0.76	0.74	0.77
	0.5	-15.89	-1.61	0.29	0.71	0.79	0.77	0.72	0.68	0.65
	0.6	-23.34	-2.69	0.07	0.68	0.80	0.77	0.69	0.60	0.49
	0.7	-32.15	-3.96	-0.18	0.66	0.82	0.78	0.67	0.51	0.27
	0.8	-42.35	-5.44	-0.47	0.64	0.85	0.79	0.63	0.41	0.00
	0.9	-53.94	-7.12	-0.80	0.61	0.88	0.81	0.60	0.28	-0.34
	1.0	-66.93	-9.01	-1.17	0.58	0.92	0.82	0.55	0.13	-0.75

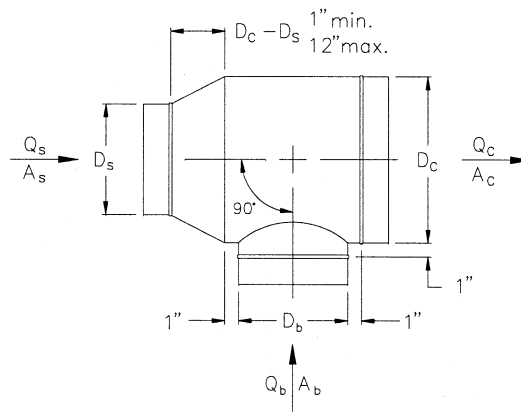
		<i>C_s Values</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	<i>Q_s/Q_c</i>								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-0.64	-0.63	0.17	1.00	1.87	2.79	3.76	4.81	5.92
	0.2	-2.38	-0.06	0.77	1.47	2.19	2.99	3.88	4.86	5.93
	0.3	-1.56	0.35	1.03	1.64	2.30	3.06	3.91	4.87	5.94
	0.4	-0.89	0.59	1.17	1.73	2.36	3.09	3.93	4.88	5.94
	0.5	-0.40	0.75	1.26	1.78	2.40	3.11	3.94	4.88	5.94
	0.6	-0.04	0.86	1.32	1.82	2.42	3.13	3.95	4.89	5.94
	0.7	0.23	0.95	1.36	1.85	2.44	3.14	3.96	4.89	5.94
	0.8	0.45	1.01	1.40	1.87	2.45	3.15	3.96	4.89	5.94
	0.9	0.62	1.06	1.42	1.88	2.46	3.15	3.96	4.89	5.94
	1.0	0.76	1.10	1.44	1.89	2.47	3.16	3.97	4.89	5.94
0.2	0.1	-0.33	-2.09	-1.13	-0.35	0.22	0.65	0.97	1.23	1.45
	0.2	-10.16	-2.08	-0.43	0.24	0.62	0.88	1.10	1.29	1.46
	0.3	-7.83	-1.20	0.03	0.50	0.77	0.97	1.14	1.30	1.46
	0.4	-5.62	-0.59	0.30	0.65	0.85	1.01	1.16	1.31	1.46
	0.5	-3.96	-0.18	0.48	0.74	0.90	1.04	1.18	1.32	1.47
	0.6	-2.71	0.12	0.60	0.80	0.94	1.06	1.19	1.32	1.47
	0.7	-1.75	0.34	0.70	0.85	0.96	1.07	1.19	1.32	1.47
	0.8	-0.99	0.52	0.77	0.88	0.98	1.08	1.20	1.32	1.47
	0.9	-0.38	0.66	0.82	0.91	0.99	1.09	1.20	1.33	1.47
	1.0	0.13	0.77	0.87	0.93	1.00	1.10	1.20	1.33	1.47

ED5-2 Wye, 45 Degree, Converging (Continued)

		C_s Values (Continued)								
		Q_s/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.3	0.1	-0.18	-4.36	-2.61	-1.29	-0.45	0.08	0.41	0.60	0.71
	0.2	-23.33	-5.14	-1.67	-0.44	0.12	0.42	0.58	0.67	0.72
	0.3	-18.44	-3.44	-0.84	0.00	0.36	0.54	0.64	0.69	0.73
	0.4	-13.64	-2.22	-0.34	0.25	0.49	0.60	0.67	0.70	0.73
	0.5	-10.00	-1.37	0.00	0.41	0.57	0.64	0.69	0.71	0.73
	0.6	-7.26	-0.75	0.24	0.52	0.62	0.67	0.70	0.72	0.73
	0.7	-5.15	-0.29	0.41	0.60	0.66	0.69	0.71	0.72	0.73
	0.8	-3.48	0.07	0.55	0.66	0.69	0.70	0.71	0.72	0.73
	0.9	-2.14	0.36	0.65	0.71	0.72	0.72	0.72	0.72	0.73
	1.0	-1.03	0.60	0.74	0.75	0.73	0.73	0.72	0.72	0.73
0.4	0.1	-0.46	-7.64	-4.66	-2.49	-1.15	-0.36	0.10	0.33	0.43
	0.2	-42.17	-9.48	-3.34	-1.23	-0.31	0.12	0.33	0.42	0.44
	0.3	-33.68	-6.60	-1.98	-0.53	0.05	0.31	0.41	0.45	0.45
	0.4	-25.24	-4.51	-1.13	-0.13	0.25	0.40	0.46	0.47	0.45
	0.5	-18.83	-3.04	-0.57	0.13	0.37	0.46	0.48	0.48	0.46
	0.6	-13.99	-1.97	-0.17	0.31	0.46	0.50	0.50	0.48	0.46
	0.7	-10.27	-1.17	0.12	0.44	0.52	0.53	0.51	0.49	0.46
	0.8	-7.32	-0.54	0.35	0.54	0.57	0.55	0.52	0.49	0.46
	0.9	-4.94	-0.04	0.53	0.62	0.61	0.57	0.53	0.49	0.46
	1.0	-2.98	0.37	0.68	0.68	0.64	0.58	0.54	0.50	0.46
0.5	0.1	-1.43	-12.03	-7.36	-4.03	-2.01	-0.84	-0.18	0.14	0.26
	0.2	-66.95	-15.18	-5.49	-2.21	-0.81	-0.16	0.14	0.26	0.28
	0.3	-53.80	-10.77	-3.45	-1.17	-0.27	0.11	0.26	0.30	0.29
	0.4	-40.66	-7.54	-2.16	-0.57	0.02	0.25	0.32	0.33	0.30
	0.5	-30.68	-5.27	-1.30	-0.18	0.21	0.33	0.36	0.34	0.30
	0.6	-23.15	-3.62	-0.69	0.09	0.33	0.39	0.38	0.35	0.30
	0.7	-17.34	-2.38	-0.24	0.29	0.42	0.43	0.40	0.35	0.30
	0.8	-12.75	-1.41	0.11	0.44	0.49	0.47	0.41	0.36	0.30
	0.9	-9.04	-0.64	0.39	0.56	0.55	0.49	0.43	0.36	0.30
	1.0	-5.99	0.00	0.61	0.65	0.59	0.51	0.43	0.36	0.30
0.6	0.1	-3.34	-17.58	-10.74	-5.94	-3.06	-1.39	-0.48	-0.03	0.13
	0.2	-97.90	-22.29	-8.18	-3.41	-1.39	-0.46	-0.03	0.13	0.16
	0.3	-79.03	-15.99	-5.28	-1.94	-0.64	-0.09	0.13	0.19	0.17
	0.4	-60.15	-11.37	-3.44	-1.09	-0.23	0.10	0.21	0.22	0.18
	0.5	-45.80	-8.13	-2.22	-0.55	0.03	0.22	0.26	0.24	0.18
	0.6	-34.97	-5.77	-1.35	-0.17	0.20	0.30	0.30	0.25	0.18
	0.7	-26.62	-3.98	-0.71	0.11	0.33	0.36	0.32	0.26	0.19
	0.8	-20.02	-2.59	-0.21	0.33	0.43	0.41	0.34	0.26	0.19
	0.9	-14.68	-1.48	0.18	0.49	0.51	0.44	0.35	0.27	0.19
	1.0	-10.29	-0.57	0.51	0.63	0.57	0.47	0.37	0.27	0.19
0.7	0.1	-6.43	-24.36	-14.82	-8.23	-4.31	-2.04	-0.81	-0.20	0.01
	0.2	-135.28	-30.88	-11.42	-4.85	-2.08	-0.80	-0.21	0.02	0.06
	0.3	-109.64	-22.35	-7.50	-2.88	-1.07	-0.31	0.00	0.09	0.07
	0.4	-83.96	-16.08	-5.02	-1.73	-0.52	-0.05	0.11	0.13	0.08
	0.5	-64.44	-11.67	-3.36	-0.99	-0.17	0.11	0.18	0.15	0.09
	0.6	-49.71	-8.47	-2.19	-0.48	0.06	0.22	0.22	0.17	0.09
	0.7	-38.35	-6.04	-1.31	-0.10	0.24	0.30	0.26	0.18	0.09
	0.8	-29.37	-4.16	-0.64	0.18	0.37	0.36	0.28	0.19	0.09
	0.9	-22.12	-2.65	-0.10	0.41	0.47	0.40	0.30	0.19	0.09
	1.0	-16.14	-1.41	0.33	0.60	0.55	0.44	0.32	0.20	0.09
0.8	0.1	-10.94	-32.43	-19.63	-10.93	-5.77	-2.80	-1.18	-0.38	-0.09
	0.2	-179.32	-41.01	-15.25	-6.55	-2.88	-1.19	-0.41	-0.10	-0.04
	0.3	-145.86	-29.89	-10.14	-3.99	-1.58	-0.55	-0.13	0.00	-0.02
	0.4	-112.34	-21.71	-6.91	-2.50	-0.86	-0.22	0.01	0.05	-0.01
	0.5	-86.85	-15.96	-4.75	-1.54	-0.41	-0.01	0.10	0.08	0.00
	0.6	-67.62	-11.78	-3.22	-0.87	-0.10	0.13	0.16	0.10	0.00
	0.7	-52.79	-8.62	-2.08	-0.38	0.12	0.23	0.20	0.11	0.00
	0.8	-41.06	-6.16	-1.20	0.00	0.29	0.31	0.23	0.12	0.01
	0.9	-31.59	-4.19	-0.51	0.29	0.43	0.37	0.26	0.13	0.01
	1.0	-23.78	-2.58	0.06	0.53	0.54	0.42	0.28	0.14	0.01

ED5-2 Wye, 45 Degree, Converging (*Continued*)

		<i>C_s Values (Concluded)</i>								
		<i>Q_s/Q_c</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.9	0.1	-17.13	-41.85	-25.21	-14.05	-7.45	-3.66	-1.59	-0.57	-0.20
	0.2	-230.27	-52.75	-19.69	-8.53	-3.81	-1.63	-0.63	-0.22	-0.13
	0.3	-187.95	-38.69	-13.24	-5.29	-2.16	-0.83	-0.28	-0.10	-0.10
	0.4	-145.53	-28.34	-9.15	-3.41	-1.26	-0.41	-0.10	-0.04	-0.09
	0.5	-113.27	-21.07	-6.42	-2.19	-0.69	-0.15	0.01	0.00	-0.09
	0.6	-88.94	-15.78	-4.48	-1.35	-0.30	0.03	0.09	0.03	-0.08
	0.7	-70.16	-11.78	-3.04	-0.73	-0.02	0.16	0.14	0.04	-0.08
	0.8	-55.33	-8.67	-1.93	-0.25	0.20	0.26	0.18	0.06	-0.07
	0.9	-43.33	-6.18	-1.05	0.12	0.37	0.33	0.21	0.07	-0.07
1.0	1.0	-33.46	-4.14	-0.34	0.42	0.50	0.39	0.24	0.08	-0.07
	0.1	-25.23	-52.69	-31.58	-17.61	-9.37	-4.64	-2.06	-0.79	-0.31
	0.2	-288.39	-66.15	-24.77	-10.80	-4.88	-2.14	-0.87	-0.35	-0.22
	0.3	-236.14	-48.79	-16.81	-6.80	-2.85	-1.15	-0.44	-0.20	-0.19
	0.4	-183.77	-36.02	-11.76	-4.47	-1.73	-0.63	-0.22	-0.12	-0.18
	0.5	-143.95	-27.05	-8.39	-2.98	-1.03	-0.31	-0.08	-0.08	-0.17
	0.6	-113.91	-20.52	-6.00	-1.93	-0.55	-0.09	0.01	-0.04	-0.16
	0.7	-90.73	-15.58	-4.23	-1.17	-0.20	0.07	0.08	-0.02	-0.16
	0.8	-72.41	-11.74	-2.86	-0.58	0.06	0.19	0.13	-0.01	-0.16
	0.9	-57.61	-8.66	-1.77	-0.12	0.27	0.28	0.16	0.01	-0.15
	1.0	-45.42	-6.15	-0.88	0.25	0.44	0.36	0.20	0.02	-0.15

ED5-3 Tee, *D_c* < or = 10 in., Converging

		<i>C_b Values</i>								
		<i>Q_b/Q_c</i>								
<i>A_s/A_c</i>	<i>A_b/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-13.39	-1.73	0.13	0.68	0.89	0.98	1.02	1.05	1.08
	0.2	-56.68	-9.99	-2.53	-0.32	0.52	0.88	1.04	1.12	1.18
	0.3	-128.89	-23.79	-6.99	-2.02	-0.12	0.68	1.04	1.20	1.29
	0.4	-230.03	-43.12	-13.26	-4.40	-1.04	0.40	1.03	1.30	1.42
	0.5	-360.10	-68.01	-21.33	-7.49	-2.23	0.02	1.00	1.40	1.53
	0.6	-519.10	-98.44	-31.20	-11.27	-3.69	-0.46	0.95	1.52	1.66
	0.7	-706.92	-134.35	-42.83	-15.70	-5.38	-0.99	0.93	1.70	1.88
	0.8	-923.64	-175.79	-56.25	-20.82	-7.34	-1.60	0.90	1.91	2.15
	0.9	-1169.	-222.75	-71.47	-26.62	-9.56	-2.30	0.87	2.14	2.44
	1.0	-1444.	-275.24	-88.47	-33.10	-12.04	-3.08	0.84	2.40	2.76
0.2	0.1	-5.33	-0.12	0.69	0.92	1.01	1.04	1.06	1.08	1.13
	0.2	-24.56	-3.63	-0.36	0.59	0.93	1.08	1.14	1.19	1.27
	0.3	-56.72	-9.54	-2.15	-0.01	0.78	1.10	1.23	1.30	1.39
	0.4	-101.83	-17.86	-4.68	-0.87	0.52	1.09	1.32	1.41	1.48
	0.5	-159.91	-28.59	-7.98	-2.02	0.17	1.05	1.40	1.51	1.51
	0.6	-230.83	-41.68	-11.98	-3.39	-0.24	1.03	1.53	1.66	1.61
	0.7	-314.56	-57.10	-16.68	-4.98	-0.69	1.04	1.71	1.90	1.82
	0.8	-411.18	-74.90	-22.10	-6.82	-1.21	1.04	1.92	2.16	2.05
	0.9	-520.69	-95.08	-28.25	-8.90	-1.81	1.04	2.15	2.45	2.31
	1.0	-643.09	-117.63	-35.12	-11.24	-2.47	1.04	2.41	2.78	2.58

ED5-3 Tee, $D_c \leq 10$ in., Converging (Continued)

		C_b Values (Continued)								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.3	0.1	-2.67	0.42	0.88	1.01	1.05	1.07	1.09	1.11	1.18
	0.2	-14.05	-1.55	0.36	0.89	1.08	1.16	1.19	1.23	1.34
	0.3	-33.18	-4.91	-0.58	0.64	1.07	1.23	1.30	1.34	1.44
	0.4	-60.09	-9.68	-1.94	0.24	1.00	1.29	1.39	1.42	1.47
	0.5	-94.80	-15.89	-3.74	-0.33	0.87	1.32	1.46	1.46	1.38
	0.6	-136.97	-23.33	-5.84	-0.92	0.81	1.45	1.65	1.66	1.53
	0.7	-186.81	-32.14	-8.32	-1.62	0.74	1.61	1.88	1.88	1.70
	0.8	-244.33	-42.30	-11.19	-2.43	0.65	1.78	2.14	2.13	1.88
	0.9	-309.54	-53.82	-14.44	-3.35	0.54	1.98	2.42	2.41	2.08
	1.0	-382.43	-66.70	-18.08	-4.39	0.42	2.19	2.74	2.72	2.29
0.4	0.1	-1.36	0.69	0.98	1.06	1.08	1.10	1.11	1.14	1.23
	0.2	-8.95	-0.54	0.71	1.04	1.15	1.20	1.22	1.26	1.40
	0.3	-21.82	-2.70	0.16	0.94	1.19	1.29	1.32	1.35	1.47
	0.4	-39.99	-5.81	-0.67	0.73	1.19	1.35	1.39	1.39	1.41
	0.5	-63.37	-9.82	-1.75	0.45	1.18	1.42	1.47	1.43	1.32
	0.6	-91.72	-14.59	-2.97	0.20	1.26	1.60	1.67	1.60	1.43
	0.7	-125.23	-20.24	-4.41	-0.10	1.34	1.81	1.90	1.81	1.56
	0.8	-163.91	-26.77	-6.09	-0.45	1.43	2.04	2.16	2.03	1.69
	0.9	-207.76	-34.17	-7.99	-0.85	1.53	2.30	2.44	2.28	1.82
	1.0	-256.79	-42.45	-10.12	-1.30	1.63	2.58	2.75	2.54	1.95
0.5	0.1	-0.60	0.85	1.04	1.09	1.11	1.12	1.13	1.16	1.27
	0.2	-6.03	0.04	0.91	1.13	1.20	1.22	1.24	1.29	1.44
	0.3	-15.35	-1.46	0.56	1.09	1.25	1.30	1.32	1.35	1.46
	0.4	-28.59	-3.67	-0.01	0.96	1.26	1.34	1.35	1.32	1.29
	0.5	-45.45	-6.42	-0.66	0.85	1.33	1.45	1.45	1.38	1.24
	0.6	-65.92	-9.70	-1.41	0.78	1.46	1.64	1.63	1.53	1.32
	0.7	-90.12	-13.58	-2.29	0.69	1.61	1.86	1.85	1.70	1.39
	0.8	-118.07	-18.07	-3.32	0.57	1.78	2.11	2.09	1.89	1.46
	0.9	-149.75	-23.18	-4.49	0.43	1.96	2.38	2.35	2.09	1.53
	1.0	-185.19	-28.89	-5.81	0.27	2.16	2.67	2.63	2.31	1.57
0.6	0.1	-0.11	0.96	1.09	1.12	1.12	1.13	1.15	1.18	1.31
	0.2	-4.20	0.39	1.03	1.18	1.22	1.24	1.26	1.30	1.47
	0.3	-11.33	-0.72	0.79	1.16	1.27	1.30	1.31	1.33	1.43
	0.4	-21.57	-2.42	0.35	1.05	1.25	1.29	1.27	1.22	1.12
	0.5	-34.29	-4.35	-0.03	1.07	1.38	1.44	1.41	1.32	1.16
	0.6	-49.85	-6.73	-0.50	1.08	1.54	1.63	1.57	1.45	1.19
	0.7	-68.26	-9.55	-1.06	1.09	1.71	1.83	1.76	1.58	1.21
	0.8	-89.52	-12.81	-1.72	1.10	1.91	2.07	1.97	1.73	1.22
	0.9	-113.64	-16.52	-2.47	1.10	2.12	2.32	2.20	1.88	1.21
	1.0	-140.62	-20.68	-3.33	1.09	2.35	2.60	2.44	2.03	1.16
0.7	0.1	0.22	1.03	1.12	1.14	1.14	1.14	1.16	1.20	1.35
	0.2	-3.00	0.62	1.10	1.21	1.23	1.24	1.26	1.31	1.49
	0.3	-8.74	-0.27	0.91	1.19	1.26	1.27	1.27	1.28	1.36
	0.4	-16.90	-1.59	0.58	1.11	1.25	1.27	1.24	1.18	1.06
	0.5	-26.99	-3.06	0.33	1.17	1.38	1.41	1.36	1.26	1.06
	0.6	-39.35	-4.86	0.02	1.22	1.54	1.57	1.50	1.35	1.05
	0.7	-53.97	-7.01	-0.35	1.29	1.72	1.76	1.65	1.45	1.02
	0.8	-70.87	-9.50	-0.79	1.35	1.91	1.97	1.82	1.54	0.96
	0.9	-90.04	-12.34	-1.31	1.41	2.12	2.19	2.00	1.64	0.86
	1.0	-111.50	-15.53	-1.89	1.46	2.34	2.43	2.19	1.73	0.72
0.8	0.1	0.46	1.08	1.14	1.15	1.15	1.16	1.17	1.22	1.38
	0.2	-2.20	0.76	1.14	1.22	1.24	1.24	1.26	1.31	1.49
	0.3	-7.04	-0.01	0.95	1.18	1.23	1.23	1.23	1.22	1.27
	0.4	-13.77	-1.06	0.71	1.13	1.24	1.24	1.20	1.13	1.00
	0.5	-22.11	-2.24	0.54	1.20	1.36	1.36	1.30	1.19	0.97
	0.6	-32.33	-3.69	0.31	1.27	1.50	1.50	1.41	1.25	0.90
	0.7	-44.42	-5.41	0.04	1.34	1.66	1.65	1.53	1.30	0.81
	0.8	-58.40	-7.42	-0.29	1.42	1.83	1.83	1.65	1.35	0.67
	0.9	-74.28	-9.72	-0.67	1.49	2.01	2.01	1.78	1.38	0.49
	1.0	-92.06	-12.30	-1.12	1.56	2.21	2.20	1.92	1.40	0.24

ED5-3 Tee, $D_c \leq 10$ in., Converging (Continued)

		C_b Values (Concluded)								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.9	0.1	0.62	1.12	1.16	1.16	1.16	1.17	1.19	1.24	1.41
	0.2	-1.67	0.85	1.16	1.22	1.23	1.24	1.25	1.30	1.48
	0.3	-5.95	0.12	0.95	1.14	1.18	1.18	1.16	1.15	1.14
	0.4	-11.68	-0.74	0.77	1.12	1.20	1.20	1.16	1.08	0.93
	0.5	-18.85	-1.74	0.63	1.18	1.31	1.30	1.23	1.11	0.86
	0.6	-27.63	-2.98	0.44	1.24	1.42	1.41	1.31	1.13	0.75
	0.7	-38.04	-4.45	0.21	1.30	1.55	1.53	1.39	1.14	0.58
	0.8	-50.07	-6.17	-0.07	1.36	1.69	1.66	1.47	1.13	0.37
	0.9	-63.75	-8.14	-0.40	1.42	1.83	1.79	1.54	1.11	0.09
	1.0	-79.08	-10.36	-0.79	1.46	1.98	1.92	1.61	1.06	-0.26
1.0	0.1	0.74	1.15	1.18	1.17	1.17	1.18	1.20	1.25	1.43
	0.2	-1.33	0.89	1.16	1.21	1.22	1.22	1.24	1.29	1.46
	0.3	-5.30	0.15	0.90	1.08	1.11	1.11	1.09	1.06	0.99
	0.4	-10.31	-0.57	0.78	1.09	1.16	1.15	1.11	1.03	0.86
	0.5	-16.71	-1.47	0.64	1.13	1.24	1.22	1.15	1.03	0.74
	0.6	-24.56	-2.59	0.46	1.17	1.32	1.30	1.20	1.01	0.57
	0.7	-33.87	-3.93	0.23	1.20	1.41	1.38	1.24	0.97	0.34
	0.8	-44.64	-5.49	-0.05	1.22	1.51	1.46	1.27	0.91	0.05
	0.9	-56.89	-7.29	-0.38	1.24	1.59	1.54	1.28	0.82	-0.33
	1.0	-70.62	-9.32	-0.77	1.24	1.68	1.61	1.28	0.69	-0.80
		C_s Values								
		Q_s/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	6.57	1.67	1.10	0.95	0.88	0.85	0.84	0.83	0.82
	0.2	4.13	1.39	1.03	0.92	0.87	0.85	0.83	0.83	0.82
	0.3	3.30	1.30	1.00	0.91	0.87	0.85	0.83	0.82	0.82
	0.4	2.89	1.24	0.99	0.90	0.86	0.84	0.83	0.82	0.82
	0.5	2.63	1.21	0.97	0.90	0.86	0.84	0.83	0.82	0.82
	0.6	2.45	1.18	0.97	0.89	0.86	0.84	0.83	0.82	0.82
	0.7	2.32	1.16	0.96	0.89	0.86	0.84	0.83	0.82	0.82
	0.8	2.22	1.15	0.95	0.89	0.85	0.84	0.83	0.82	0.82
	0.9	2.14	1.13	0.95	0.88	0.85	0.84	0.83	0.82	0.82
	1.0	2.07	1.12	0.94	0.88	0.85	0.84	0.83	0.82	0.82
0.2	0.1	34.53	5.26	2.11	1.29	0.98	0.84	0.76	0.71	0.68
	0.2	18.11	3.42	1.62	1.11	0.90	0.80	0.74	0.70	0.68
	0.3	12.67	2.79	1.45	1.04	0.87	0.78	0.73	0.70	0.68
	0.4	9.98	2.47	1.36	1.01	0.85	0.77	0.72	0.69	0.67
	0.5	8.39	2.27	1.30	0.98	0.84	0.76	0.72	0.69	0.67
	0.6	7.34	2.13	1.26	0.96	0.83	0.76	0.72	0.69	0.67
	0.7	6.61	2.02	1.22	0.95	0.82	0.75	0.71	0.69	0.67
	0.8	6.08	1.94	1.19	0.93	0.81	0.75	0.71	0.68	0.67
	0.9	5.68	1.87	1.17	0.92	0.80	0.74	0.70	0.68	0.66
	1.0	4.55	1.61	1.05	0.86	0.76	0.71	0.68	0.66	0.65
0.3	0.1	90.35	12.35	4.15	2.07	1.30	0.95	0.76	0.65	0.59
	0.2	44.33	7.19	2.80	1.57	1.08	0.84	0.71	0.63	0.57
	0.3	29.24	5.46	2.33	1.40	1.00	0.80	0.69	0.62	0.57
	0.4	21.88	4.59	2.09	1.30	0.96	0.78	0.67	0.61	0.56
	0.5	17.62	4.06	1.93	1.24	0.92	0.76	0.66	0.60	0.56
	0.6	14.90	3.71	1.82	1.19	0.90	0.74	0.65	0.59	0.55
	0.7	13.06	3.45	1.74	1.15	0.88	0.73	0.64	0.59	0.55
	0.8	11.78	3.26	1.67	1.12	0.86	0.72	0.63	0.58	0.54
	0.9	9.02	2.64	1.41	0.97	0.77	0.66	0.59	0.54	0.51
	1.0	8.36	2.52	1.36	0.95	0.75	0.65	0.58	0.54	0.51
0.4	0.1	167.76	22.21	7.04	3.22	1.81	1.17	0.84	0.64	0.52
	0.2	78.99	12.25	4.42	2.26	1.39	0.97	0.74	0.60	0.50
	0.3	50.14	8.96	3.54	1.92	1.24	0.90	0.70	0.57	0.49
	0.4	36.26	7.32	3.08	1.74	1.16	0.85	0.67	0.56	0.48
	0.5	28.38	6.35	2.80	1.63	1.10	0.82	0.65	0.54	0.47
	0.6	23.50	5.72	2.61	1.54	1.05	0.79	0.63	0.53	0.46
	0.7	20.32	5.27	2.46	1.47	1.02	0.77	0.62	0.52	0.45
	0.8	14.94	4.13	1.98	1.21	0.85	0.65	0.53	0.46	0.40
	0.9	13.55	3.88	1.89	1.16	0.82	0.63	0.52	0.45	0.39
	1.0	12.66	3.69	1.80	1.12	0.79	0.62	0.51	0.44	0.39

ED5-3 Tee, $D_c \leq 10$ in., Converging (Continued)

		C_s Values (Concluded)								
		Q_s/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.5	0.1	252.09	33.17	10.32	4.56	2.44	1.47	0.97	0.67	0.49
	0.2	114.73	17.76	6.27	3.07	1.79	1.16	0.81	0.60	0.46
	0.3	70.56	12.71	4.92	2.56	1.56	1.05	0.75	0.56	0.44
	0.4	49.68	10.24	4.23	2.29	1.43	0.98	0.71	0.54	0.42
	0.5	38.12	8.81	3.81	2.11	1.34	0.93	0.68	0.52	0.41
	0.6	31.23	7.90	3.53	1.99	1.27	0.88	0.65	0.50	0.39
	0.7	21.87	6.00	2.75	1.57	1.01	0.71	0.52	0.40	0.32
	0.8	19.30	5.57	2.59	1.49	0.96	0.67	0.50	0.38	0.30
	0.9	17.84	5.27	2.46	1.42	0.92	0.65	0.48	0.37	0.29
	1.0	17.16	5.05	2.36	1.36	0.88	0.62	0.46	0.35	0.28
0.6	0.1	323.56	42.99	13.40	5.88	3.09	1.80	1.12	0.73	0.48
	0.2	142.32	22.64	8.06	3.91	2.23	1.39	0.92	0.63	0.44
	0.3	84.89	16.05	6.28	3.24	1.92	1.23	0.83	0.58	0.41
	0.4	58.43	12.90	5.39	2.88	1.75	1.14	0.78	0.55	0.39
	0.5	44.34	11.13	4.86	2.66	1.63	1.07	0.74	0.52	0.37
	0.6	29.06	8.20	3.69	2.04	1.25	0.81	0.55	0.38	0.26
	0.7	24.71	7.51	3.44	1.91	1.18	0.77	0.52	0.35	0.24
	0.8	22.56	7.06	3.26	1.81	1.11	0.72	0.48	0.33	0.22
	0.9	21.89	6.78	3.12	1.73	1.06	0.68	0.45	0.30	0.20
	1.0	22.24	6.61	3.00	1.65	1.00	0.65	0.43	0.28	0.18
0.7	0.1	360.67	49.26	15.65	6.94	3.65	2.11	1.29	0.80	0.49
	0.2	152.32	25.82	9.48	4.66	2.65	1.63	1.04	0.68	0.44
	0.3	87.85	18.38	7.46	3.88	2.29	1.44	0.94	0.62	0.40
	0.4	59.34	14.92	6.47	3.48	2.09	1.33	0.87	0.58	0.37
	0.5	35.18	10.56	4.78	2.60	1.55	0.97	0.62	0.38	0.22
	0.6	28.26	9.51	4.41	2.42	1.45	0.90	0.57	0.35	0.19
	0.7	25.45	8.91	4.16	2.28	1.36	0.85	0.53	0.32	0.17
	0.8	25.21	8.60	3.99	2.18	1.29	0.79	0.49	0.28	0.14
	0.9	26.68	8.48	3.86	2.08	1.22	0.74	0.45	0.25	0.12
	1.0	29.34	8.49	3.77	2.01	1.16	0.70	0.41	0.22	0.10
0.8	0.1	343.46	49.71	16.47	7.52	4.02	2.35	1.43	0.87	0.51
	0.2	136.74	26.38	10.30	5.22	3.01	1.85	1.17	0.74	0.45
	0.3	75.52	19.20	8.32	4.45	2.64	1.66	1.06	0.67	0.41
	0.4	37.55	12.79	5.92	3.23	1.91	1.17	0.72	0.42	0.21
	0.5	27.25	11.28	5.41	2.98	1.77	1.08	0.66	0.37	0.18
	0.6	24.23	10.57	5.10	2.81	1.66	1.01	0.60	0.33	0.14
	0.7	25.36	10.32	4.91	2.69	1.57	0.94	0.55	0.29	0.11
	0.8	29.09	10.37	4.80	2.59	1.50	0.88	0.50	0.25	0.08
	0.9	34.55	10.60	4.74	2.50	1.42	0.82	0.46	0.21	0.05
	1.0	41.23	10.98	4.71	2.43	1.36	0.77	0.41	0.18	0.01
0.9	0.1	256.86	42.66	15.41	7.44	4.14	2.48	1.53	0.93	0.54
	0.2	90.70	23.73	10.34	5.54	3.28	2.05	1.30	0.81	0.47
	0.3	29.93	14.20	6.95	3.86	2.30	1.41	0.85	0.48	0.22
	0.4	16.27	12.21	6.28	3.55	2.12	1.29	0.77	0.42	0.18
	0.5	14.80	11.58	5.96	3.35	1.99	1.20	0.70	0.37	0.14
	0.6	19.43	11.62	5.81	3.23	1.89	1.13	0.64	0.32	0.10
	0.7	27.55	12.06	5.77	3.14	1.81	1.06	0.59	0.27	0.06
	0.8	37.84	12.73	5.79	3.07	1.74	0.99	0.53	0.23	0.02
	0.9	49.59	13.57	5.85	3.01	1.67	0.93	0.48	0.18	−0.02
	1.0	62.35	14.52	5.94	2.97	1.61	0.87	0.42	0.14	−0.06
1.0	0.1	94.95	27.29	12.24	6.64	3.96	2.48	1.57	0.98	0.57
	0.2	−6.40	12.70	7.32	4.31	2.64	1.64	1.00	0.56	0.25
	0.3	−17.35	10.90	6.66	3.97	2.44	1.51	0.90	0.49	0.20
	0.4	−11.05	11.02	6.50	3.82	2.32	1.41	0.83	0.43	0.15
	0.5	2.15	11.91	6.54	3.74	2.23	1.33	0.76	0.38	0.10
	0.6	18.80	13.18	6.67	3.70	2.16	1.26	0.70	0.32	0.06
	0.7	37.42	14.67	6.86	3.68	2.09	1.19	0.63	0.26	0.01
	0.8	57.27	16.30	7.09	3.67	2.03	1.12	0.57	0.21	−0.04
	0.9	77.95	18.02	7.35	3.66	1.97	1.06	0.51	0.15	−0.09
	1.0	99.20	19.80	7.61	3.67	1.92	1.00	0.45	0.10	−0.14

ED5-3, $D_c > 10$ in., Converging

		C_b Values								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-13.86	-1.90	0.03	0.61	0.83	0.92	0.96	0.98	0.98
	0.2	-58.25	-10.48	-2.80	-0.51	0.36	0.74	0.90	0.96	0.96
	0.3	-132.23	-24.75	-7.50	-2.36	-0.39	0.45	0.82	0.96	0.96
	0.4	-235.84	-44.74	-14.07	-4.93	-1.43	0.07	0.73	0.98	0.99
	0.5	-369.15	-70.45	-22.51	-8.23	-2.76	-0.42	0.61	1.01	1.05
	0.6	-532.21	-101.89	-32.83	-12.26	-4.38	-1.00	0.48	1.06	1.13
	0.7	-725.06	-139.08	-45.04	-17.02	-6.30	-1.70	0.33	1.13	1.24
	0.8	-947.77	-182.03	-59.15	-22.53	-8.52	-2.50	0.16	1.22	1.38
	0.9	-1200.	-230.76	-75.15	-28.78	-11.03	-3.40	-0.03	1.32	1.55
	1.0	-1483.	-285.27	-93.06	-35.78	-13.84	-4.41	-0.25	1.43	1.75
0.2	0.1	-5.86	-0.35	0.54	0.81	0.91	0.95	0.97	0.97	0.96
	0.2	-26.08	-4.19	-0.70	0.33	0.71	0.87	0.93	0.95	0.93
	0.3	-59.71	-10.53	-2.72	-0.43	0.43	0.78	0.91	0.95	0.91
	0.4	-106.78	-19.39	-5.53	-1.46	0.05	0.67	0.91	0.97	0.91
	0.5	-167.36	-30.77	-9.12	-2.78	-0.42	0.55	0.93	1.02	0.93
	0.6	-241.50	-44.68	-13.50	-4.37	-0.97	0.42	0.96	1.10	0.98
	0.7	-329.25	-61.15	-18.68	-6.25	-1.62	0.27	1.02	1.21	1.06
	0.8	-430.67	-80.18	-24.67	-8.42	-2.37	0.10	1.09	1.35	1.17
	0.9	-545.81	-101.78	-31.47	-10.89	-3.22	-0.08	1.17	1.52	1.31
	1.0	-674.72	-125.98	-39.08	-13.64	-4.17	-0.28	1.28	1.72	1.48
0.3	0.1	-3.26	0.15	0.70	0.86	0.93	0.96	0.97	0.97	0.95
	0.2	-15.50	-2.16	-0.04	0.58	0.81	0.90	0.93	0.94	0.91
	0.3	-35.76	-5.90	-1.20	0.16	0.66	0.85	0.92	0.92	0.88
	0.4	-64.09	-11.09	-2.78	-0.38	0.48	0.82	0.93	0.94	0.86
	0.5	-100.54	-17.73	-4.78	-1.06	0.29	0.80	0.97	0.98	0.87
	0.6	-145.16	-25.85	-7.21	-1.86	0.06	0.80	1.05	1.05	0.90
	0.7	-198.01	-35.46	-10.08	-2.81	-0.19	0.82	1.15	1.16	0.96
	0.8	-259.13	-46.56	-13.39	-3.89	-0.47	0.85	1.28	1.30	1.05
	0.9	-328.59	-59.18	-17.15	-5.11	-0.78	0.89	1.44	1.47	1.17
	1.0	-406.44	-73.33	-21.37	-6.48	-1.12	0.94	1.63	1.68	1.32
0.4	0.1	-1.99	0.38	0.77	0.89	0.94	0.96	0.97	0.97	0.95
	0.2	-10.31	-1.18	0.26	0.69	0.84	0.91	0.93	0.93	0.90
	0.3	-23.96	-3.65	-0.48	0.43	0.75	0.88	0.91	0.91	0.86
	0.4	-42.98	-7.03	-1.46	0.11	0.67	0.87	0.93	0.91	0.84
	0.5	-67.44	-11.35	-2.69	-0.26	0.59	0.90	0.97	0.94	0.84
	0.6	-97.39	-16.60	-4.17	-0.69	0.52	0.95	1.06	1.01	0.87
	0.7	-132.88	-22.81	-5.91	-1.17	0.46	1.03	1.17	1.11	0.92
	0.8	-173.96	-29.99	-7.90	-1.73	0.40	1.15	1.33	1.24	1.00
	0.9	-220.69	-38.15	-10.16	-2.35	0.35	1.29	1.51	1.40	1.11
	1.0	-273.12	-47.31	-12.70	-3.04	0.29	1.45	1.74	1.61	1.26
0.5	0.1	-1.26	0.51	0.81	0.90	0.94	0.96	0.97	0.96	0.95
	0.2	-7.26	-0.62	0.43	0.75	0.86	0.91	0.93	0.93	0.90
	0.3	-16.99	-2.35	-0.07	0.57	0.80	0.89	0.91	0.90	0.87
	0.4	-30.49	-4.67	-0.72	0.38	0.76	0.89	0.92	0.90	0.85
	0.5	-47.82	-7.61	-1.50	0.19	0.75	0.93	0.97	0.93	0.85
	0.6	-69.03	-11.17	-2.42	-0.03	0.76	1.01	1.05	0.98	0.88
	0.7	-94.17	-15.37	-3.49	-0.26	0.80	1.13	1.17	1.07	0.93
	0.8	-123.30	-20.22	-4.71	-0.50	0.87	1.29	1.33	1.20	1.02
	0.9	-156.48	-25.73	-6.09	-0.77	0.96	1.48	1.53	1.36	1.13
	1.0	-193.74	-31.92	-7.63	-1.07	1.06	1.71	1.77	1.56	1.28
0.6	0.1	-0.79	0.59	0.83	0.91	0.95	0.96	0.97	0.97	0.95
	0.2	-5.28	-0.27	0.54	0.78	0.88	0.91	0.93	0.93	0.91
	0.3	-12.43	-1.51	0.18	0.66	0.83	0.89	0.91	0.91	0.89
	0.4	-22.29	-3.15	-0.25	0.55	0.82	0.90	0.92	0.91	0.88
	0.5	-34.92	-5.19	-0.74	0.46	0.84	0.95	0.96	0.93	0.89
	0.6	-50.35	-7.64	-1.30	0.38	0.91	1.05	1.04	0.98	0.93
	0.7	-68.66	-10.52	-1.94	0.32	1.01	1.18	1.16	1.07	0.99
	0.8	-89.89	-13.83	-2.65	0.26	1.15	1.36	1.33	1.19	1.08
	0.9	-114.09	-17.61	-3.46	0.22	1.32	1.59	1.53	1.35	1.21
	1.0	-141.33	-21.84	-4.35	0.18	1.54	1.85	1.77	1.54	1.37

ED5-3, $D_c > 10$ in., Converging (Continued)

		C_b Values (Continued)								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.7	0.1	-0.47	0.65	0.85	0.92	0.95	0.96	0.97	0.97	0.96
	0.2	-3.90	-0.03	0.61	0.81	0.89	0.92	0.94	0.94	0.93
	0.3	-9.25	-0.94	0.35	0.72	0.85	0.90	0.92	0.92	0.92
	0.4	-16.54	-2.10	0.07	0.66	0.85	0.91	0.93	0.92	0.92
	0.5	-25.85	-3.51	-0.22	0.64	0.90	0.97	0.97	0.94	0.95
	0.6	-37.21	-5.18	-0.54	0.65	1.00	1.07	1.05	1.00	1.00
	0.7	-50.68	-7.13	-0.87	0.70	1.14	1.22	1.17	1.08	1.08
	0.8	-66.31	-9.37	-1.24	0.78	1.33	1.41	1.33	1.21	1.20
	0.9	-84.17	-11.92	-1.64	0.89	1.56	1.65	1.53	1.36	1.34
	1.0	-104.29	-14.78	-2.09	1.03	1.84	1.94	1.78	1.56	1.52
0.8	0.1	-0.23	0.69	0.87	0.93	0.95	0.97	0.97	0.98	0.97
	0.2	-2.90	0.15	0.67	0.83	0.90	0.93	0.94	0.95	0.96
	0.3	-6.91	-0.53	0.47	0.76	0.87	0.91	0.93	0.94	0.96
	0.4	-12.31	-1.34	0.30	0.74	0.88	0.93	0.94	0.95	0.98
	0.5	-19.16	-2.29	0.15	0.77	0.94	0.99	0.98	0.98	1.03
	0.6	-27.50	-3.39	0.01	0.84	1.06	1.09	1.06	1.03	1.11
	0.7	-37.38	-4.66	-0.11	0.97	1.23	1.24	1.18	1.12	1.21
	0.8	-48.87	-6.11	-0.22	1.15	1.46	1.45	1.35	1.25	1.35
	0.9	-62.01	-7.75	-0.33	1.37	1.73	1.70	1.55	1.41	1.52
	1.0	-76.85	-9.59	-0.44	1.63	2.06	2.00	1.80	1.61	1.73
0.9	0.1	-0.05	0.72	0.88	0.93	0.96	0.97	0.98	0.99	0.99
	0.2	-2.14	0.28	0.71	0.85	0.91	0.94	0.96	0.97	0.99
	0.3	-5.14	-0.21	0.57	0.80	0.88	0.92	0.95	0.97	1.02
	0.4	-9.09	-0.76	0.47	0.80	0.91	0.94	0.96	0.98	1.06
	0.5	-14.06	-1.36	0.42	0.86	0.98	1.01	1.01	1.02	1.14
	0.6	-20.08	-2.04	0.42	0.99	1.11	1.12	1.09	1.09	1.24
	0.7	-27.21	-2.79	0.47	1.17	1.30	1.27	1.21	1.19	1.38
	0.8	-35.50	-3.63	0.55	1.42	1.55	1.49	1.38	1.32	1.55
	0.9	-45.01	-4.57	0.66	1.72	1.86	1.75	1.59	1.49	1.75
	1.0	-55.79	-5.64	0.80	2.08	2.22	2.06	1.84	1.69	1.99
1.0	0.1	0.09	0.75	0.89	0.94	0.97	0.98	0.99	1.00	1.01
	0.2	-1.54	0.39	0.74	0.87	0.92	0.95	0.97	0.99	1.03
	0.3	-3.75	0.03	0.64	0.83	0.90	0.94	0.97	1.00	1.08
	0.4	-6.57	-0.32	0.61	0.85	0.93	0.97	0.99	1.03	1.16
	0.5	-10.05	-0.65	0.64	0.94	1.02	1.03	1.04	1.08	1.26
	0.6	-14.24	-0.98	0.74	1.10	1.16	1.15	1.13	1.16	1.40
	0.7	-19.20	-1.32	0.91	1.33	1.37	1.31	1.26	1.27	1.57
	0.8	-24.98	-1.69	1.14	1.63	1.63	1.53	1.43	1.41	1.78
	0.9	-31.62	-2.10	1.42	2.00	1.96	1.80	1.64	1.59	2.02
	1.0	-39.19	-2.55	1.76	2.43	2.35	2.12	1.90	1.81	2.30
		C_s Values								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	7.87	1.70	1.07	0.92	0.86	0.84	0.82	0.82	0.81
	0.2	4.21	1.30	0.97	0.88	0.85	0.83	0.82	0.81	0.81
	0.3	3.02	1.16	0.93	0.87	0.84	0.83	0.82	0.81	0.81
	0.4	2.45	1.10	0.92	0.86	0.84	0.83	0.82	0.81	0.81
	0.5	2.13	1.07	0.91	0.86	0.84	0.82	0.82	0.81	0.81
	0.6	1.93	1.04	0.90	0.86	0.84	0.82	0.82	0.81	0.81
	0.7	1.80	1.03	0.90	0.85	0.83	0.82	0.82	0.81	0.81
	0.8	1.72	1.02	0.90	0.85	0.83	0.82	0.82	0.81	0.81
	0.9	1.67	1.01	0.89	0.85	0.83	0.82	0.82	0.81	0.81
	1.0	1.63	1.01	0.89	0.85	0.83	0.82	0.82	0.81	0.81
0.2	0.1	44.93	6.00	2.16	1.24	0.92	0.78	0.71	0.67	0.65
	0.2	20.43	3.28	1.45	0.98	0.81	0.73	0.69	0.66	0.64
	0.3	12.53	2.40	1.22	0.90	0.77	0.71	0.68	0.66	0.64
	0.4	8.78	1.98	1.12	0.86	0.76	0.70	0.67	0.66	0.64
	0.5	6.69	1.75	1.06	0.84	0.75	0.70	0.67	0.65	0.64
	0.6	5.43	1.61	1.02	0.83	0.74	0.70	0.67	0.65	0.64
	0.7	4.64	1.52	1.00	0.82	0.74	0.70	0.67	0.65	0.64
	0.8	4.15	1.47	0.98	0.81	0.74	0.69	0.67	0.65	0.64
	0.9	3.86	1.43	0.97	0.81	0.74	0.69	0.67	0.65	0.64
	1.0	3.71	1.42	0.97	0.81	0.73	0.69	0.67	0.65	0.64

ED5-3, $D_c > 10$ in., Converging (Continued)

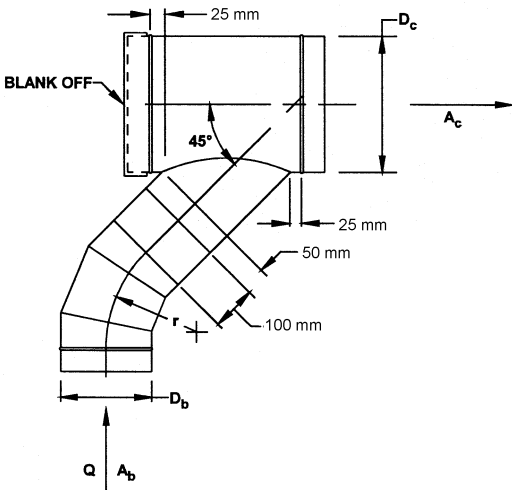
		C_s Values (Continued)								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.3	0.1	118.96	14.64	4.45	2.03	1.20	0.84	0.66	0.57	0.51
	0.2	51.24	7.11	2.49	1.33	0.90	0.70	0.60	0.54	0.50
	0.3	29.57	4.70	1.87	1.10	0.80	0.66	0.58	0.53	0.50
	0.4	19.40	3.57	1.58	1.00	0.76	0.64	0.57	0.52	0.50
	0.5	13.84	2.96	1.42	0.94	0.73	0.62	0.56	0.52	0.50
	0.6	10.58	2.59	1.32	0.90	0.72	0.62	0.56	0.52	0.49
	0.7	8.64	2.38	1.27	0.88	0.71	0.61	0.56	0.52	0.49
	0.8	7.52	2.25	1.23	0.87	0.70	0.61	0.56	0.52	0.49
	0.9	6.95	2.19	1.22	0.87	0.70	0.61	0.56	0.52	0.49
0.4	1.0	6.76	2.17	1.21	0.86	0.70	0.61	0.55	0.52	0.49
	0.1	218.57	26.35	7.61	3.18	1.65	1.00	0.68	0.50	0.40
	0.2	90.30	12.10	3.91	1.85	1.08	0.74	0.55	0.45	0.38
	0.3	49.68	7.59	2.74	1.42	0.90	0.65	0.51	0.43	0.37
	0.4	30.96	5.51	2.21	1.23	0.82	0.61	0.49	0.42	0.37
	0.5	21.00	4.40	1.92	1.13	0.78	0.59	0.48	0.42	0.37
	0.6	15.43	3.78	1.76	1.07	0.75	0.58	0.48	0.41	0.37
	0.7	12.36	3.44	1.67	1.04	0.74	0.57	0.48	0.41	0.37
	0.8	10.86	3.27	1.63	1.02	0.73	0.57	0.47	0.41	0.37
0.5	0.9	10.40	3.22	1.61	1.01	0.73	0.57	0.47	0.41	0.37
	1.0	10.67	3.25	1.62	1.02	0.73	0.57	0.47	0.41	0.37
	0.1	320.10	38.52	10.97	4.44	2.18	1.21	0.72	0.46	0.31
	0.2	126.36	16.99	5.39	2.42	1.32	0.81	0.54	0.38	0.28
	0.3	65.94	10.28	3.65	1.79	1.05	0.68	0.48	0.35	0.27
	0.4	38.84	7.27	2.87	1.51	0.93	0.63	0.45	0.34	0.27
	0.5	25.07	5.74	2.47	1.37	0.87	0.60	0.44	0.33	0.26
	0.6	17.98	4.95	2.27	1.29	0.84	0.58	0.43	0.33	0.26
	0.7	14.69	4.58	2.17	1.26	0.82	0.58	0.43	0.33	0.26
0.6	0.8	13.78	4.48	2.15	1.25	0.82	0.57	0.43	0.33	0.26
	0.9	14.45	4.56	2.17	1.26	0.82	0.58	0.43	0.33	0.26
	1.0	16.24	4.76	2.22	1.28	0.83	0.58	0.43	0.33	0.26
	0.1	393.66	47.81	13.66	5.50	2.64	1.40	0.78	0.44	0.23
	0.2	146.22	20.32	6.54	2.92	1.54	0.89	0.54	0.33	0.20
	0.3	70.93	11.95	4.37	2.13	1.20	0.73	0.46	0.30	0.18
	0.4	38.66	8.37	3.44	1.80	1.06	0.67	0.43	0.28	0.18
	0.5	23.61	6.70	3.00	1.64	0.99	0.64	0.42	0.28	0.18
	0.6	17.17	5.98	2.82	1.57	0.97	0.62	0.41	0.27	0.18
0.7	0.7	15.64	5.81	2.77	1.56	0.96	0.62	0.41	0.27	0.18
	0.8	17.19	5.98	2.82	1.57	0.97	0.62	0.41	0.27	0.18
	0.9	20.79	6.38	2.92	1.61	0.98	0.63	0.42	0.27	0.18
	1.0	25.82	6.94	3.07	1.66	1.00	0.64	0.42	0.28	0.18
	0.1	409.10	50.88	14.82	6.03	2.90	1.51	0.81	0.41	0.17
	0.2	137.78	20.74	7.01	3.21	1.70	0.96	0.54	0.29	0.13
	0.3	58.74	11.96	4.73	2.39	1.34	0.79	0.47	0.26	0.12
	0.4	27.78	8.52	3.84	2.06	1.21	0.73	0.44	0.24	0.11
	0.5	16.04	7.21	3.50	1.94	1.15	0.71	0.43	0.24	0.11
0.8	0.6	13.91	6.97	3.44	1.92	1.14	0.70	0.42	0.24	0.11
	0.7	17.28	7.35	3.54	1.95	1.16	0.71	0.43	0.24	0.11
	0.8	24.08	8.10	3.73	2.02	1.19	0.72	0.43	0.24	0.11
	0.9	33.17	9.11	3.99	2.12	1.23	0.74	0.44	0.25	0.11
	1.0	43.86	10.30	4.30	2.23	1.28	0.76	0.45	0.25	0.11
	0.1	341.98	45.02	13.75	5.80	2.86	1.50	0.79	0.38	0.12
	0.2	92.97	17.35	6.57	3.21	1.75	0.99	0.55	0.27	0.08
	0.3	26.98	10.02	4.67	2.52	1.46	0.86	0.48	0.24	0.07
	0.4	6.75	7.77	4.09	2.31	1.37	0.81	0.46	0.23	0.06
	0.5	4.83	7.56	4.03	2.29	1.36	0.81	0.46	0.23	0.06
	0.6	12.05	8.36	4.24	2.37	1.39	0.83	0.47	0.23	0.07
	0.7	24.51	9.75	4.60	2.49	1.45	0.85	0.48	0.24	0.07
	0.8	40.23	11.49	5.05	2.66	1.52	0.88	0.50	0.24	0.07
	0.9	58.13	13.48	5.57	2.85	1.60	0.92	0.51	0.25	0.07
	1.0	77.56	15.64	6.13	3.05	1.68	0.96	0.53	0.26	0.08

ED5-3, $D_c > 10$ in., Converging (Continued)

		C_s Values (Concluded)								
		Q_b/Q_c								
A_s/A_c	A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.9	0.1	179.59	28.81	10.06	4.66	2.45	1.34	0.71	0.32	0.07
	0.2	10.77	10.05	5.20	2.91	1.70	0.99	0.55	0.25	0.04
	0.3	−21.27	6.49	4.28	2.57	1.56	0.93	0.52	0.24	0.04
	0.4	−19.11	6.73	4.34	2.60	1.57	0.93	0.52	0.24	0.04
	0.5	−3.28	8.49	4.80	2.76	1.64	0.97	0.54	0.24	0.04
	0.6	19.39	11.01	5.45	3.00	1.74	1.01	0.56	0.25	0.04
	0.7	45.97	13.96	6.21	3.27	1.86	1.07	0.58	0.27	0.05
	0.8	74.99	17.18	7.05	3.58	1.98	1.13	0.61	0.28	0.05
	0.9	105.64	20.59	7.93	3.89	2.12	1.19	0.64	0.29	0.06
1.0	1.0	137.43	24.12	8.85	4.23	2.26	1.26	0.67	0.31	0.06
	0.1	−73.14	2.79	3.92	2.68	1.70	1.04	0.58	0.26	0.03
	0.2	−99.78	−0.17	3.15	2.40	1.58	0.98	0.56	0.25	0.02
	0.3	−75.42	2.54	3.85	2.65	1.69	1.03	0.58	0.26	0.03
	0.4	−38.31	6.66	4.92	3.04	1.86	1.11	0.62	0.28	0.03
	0.5	3.90	11.35	6.14	3.48	2.04	1.20	0.66	0.29	0.04
	0.6	48.66	16.32	7.43	3.94	2.24	1.29	0.70	0.31	0.04
	0.7	94.88	21.46	8.76	4.43	2.45	1.38	0.75	0.33	0.05
	0.8	142.01	26.70	10.12	4.92	2.66	1.48	0.79	0.35	0.06
	0.9	189.74	32.00	11.49	5.41	2.87	1.58	0.84	0.37	0.07
	1.0	237.90	37.35	12.88	5.92	3.08	1.68	0.88	0.39	0.07

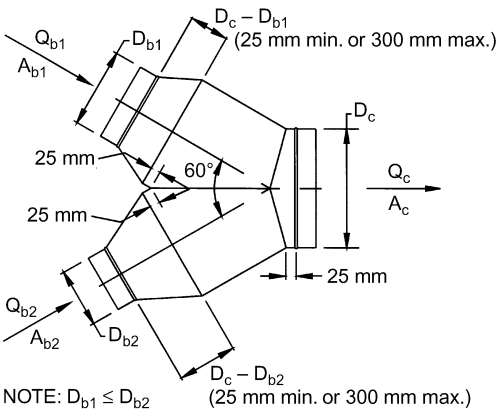
ED5-6 Capped Wye, Branch with 45-Degree Elbow, Branch 90 Degrees to Main, Converging, $r/D_b = 1.5$

A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_b	1.02	0.97	0.93	0.88	0.84	0.79	0.75	0.70	0.66	0.61



ED5-9 Symmetrical Wye, 60 Degree, $D_{b1} \geq D_{b2}$, Converging

		C_{b1} Values								
		Q_{b1}/Q_c								
A_{b1}/A_c	A_{b2}/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	−3.00	−0.50	−0.11	0.06	0.12	0.14	0.14	0.13	0.11
	0.2	−16.00	−3.00	−1.01	0.01	0.32	0.44	0.49	0.56	0.49
0.2	0.2	−11.95	−1.89	−0.09	0.41	0.62	0.74	0.80	0.80	0.79
	0.3	−54.00	−11.25	−3.57	−0.43	−0.22	0.38	0.55	1.41	1.22
0.3	0.2	−45.45	−9.39	−2.44	−0.41	0.33	0.68	0.89	1.03	1.13
	0.3	−16.88	−2.92	−0.09	0.59	0.85	1.02	1.12	1.12	1.22
0.4	0.1	−97.28	−18.48	−6.35	−1.58	−0.57	−0.15	0.23	0.35	0.50
	0.2	−72.04	−14.00	−4.26	−1.24	−0.32	0.09	0.40	0.50	0.62
0.3	0.3	−52.95	−9.91	−2.86	−0.91	−0.06	0.32	0.56	0.64	0.73
	0.4	−40.00	−6.22	−2.15	−0.57	0.19	0.56	0.72	0.79	0.85
0.5	0.1	−167.71	−32.20	−10.05	−2.52	−1.25	−0.26	0.17	0.34	0.36
	0.2	−126.04	−23.80	−7.44	−2.64	−0.85	−0.13	0.16	0.26	0.28
0.3	0.3	−91.07	−16.91	−5.16	−1.73	−0.46	0.04	0.23	0.29	0.28
	0.4	−56.41	−10.07	−2.90	−0.82	−0.07	0.21	0.30	0.31	0.29
	0.5	−30.58	−5.23	−1.06	0.00	0.32	0.43	0.47	0.47	0.41



NOTE: $D_{b1} \leq D_{b2}$ (25 mm min. or 300 mm max.)

ED5-9 Symmetrical Wye, 60 Degree, $D_{b1} \geq D_{b2}$, Converging (Continued)

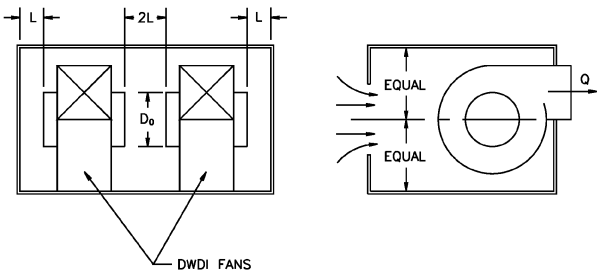
		C_{b1} Values (Concluded)								
		Q_{b1}/Q_c								
A_{b1}/A_c	A_{b2}/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.6	0.1	-299.02	-55.99	-16.77	-5.89	-2.09	-0.54	0.11	0.25	0.23
	0.2	-209.81	-39.31	-12.13	-4.35	-1.54	-0.40	0.06	0.25	0.23
	0.3	-147.43	-27.69	-8.75	-3.20	-1.13	-0.29	0.07	0.23	0.22
	0.4	-85.06	-16.07	-5.38	-2.04	-0.71	-0.17	0.08	0.23	0.22
	0.5	-58.22	-11.03	-3.84	-1.49	-0.50	-0.09	0.11	0.23	0.22
	0.6	-40.57	-7.86	-2.60	-0.99	-0.32	0.00	0.14	0.23	0.22
0.7	0.1	-420.02	-77.23	-23.37	-8.01	-3.30	-1.46	-0.71	-0.10	0.03
	0.2	-285.70	-53.45	-16.65	-6.05	-2.52	-1.02	-0.46	-0.02	0.06
	0.3	-195.01	-37.35	-12.21	-4.72	-1.87	-0.77	-0.14	0.04	0.09
	0.4	-104.16	-21.18	-7.20	-3.23	-1.37	-0.39	-0.10	0.08	0.12
	0.5	-67.21	-13.02	-4.52	-1.78	-0.73	-0.26	-0.03	0.12	0.15
	0.6	-49.01	-9.63	-3.13	-1.28	-0.51	-0.14	-0.02	0.16	0.17
	0.7	-59.33	-10.05	-2.53	-0.54	-0.21	-0.09	-0.01	0.23	0.24
0.8	0.1	-518.26	-95.93	-30.34	-11.09	-4.30	-2.51	-1.58	-0.63	-0.31
	0.2	-373.33	-69.73	-21.93	-8.08	-3.84	-1.96	-1.31	-0.50	-0.24
	0.3	-247.31	-48.35	-16.32	-6.65	-2.89	-1.51	-0.49	-0.30	-0.16
	0.4	-120.88	-26.76	-9.24	-4.80	-2.30	-0.71	-0.39	-0.20	-0.08
	0.5	-72.08	-14.20	-4.98	-2.00	-1.02	-0.53	-0.26	-0.10	0.01
	0.6	-55.91	-11.20	-3.56	-1.60	-0.77	-0.36	-0.13	0.01	0.05
	0.7	-35.96	-7.20	-2.31	-1.08	-0.45	-0.09	0.03	0.11	0.13
	0.8	-16.00	-3.20	-1.07	-0.56	-0.13	0.18	0.20	0.20	0.21
0.9	0.1	-629.39	-114.67	-35.12	-13.73	-6.55	-3.65	-2.25	-1.20	-0.70
	0.2	-473.23	-88.43	-27.99	-11.44	-5.67	-3.21	-2.07	-1.11	-0.65
	0.3	-303.64	-60.65	-21.13	-9.65	-4.91	-2.87	-1.51	-0.95	-0.58
	0.4	-216.44	-44.78	-16.20	-8.35	-4.46	-2.31	-1.43	-0.87	-0.52
	0.5	-116.49	-28.35	-12.15	-6.45	-3.65	-2.19	-1.35	-0.81	-0.47
	0.6	-98.16	-25.31	-10.76	-5.82	-3.48	-2.16	-1.35	-0.81	-0.49
	0.7	-78.15	-21.31	-9.54	-5.37	-3.28	-1.99	-1.25	-0.75	-0.44
	0.8	-58.15	-17.32	-8.33	-4.93	-3.08	-1.82	-1.15	-0.69	-0.39
	0.9	-72.90	-18.23	-8.10	-4.56	-2.92	-1.92	-1.29	-0.66	-0.39
1.0	0.1	-677.01	-124.30	-37.45	-16.24	-8.10	-4.89	-3.06	-1.95	-1.23
	0.2	-585.16	-109.39	-34.85	-15.63	-8.00	-4.86	-3.06	-1.95	-1.23
	0.3	-363.31	-74.20	-26.68	-13.44	-7.60	-4.72	-2.96	-1.88	-1.17
	0.4	-345.54	-68.75	-25.56	-13.13	-7.40	-4.58	-2.92	-1.84	-1.16
	0.5	-175.00	-47.50	-22.22	-12.81	-7.40	-4.58	-2.92	-1.84	-1.16
	0.6	-155.00	-45.00	-21.00	-11.88	-7.40	-4.77	-3.13	-2.02	-1.28
	0.7	-136.79	-41.38	-19.95	-11.58	-7.40	-4.77	-3.13	-2.02	-1.28
	0.8	-118.58	-37.76	-18.91	-11.29	-7.40	-4.77	-3.13	-2.02	-1.28
	0.9	-100.29	-34.13	-17.90	-10.99	-7.39	-4.77	-3.13	-2.02	-1.28
	1.0	-82.00	-30.50	-16.89	-10.69	-7.39	-4.77	-3.13	-2.02	-1.28
		C_{b1} Values								
		Q_{b2}/Q_c								
A_{b1}/A_c	A_{b2}/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.1	-3.00	-0.50	-0.11	0.06	0.12	0.14	0.14	0.13	0.11
0.2	0.1	-2.70	-0.04	0.23	0.15	0.16	0.18	0.20	0.17	0.16
	0.2	-11.95	-1.89	-0.09	0.41	0.62	0.74	0.80	0.80	0.79
0.3	0.1	-2.12	0.12	0.33	0.22	0.22	0.23	0.26	0.22	0.22
	0.2	-2.00	-0.30	0.22	0.42	0.61	0.73	0.78	0.77	0.76
	0.3	-16.88	-2.92	-0.09	0.59	0.85	1.02	1.12	1.12	1.22
0.4	0.1	-2.38	-0.17	0.13	0.23	0.25	0.24	0.23	0.24	0.24
	0.2	-6.95	-1.00	0.16	0.53	0.67	0.71	0.72	0.72	0.71
	0.3	-16.21	-2.90	-0.44	0.40	0.79	0.98	1.05	1.06	1.05
	0.4	-40.00	-6.22	-2.15	-0.57	0.19	0.56	0.72	0.79	0.85
0.5	0.1	-1.58	0.11	0.33	0.31	0.32	0.33	0.34	0.32	0.32
	0.2	-4.82	-0.01	0.56	0.71	0.82	0.89	0.92	0.90	0.89
	0.3	-12.27	-1.17	0.44	0.88	1.11	1.25	1.29	1.25	1.23
	0.4	-22.40	-2.93	-0.21	0.48	0.73	0.84	0.88	0.87	0.82
	0.5	-30.58	-5.23	-1.06	0.00	0.32	0.43	0.47	0.46	0.41

ED5-9 Symmetrical Wye, 60 Degree, $D_{b1} \geq D_{b2}$, Converging (Continued)

		C_{b1} Values (Concluded)								
		Q_{b2}/Q_c								
A_{b1}/A_c	A_{b2}/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.6	0.1	-0.78	0.11	0.32	0.40	0.42	0.43	0.43	0.42	0.42
	0.2	-3.68	0.07	0.77	0.98	1.06	1.08	1.08	1.06	1.04
	0.3	-9.06	-0.55	0.86	1.27	1.42	1.48	1.49	1.46	1.42
	0.4	-17.62	-2.12	0.06	0.60	0.83	0.95	0.98	0.95	0.91
	0.5	-28.00	-4.26	-0.99	-0.16	0.20	0.39	0.45	0.41	0.38
	0.6	-40.57	-7.86	-2.60	-0.99	-0.32	0.00	0.14	0.23	0.22
0.7	0.1	-0.12	0.17	0.22	0.34	0.39	0.40	0.40	0.39	0.39
	0.2	-1.24	0.33	0.55	0.86	0.98	1.02	1.04	1.03	1.02
	0.3	-4.03	0.06	0.73	1.20	1.39	1.47	1.49	1.47	1.44
	0.4	-9.77	-0.84	0.30	0.36	0.71	0.89	0.97	0.98	0.97
	0.5	-15.88	-2.51	-0.34	-0.06	0.21	0.51	0.65	0.68	0.70
	0.6	-23.89	-4.60	-1.54	-0.55	-0.51	-0.04	0.21	0.37	0.44
0.8	0.1	-59.33	-10.05	-2.53	-0.54	-0.21	-0.09	-0.01	0.23	0.24
	0.2	0.53	0.24	0.12	0.29	0.36	0.37	0.37	0.36	0.35
	0.3	1.20	0.60	0.33	0.73	0.90	0.97	1.00	1.00	0.99
	0.4	0.99	0.68	0.60	1.13	1.36	1.45	1.49	1.48	1.46
	0.5	-1.92	0.44	0.53	0.11	0.59	0.83	0.96	1.01	1.03
	0.6	-3.75	-0.75	0.31	0.05	0.22	0.62	0.84	0.96	1.03
0.9	0.1	-7.20	-1.35	-0.48	-0.11	-0.70	-0.09	0.28	0.51	0.65
	0.2	-11.03	-2.14	-0.74	-0.29	-2.11	0.01	0.26	0.42	0.52
	0.3	-16.00	-3.20	-1.07	-0.56	-0.13	0.18	0.20	0.20	0.21
	0.4	-0.13	0.32	0.23	0.32	0.36	0.36	0.36	0.35	0.34
	0.5	-0.98	0.80	0.61	0.85	0.97	1.03	1.04	1.03	1.01
	0.6	-3.06	0.35	0.55	1.06	1.32	1.44	1.49	1.49	1.48
1.0	0.1	-7.36	-2.06	-1.01	-0.12	0.47	0.78	0.95	1.04	1.09
	0.2	-11.88	-4.00	-1.88	-0.98	-0.30	0.24	0.56	0.75	0.87
	0.3	-18.18	-5.99	-3.20	-1.67	-1.08	-0.30	0.18	0.49	0.70
	0.4	-25.36	-8.36	-4.42	-2.45	-2.82	-0.55	-0.01	0.34	0.56
	0.5	-33.92	-11.20	-5.87	-3.43	-1.94	-0.90	-0.35	0.00	0.24
	0.6	-72.90	-18.23	-8.10	-4.56	-2.92	-1.92	-1.29	-0.66	-0.39
	0.1	-0.78	0.40	0.33	0.35	0.36	0.36	0.35	0.34	0.33
	0.2	-3.16	1.00	0.89	0.96	1.05	1.08	1.08	1.06	1.04
	0.3	-7.11	0.02	0.50	0.99	1.29	1.43	1.49	1.50	1.50
	0.4	-12.80	-4.56	-2.56	-0.36	0.35	0.72	0.93	1.07	1.15
	0.5	-20.00	-7.25	-4.06	-2.02	-0.81	-0.14	0.27	0.54	0.72
	0.6	-29.16	-10.62	-5.92	-3.24	-1.47	-0.50	0.09	0.48	0.74
	0.1	-39.69	-14.58	-8.11	-4.61	-3.53	-1.10	-0.28	0.25	0.60
	0.2	-51.84	-19.20	-10.67	-6.30	-3.75	-1.97	-0.89	-0.20	0.27
	0.3	-66.02	-24.50	-13.59	-8.31	-5.93	-3.18	-1.83	-0.95	-0.35
	0.4	-82.00	-30.50	-16.89	-10.69	-7.39	-4.77	-3.13	-2.02	-1.28
	0.5									
	0.6									

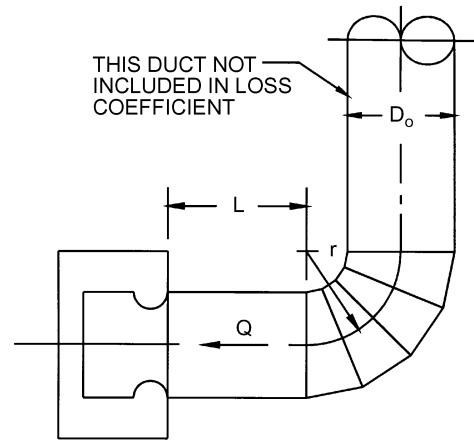
ED7-1 Centrifugal Fan Located in Plenum or Cabinet

L/D_o	0.30	0.40	0.50	0.75
C_o	0.80	0.53	0.40	0.22



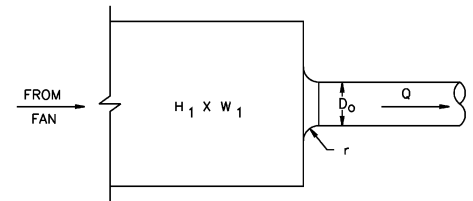
ED7-2 Fan Inlet, Centrifugal, SWSI, with 4 Gore Elbow

r/D_o	C_o Values			
	0.0	2.0	5.0	10.0
	L/D_o			
0.50	1.80	1.00	0.53	0.53
0.75	1.40	0.80	0.40	0.40
1.00	1.20	0.67	0.33	0.33
1.50	1.10	0.60	0.33	0.33
2.00	1.00	0.53	0.33	0.33
3.00	0.67	0.40	0.22	0.22



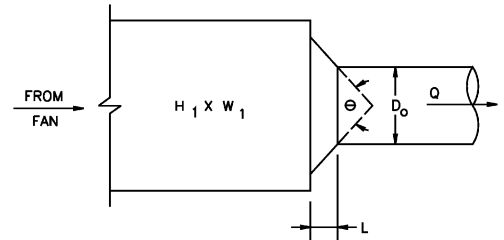
SD1-1 Bellmouth, Plenum to Round, Supply Air Systems

r/D_o	0.0	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.16	0.20	10.0
C_o	0.50	0.44	0.37	0.31	0.26	0.22	0.20	0.15	0.12	0.09	0.06	0.03	0.03



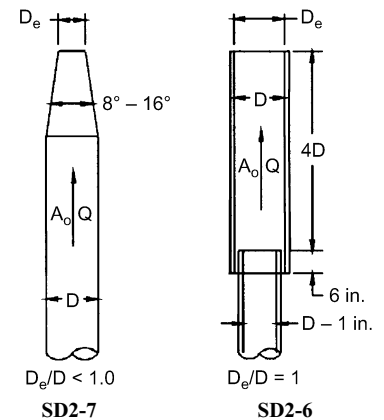
SD1-2 Conical Bellmouth/Sudden Contraction, Plenum to Round, Supply Air Systems

L/D_o	C_o Values								
	0	10	20	30	θ 45	60	100	140	180
0.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.025	0.50	0.47	0.45	0.43	0.41	0.40	0.42	0.45	0.50
0.05	0.50	0.45	0.41	0.36	0.33	0.30	0.35	0.42	0.50
0.075	0.50	0.42	0.35	0.30	0.26	0.23	0.30	0.40	0.50
0.10	0.50	0.39	0.32	0.25	0.22	0.18	0.27	0.38	0.50
0.15	0.50	0.37	0.27	0.20	0.16	0.15	0.25	0.37	0.50
0.60	0.50	0.27	0.18	0.13	0.11	0.12	0.23	0.36	0.50

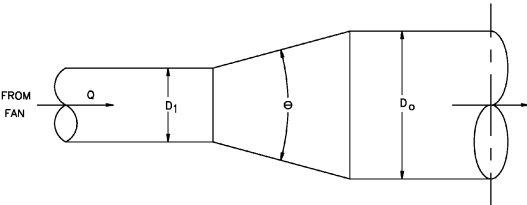


SD2-6 and SD2-7 Stackheads

D_e/D	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_o	130.	41.02	16.80	8.10	4.37	2.56	1.60	1.00

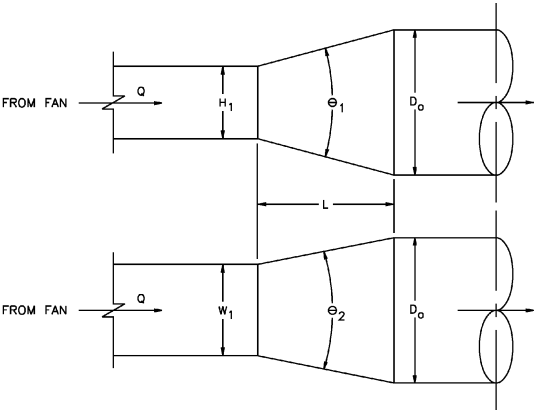


SD4-1 Transition, Round to Round, Supply Air Systems



<i>C_o</i> Values													
θ													
<i>A_o</i> / <i>A_i</i>	0	3	5	10	15	20	30	45	60	90	120	150	180
0.10	0.0	0.12	0.09	0.05	0.05	0.05	0.05	0.06	0.08	0.19	0.29	0.37	0.43
0.167	0.0	0.11	0.08	0.05	0.04	0.04	0.04	0.06	0.07	0.18	0.28	0.36	0.42
0.25	0.0	0.10	0.07	0.05	0.04	0.04	0.04	0.06	0.07	0.17	0.27	0.35	0.41
0.39	0.0	0.10	0.07	0.05	0.05	0.05	0.05	0.06	0.06	0.16	0.25	0.32	0.36
0.50	0.0	0.07	0.06	0.05	0.05	0.05	0.05	0.06	0.07	0.13	0.18	0.23	0.24
0.64	0.0	0.07	0.07	0.05	0.04	0.04	0.04	0.05	0.06	0.09	0.13	0.17	0.19
1.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	0.0	0.59	0.51	0.43	0.52	0.76	1.26	1.32	1.30	1.26	1.23	1.21	1.19
4.0	0.0	3.15	2.78	2.51	3.38	4.77	7.38	9.70	10.88	10.29	10.08	9.96	9.84
6.0	0.0	6.55	6.08	6.44	9.14	11.92	17.35	23.58	27.58	26.71	26.32	26.15	25.99
10.0	0.0	19.50	18.25	20.00	27.30	38.00	58.50	76.00	80.00	83.40	84.00	83.35	82.70
16.0	0.0	45.82	44.80	50.18	73.73	96.77	153.60	215.04	225.28	225.28	225.28	225.28	225.28

SD4-2 Transition, Rectangular to Round, Supply Air Systems

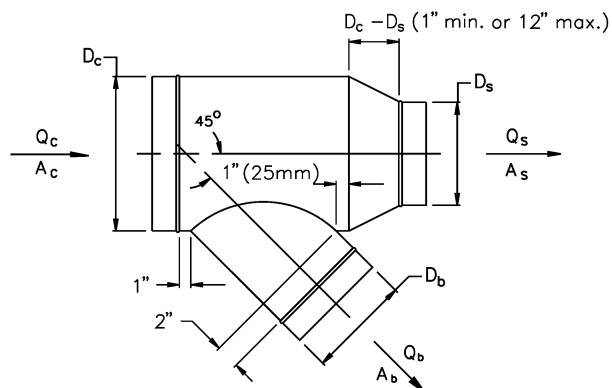


<i>C_o</i> Values													
θ													
<i>A_o</i> / <i>A_i</i>	0	3	5	10	15	20	30	45	60	90	120	150	180
0.10	0.0	0.12	0.09	0.05	0.05	0.05	0.05	0.06	0.08	0.19	0.29	0.37	0.43
0.167	0.0	0.11	0.08	0.05	0.05	0.05	0.05	0.06	0.07	0.19	0.28	0.37	0.42
0.25	0.0	0.10	0.07	0.05	0.05	0.05	0.05	0.06	0.07	0.17	0.27	0.35	0.41
0.50	0.0	0.08	0.07	0.06	0.07	0.06	0.05	0.06	0.07	0.13	0.19	0.23	0.24
1.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	0.0	0.57	0.55	0.61	0.87	1.00	1.20	1.30	1.30	1.30	1.28	1.24	1.20
4.0	0.0	2.60	2.84	3.92	5.72	7.20	8.32	9.28	9.92	10.24	10.24	10.24	10.24
6.0	0.0	6.57	6.75	10.62	15.84	18.90	22.50	25.74	27.90	28.44	28.44	28.35	28.26
10.0	0.0	17.25	18.75	30.00	45.00	53.00	63.50	75.00	84.00	89.00	89.00	88.50	88.00
16.0	0.0	42.75	48.13	77.57	116.74	136.45	164.10	196.86	224.26	241.92	241.92	240.38	238.59

SD5-1 Wye, 45 Degree, Diverging

C_b Values									
Q_b/Q_c									
A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.38	0.38	0.48	0.45	0.40	0.36	0.32	0.29	0.26
0.2	2.25	0.38	0.31	0.38	0.47	0.48	0.47	0.45	0.42
0.3	6.29	1.02	0.38	0.30	0.33	0.38	0.45	0.48	0.48
0.4	12.41	2.25	0.74	0.38	0.30	0.31	0.35	0.38	0.44
0.5	20.58	4.01	1.37	0.62	0.38	0.30	0.30	0.32	0.36
0.6	30.78	6.29	2.25	1.02	0.56	0.38	0.31	0.30	0.31
0.7	43.02	9.10	3.36	1.57	0.85	0.52	0.38	0.31	0.30
0.8	57.29	12.41	4.71	2.25	1.22	0.74	0.50	0.38	0.32
0.9	73.59	16.24	6.29	3.06	1.69	1.02	0.67	0.48	0.38
1.0	91.92	20.58	8.11	4.01	2.25	1.37	0.90	0.62	0.47

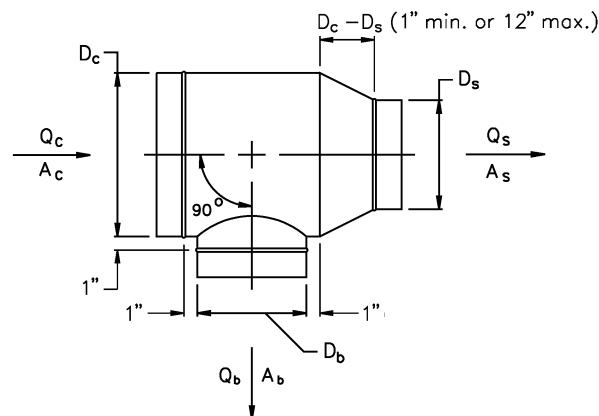
C_s Values									
Q_s/Q_c									
A_s/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.13	0.24	0.57	0.74	0.74	0.70	0.65	0.60	0.56
0.2	0.20	0.13	0.15	0.16	0.28	0.57	0.69	0.74	0.75
0.3	0.90	0.14	0.13	0.14	0.15	0.16	0.20	0.42	0.57
0.4	2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5	6.25	0.38	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6	11.88	0.90	0.20	0.14	0.14	0.13	0.14	0.14	0.15
0.7	18.62	1.72	0.33	0.18	0.16	0.14	0.13	0.15	0.14
0.8	26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13	0.14
0.9	36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14	0.13
1.0	45.00	6.25	1.44	0.38	0.20	0.17	0.12	0.13	0.14



SD5-9 Tee, Diverging

C_b Values									
Q_b/Q_c									
A_b/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	1.20	0.62	0.80	1.28	1.99	2.92	4.07	5.44	7.02
0.2	4.10	1.20	0.72	0.62	0.66	0.80	1.01	1.28	1.60
0.3	8.99	2.40	1.20	0.81	0.66	0.62	0.64	0.70	0.80
0.4	15.89	4.10	1.94	1.20	0.88	0.72	0.64	0.62	0.63
0.5	24.80	6.29	2.91	1.74	1.20	0.92	0.77	0.68	0.63
0.6	35.73	8.99	4.10	2.40	1.62	1.20	0.96	0.81	0.72
0.7	48.67	12.19	5.51	3.19	2.12	1.55	1.20	0.99	0.85
0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.49	1.20	1.01
0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.46	1.20
1.0	99.60	24.80	11.07	6.29	4.10	2.91	2.20	1.74	1.43

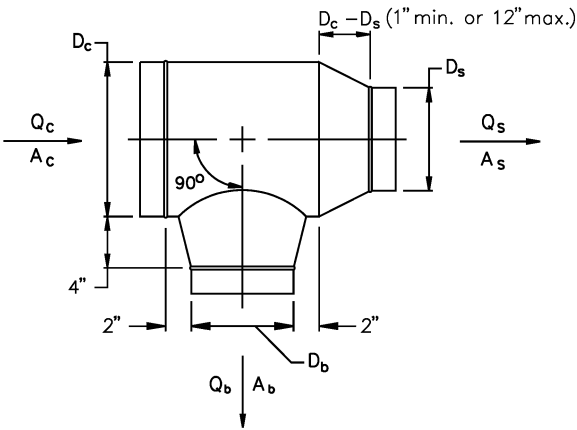
C_s Values									
Q_s/Q_c									
A_s/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.13	0.24	0.57	0.74	0.74	0.70	0.65	0.60	0.56
0.2	0.20	0.13	0.15	0.16	0.28	0.57	0.69	0.74	0.75
0.3	0.90	0.14	0.13	0.14	0.15	0.16	0.20	0.42	0.57
0.4	2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5	6.25	0.38	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6	11.88	0.90	0.20	0.14	0.14	0.13	0.14	0.14	0.15
0.7	18.62	1.72	0.33	0.18	0.16	0.14	0.13	0.15	0.14
0.8	26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13	0.14
0.9	36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14	0.13
1.0	45.00	6.25	1.44	0.38	0.20	0.17	0.12	0.13	0.14



SD5-10 Tee, Conical Branch Tapered into Body, Diverging

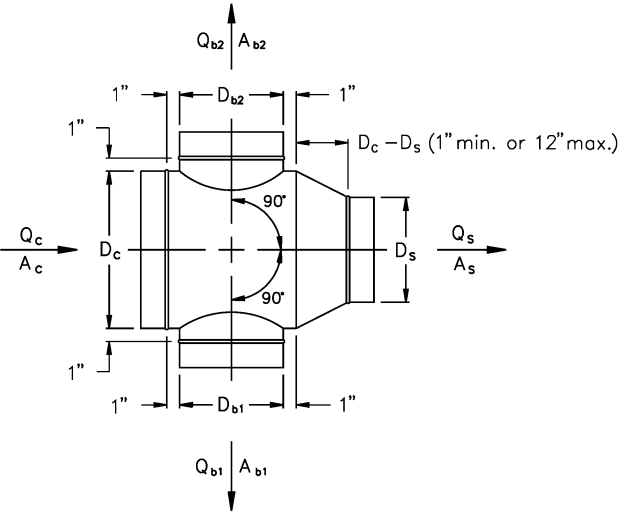
<i>C_b</i> Values									
<i>A_b/A_c</i>	<i>Q_b/Q_c</i>								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.65	0.24	0.15	0.11	0.09	0.07	0.06	0.05	0.05
0.2	2.98	0.65	0.33	0.24	0.18	0.15	0.13	0.11	0.10
0.3	7.36	1.56	0.65	0.39	0.29	0.24	0.20	0.17	0.15
0.4	13.78	2.98	1.20	0.65	0.43	0.33	0.27	0.24	0.21
0.5	22.24	4.92	1.98	1.04	0.65	0.47	0.36	0.31	0.27
0.6	32.73	7.36	2.98	1.56	0.96	0.65	0.49	0.39	0.33
0.7	45.26	10.32	4.21	2.21	1.34	0.90	0.65	0.51	0.42
0.8	59.82	13.78	5.67	2.98	1.80	1.20	0.86	0.65	0.52
0.9	76.41	17.75	7.36	3.88	2.35	1.56	1.11	0.83	0.65
1.0	95.04	22.24	9.27	4.92	2.98	1.98	1.40	1.04	0.81

<i>C_s</i> Values									
<i>A_s/A_c</i>	<i>Q_s/Q_c</i>								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.13	0.24	0.57	0.74	0.74	0.70	0.65	0.60	0.56
0.2	0.20	0.13	0.15	0.16	0.28	0.57	0.69	0.74	0.75
0.3	0.90	0.14	0.13	0.14	0.15	0.16	0.20	0.42	0.57
0.4	2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5	6.25	0.38	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6	11.88	0.90	0.20	0.14	0.14	0.13	0.14	0.14	0.15
0.7	18.62	1.72	0.33	0.18	0.16	0.14	0.13	0.15	0.14
0.8	26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13	0.14
0.9	36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14	0.13
1.0	45.00	6.25	1.44	0.38	0.20	0.17	0.12	0.13	0.14



SD5-24 Cross, Diverging

<i>C_{b1}</i> Values										
<i>A_s/A_c</i>	<i>A_{b1}/A_c</i>	<i>Q_{b1}/Q_c</i>								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.20	0.1	2.07	2.08	1.62	1.30	1.99	2.92	4.07	5.44	7.02
	0.2	4.10	2.07	2.31	2.08	1.83	1.62	1.44	1.30	1.60
	0.3	8.99	2.40	2.07	2.34	2.24	2.08	1.91	1.76	1.62
	0.4	15.89	4.10	1.94	2.07	2.32	2.31	2.21	2.08	1.95
	0.5	24.80	6.29	2.91	1.74	2.07	2.30	2.33	2.27	2.18
	0.6	35.73	8.99	4.10	2.40	1.62	2.07	2.29	2.34	2.31
	0.7	48.67	12.19	5.51	3.19	2.12	1.60	2.07	2.27	2.33
	0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.68	2.07	2.25
	0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.74	2.07
	1.0	99.60	24.80	11.07	6.29	4.10	2.91	2.20	1.74	1.78
0.35	0.1	1.20	3.25	3.11	2.69	2.32	2.92	4.07	5.44	7.02
	0.2	4.10	1.20	2.44	3.25	3.28	3.11	2.90	2.69	2.49
	0.3	8.99	2.40	1.20	1.69	2.88	3.25	3.31	3.23	3.11
	0.4	15.89	4.10	1.94	1.20	1.12	2.44	3.02	3.25	3.31
	0.5	24.80	6.29	2.91	1.74	1.20	0.92	2.04	2.73	3.09
	0.6	35.73	8.99	4.10	2.40	1.62	1.20	0.96	1.69	2.44
	0.7	48.67	12.19	5.51	3.19	2.12	1.55	1.20	0.99	1.38
	0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.49	1.20	1.01
	0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.46	1.20
	1.0	99.60	24.80	11.07	6.29	4.10	2.91	2.20	1.74	1.43
0.55	0.1	1.20	0.62	0.80	1.28	1.99	2.92	4.07	5.44	7.02
	0.2	4.10	1.20	0.72	0.62	0.66	0.80	1.01	1.28	1.60
	0.3	8.99	2.40	1.20	0.81	0.66	0.62	0.64	0.70	0.80
	0.4	15.89	4.10	1.94	1.20	0.88	0.72	0.64	0.62	0.63
	0.5	24.80	6.29	2.91	1.74	1.20	0.92	0.77	0.68	0.63
	0.6	35.73	8.99	4.10	2.40	1.62	1.20	0.96	0.81	0.72
	0.7	48.67	12.19	5.51	3.19	2.12	1.55	1.20	0.99	0.85
	0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.49	1.20	1.01
	0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.46	1.20
	1.0	99.60	24.80	11.07	6.29	4.10	2.91	2.20	1.74	1.43



SD5-24 Cross, Diverging (Continued)

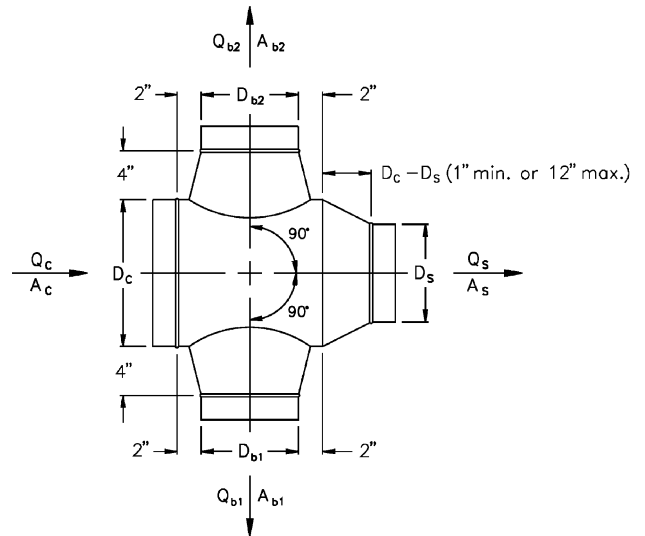
		C_{b1} Values (Concluded)								
		Q_{b1}/Q_c								
A_s/A_c	A_{b1}/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.80	0.1	1.20	0.62	0.80	1.28	1.99	2.92	4.07	5.44	7.02
	0.2	4.10	1.20	0.72	0.62	0.66	0.80	1.01	1.28	1.60
	0.3	8.99	2.40	1.20	0.81	0.66	0.62	0.64	0.70	0.80
	0.4	15.89	4.10	1.94	1.20	0.88	0.72	0.64	0.62	0.63
	0.5	24.80	6.29	2.91	1.74	1.20	0.92	0.77	0.68	0.63
	0.6	35.73	8.99	4.10	2.40	1.62	1.20	0.96	0.81	0.72
	0.7	48.67	12.19	5.51	3.19	2.12	1.55	1.20	0.99	0.85
	0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.49	1.20	1.01
	0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.46	1.20
	1.0	99.60	24.80	11.07	6.29	4.10	2.91	2.20	1.74	1.43
1.00	0.1	1.20	0.62	0.80	1.28	1.99	2.92	4.07	5.44	7.02
	0.2	4.10	1.20	0.72	0.62	0.66	0.80	1.01	1.28	1.60
	0.3	8.99	2.40	1.20	0.81	0.66	0.62	0.64	0.70	0.80
	0.4	15.89	4.10	1.94	1.20	0.88	0.72	0.64	0.62	0.63
	0.5	24.80	6.29	2.91	1.74	1.20	0.92	0.77	0.68	0.63
	0.6	35.73	8.99	4.10	2.40	1.62	1.20	0.96	0.81	0.72
	0.7	48.67	12.19	5.51	3.19	2.12	1.55	1.20	0.99	0.85
	0.8	63.63	15.89	7.14	4.10	2.70	1.94	1.49	1.20	1.01
	0.9	80.60	20.10	8.99	5.13	3.36	2.40	1.83	1.46	1.20
	1.0	99.60	24.80	11.07	6.29	4.10	2.91	2.20	1.74	1.43

		C_s Values								
		Q_s/Q_c								
A_s/A_c		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1		0.13	0.24	0.57	0.74	0.74	0.70	0.65	0.60	0.56
0.2		0.20	0.13	0.15	0.16	0.28	0.57	0.69	0.74	0.75
0.3		0.90	0.14	0.13	0.14	0.15	0.16	0.20	0.42	0.57
0.4		2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5		6.25	0.38	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6		11.88	0.90	0.20	0.14	0.14	0.13	0.14	0.14	0.15
0.7		18.62	1.72	0.33	0.18	0.16	0.14	0.13	0.15	0.14
0.8		26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13	0.14
0.9		36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14	0.13
1.0		45.00	6.25	1.44	0.38	0.20	0.17	0.12	0.13	0.14

For the other branch, subscripts 1 and 2 change places.

SD5-25 Cross, Conical Branches Tapered into Body, Diverging

		C_{b1} Values								
		Q_{b1}/Q_c								
A_s/A_c	A_{b1}/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.20	0.1	2.07	2.08	1.62	1.30	1.08	0.93	0.81	0.72	0.64
	0.2	2.98	2.07	2.31	2.08	1.83	1.62	1.44	1.30	1.18
	0.3	7.36	1.56	2.07	2.34	2.24	2.08	1.91	1.76	1.62
	0.4	13.78	2.98	1.20	2.07	2.32	2.31	2.21	2.08	1.95
	0.5	22.24	4.92	1.98	1.28	2.07	2.30	2.33	2.27	2.18
	0.6	32.73	7.36	2.98	1.56	1.48	2.07	2.29	2.34	2.31
	0.7	45.26	10.32	4.21	2.21	1.34	1.60	2.07	2.27	2.33
	0.8	59.82	13.78	5.67	2.98	1.80	1.20	1.68	2.07	2.25
	0.9	76.41	17.75	7.36	3.88	2.35	1.56	1.12	1.74	2.07
	1.0	95.04	22.24	9.27	4.92	2.98	1.98	1.40	1.28	1.78
0.35	0.1	0.65	3.25	3.11	2.69	2.32	2.03	1.80	1.61	1.46
	0.2	2.98	0.65	2.44	3.25	3.28	3.11	2.90	2.69	2.49
	0.3	7.36	1.56	0.65	1.69	2.88	3.25	3.31	3.23	3.11
	0.4	13.78	2.98	1.20	0.65	1.12	2.44	3.02	3.25	3.31
	0.5	22.24	4.92	1.98	1.04	0.65	0.69	2.04	2.73	3.09
	0.6	32.73	7.36	2.98	1.56	0.96	0.65	0.49	1.69	2.44
	0.7	45.26	10.32	4.21	2.21	1.34	0.90	0.65	0.51	1.38
	0.8	59.82	13.78	5.67	2.98	1.80	1.20	0.86	0.65	0.52
	0.9	76.41	17.75	7.36	3.88	2.35	1.56	1.11	0.83	0.65
	1.0	95.04	22.24	9.27	4.92	2.98	1.98	1.40	1.04	0.81
0.55	0.1	0.65	1.50	1.56	1.38	1.20	1.06	0.94	0.84	0.77
	0.2	2.98	0.65	0.89	1.50	1.60	1.56	1.47	1.38	1.28
	0.3	7.36	1.56	0.65	0.39	1.20	1.50	1.59	1.59	1.56
	0.4	13.78	2.98	1.20	0.65	0.43	0.89	1.31	1.50	1.58
	0.5	22.24	4.92	1.98	1.04	0.65	0.47	0.61	1.09	1.36
	0.6	32.73	7.36	2.98	1.56	0.96	0.65	0.49	0.39	0.89
	0.7	45.26	10.32	4.21	2.21	1.34	0.90	0.65	0.51	0.42
	0.8	59.82	13.78	5.67	2.98	1.80	1.20	0.86	0.65	0.52
	0.9	76.41	17.75	7.36	3.88	2.35	1.56	1.11	0.83	0.65
	1.0	95.04	22.24	9.27	4.92	2.98	1.98	1.40	1.04	0.81



SD5-25 Cross, Conical Branches Tapered into Body, Diverging (Continued)

<i>C_{b1}</i> Values (Concluded)										
		<i>Q_{b1}/Q_c</i>								
<i>A_s/A_c</i>	<i>A_{b1}/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.80	0.1	0.65	0.24	0.15	0.11	0.09	0.07	0.06	0.05	0.05
	0.2	2.98	0.65	0.33	0.24	0.18	0.15	0.13	0.11	0.10
	0.3	7.36	1.56	0.65	0.39	0.29	0.24	0.20	0.17	0.15
	0.4	13.78	2.98	1.20	0.65	0.43	0.33	0.27	0.24	0.21
	0.5	22.24	4.92	1.98	1.04	0.65	0.47	0.36	0.31	0.27
	0.6	32.73	7.36	2.98	1.56	0.96	0.65	0.49	0.39	0.33
	0.7	45.26	10.32	4.21	2.21	1.34	0.90	0.65	0.51	0.42
	0.8	59.82	13.78	5.67	2.98	1.80	1.20	0.86	0.65	0.52
	0.9	76.41	17.75	7.36	3.88	2.35	1.56	1.11	0.83	0.65
	1.0	95.04	22.24	9.27	4.92	2.98	1.98	1.40	1.04	0.81
1.00	0.1	0.65	0.24	0.15	0.11	0.09	0.07	0.06	0.05	0.05
	0.2	2.98	0.65	0.33	0.24	0.18	0.15	0.13	0.11	0.10
	0.3	7.36	1.56	0.65	0.39	0.29	0.24	0.20	0.17	0.15
	0.4	13.78	2.98	1.20	0.65	0.43	0.33	0.27	0.24	0.21
	0.5	22.24	4.92	1.98	1.04	0.65	0.47	0.36	0.31	0.27
	0.6	32.73	7.36	2.98	1.56	0.96	0.65	0.49	0.39	0.33
	0.7	45.26	10.32	4.21	2.21	1.34	0.90	0.65	0.51	0.42
	0.8	59.82	13.78	5.67	2.98	1.80	1.20	0.86	0.65	0.52
	0.9	76.41	17.75	7.36	3.88	2.35	1.56	1.11	0.83	0.65
	1.0	95.04	22.24	9.27	4.92	2.98	1.98	1.40	1.04	0.81

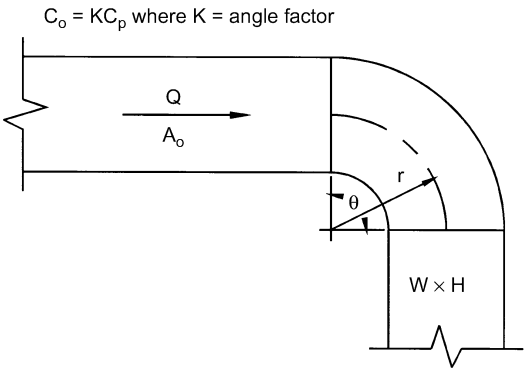
<i>C_s</i> Values										
		<i>Q_s/Q_c</i>								
<i>A_s/A_c</i>		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1		0.13	0.24	0.57	0.74	0.74	0.70	0.65	0.60	0.56
0.2		0.20	0.13	0.15	0.16	0.28	0.57	0.69	0.74	0.75
0.3		0.90	0.14	0.13	0.14	0.15	0.16	0.20	0.42	0.57
0.4		2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5		6.25	0.38	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6		11.88	0.90	0.20	0.14	0.14	0.13	0.14	0.14	0.15
0.7		18.62	1.72	0.33	0.18	0.16	0.14	0.13	0.15	0.14
0.8		26.88	2.88	0.50	0.20	0.15	0.14	0.13	0.13	0.14
0.9		36.45	4.46	0.90	0.30	0.19	0.16	0.15	0.14	0.13
1.0		45.00	6.25	1.44	0.38	0.20	0.17	0.12	0.13	0.14

For the other branch, subscripts 1 and 2 change places

RECTANGULAR FITTINGS

CR3-1 Elbow, Smooth Radius, Without Vanes

C_p Values											
	H/W										
r/W	0.25	0.50	0.75	1.0	1.50	2.0	3.0	4.0	5.0	6.0	8.0
0.50	1.53	1.38	1.29	1.18	1.06	1.00	1.00	1.06	1.12	1.16	1.18
0.75	0.57	0.52	0.48	0.44	0.40	0.39	0.39	0.40	0.42	0.43	0.44
1.00	0.27	0.25	0.23	0.21	0.19	0.18	0.18	0.19	0.20	0.21	0.21
1.50	0.22	0.20	0.19	0.17	0.15	0.14	0.14	0.15	0.16	0.17	0.17
2.00	0.20	0.18	0.16	0.15	0.14	0.13	0.13	0.14	0.14	0.15	0.15
Angle Factor K											
θ	0	20	30	45	60	75	90	110	130	150	180
K	0.0	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40



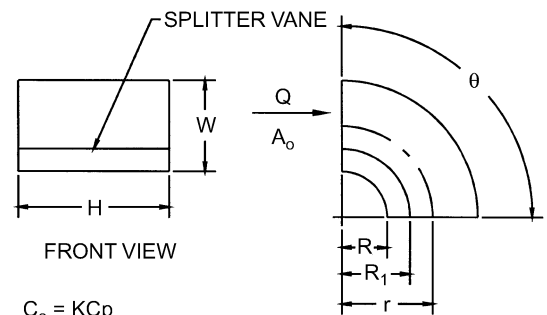
CR3-3 Elbow, Smooth Radius, One Splitter Vane

C_p Values											
	H/W										
r/W	0.25	0.50	1.0	1.50	2.0	3.0	4.0	5.0	6.0	7.0	8.0
0.55	0.52	0.40	0.43	0.49	0.55	0.66	0.75	0.84	0.93	1.01	1.09
0.60	0.36	0.27	0.25	0.28	0.30	0.35	0.39	0.42	0.46	0.49	0.52
0.65	0.28	0.21	0.18	0.19	0.20	0.22	0.25	0.26	0.28	0.30	0.32
0.70	0.22	0.16	0.14	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21
0.75	0.18	0.13	0.11	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.15
0.80	0.15	0.11	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12
0.85	0.13	0.09	0.08	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09
0.90	0.11	0.08	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
0.95	0.10	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
1.00	0.09	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05

Angle Factor K					
θ	0	30	45	60	90
K	0.00	0.45	0.60	0.78	1.00

Curve Ratio CR										
r/W	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.0
CR	0.218	0.302	0.361	0.408	0.447	0.480	0.509	0.535	0.557	0.577

Throat Radius/Width Ratio (R/W)										
r/W	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.0
R/W	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50



$$C_o = KC_p$$

$$R_1 = R/CR$$

where

R = throat radius

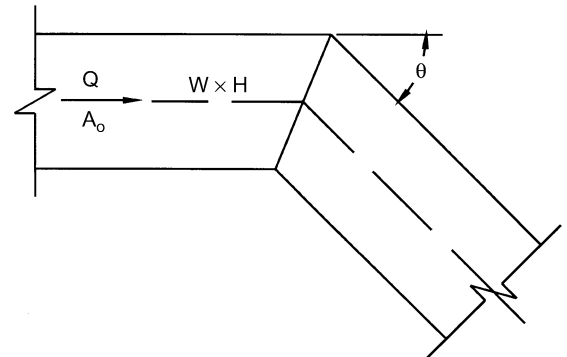
R_1 = splitter vane radius

CR = curve ratio

K = angle factor

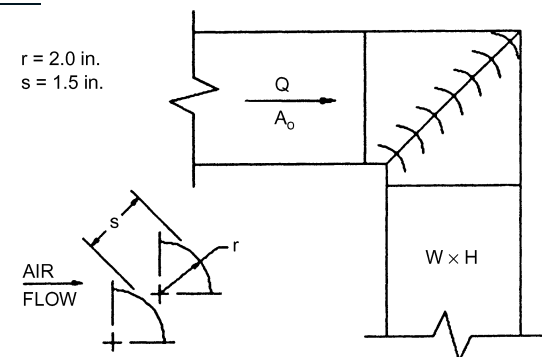
CR3-6 Elbow, Mitered

C_o Values											
	H/W										
θ	0.25	0.50	0.75	1.00	1.50	2.0	3.0	4.0	5.0	6.0	8.0
20	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
30	0.18	0.17	0.17	0.16	0.15	0.15	0.13	0.13	0.12	0.12	0.11
45	0.38	0.37	0.36	0.34	0.33	0.31	0.28	0.27	0.26	0.25	0.24
60	0.60	0.59	0.57	0.55	0.52	0.49	0.46	0.43	0.41	0.39	0.38
75	0.89	0.87	0.84	0.81	0.77	0.73	0.67	0.63	0.61	0.58	0.57
90	1.30	1.27	1.23	1.18	1.13	1.07	0.98	0.92	0.89	0.85	0.83



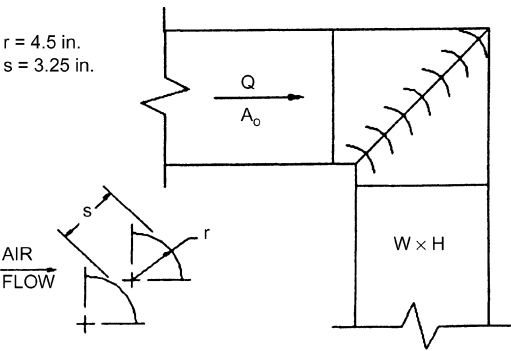
CR3-9 Elbow, Mitered, 90 Degree, Single-Thickness Vanes (1.5 in. Vane Spacing)

$$C_o = 0.11$$



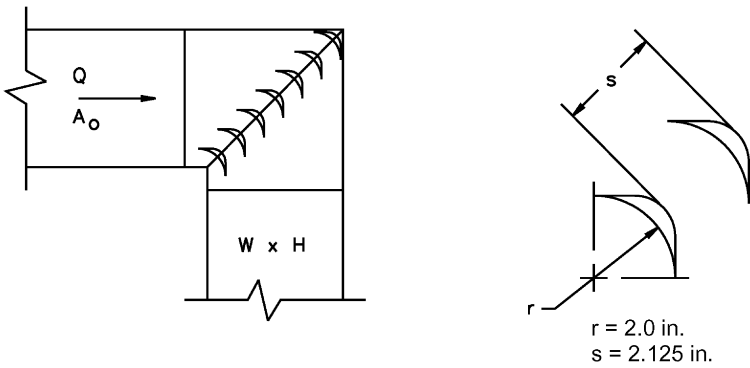
CR3-12 Elbow, Mitered, 90 Degree, Single-Thickness Vanes (3.25 in. Vane Spacing)

$C_o = 0.33$



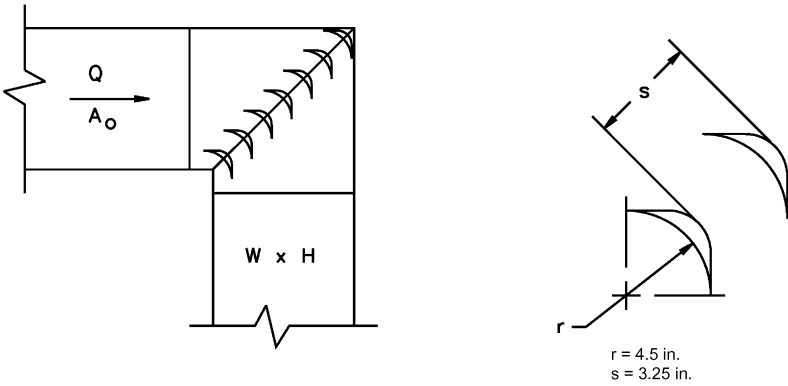
CR3-15 Elbow, Mitered, 90 Degree, Double-Thickness Vanes (2.125 in. Vane Spacing)

$C_o = 0.25$



CR3-16 Elbow, Mitered, 90 Degree, Double-Thickness Vanes (3.25 in. Vane Spacing)

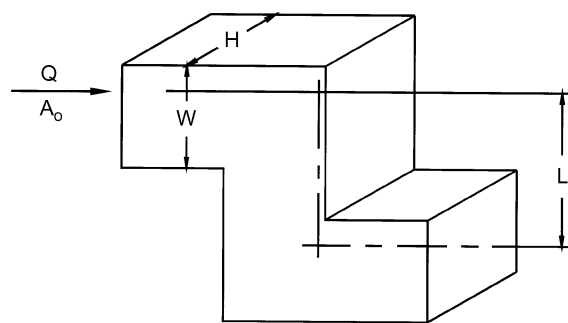
$C_o = 0.41$



CR3-17 Elbow, Z-Shaped

C_p Values														
	L/W													
H/W	0.0	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	4.0	8.0	10.0	
0.25	0.0	0.68	0.99	1.77	2.89	3.97	4.41	4.60	4.64	4.60	3.39	3.03	2.70	
0.50	0.0	0.66	0.96	1.72	2.81	3.86	4.29	4.47	4.52	4.47	3.30	2.94	2.62	
0.75	0.0	0.64	0.94	1.67	2.74	3.75	4.17	4.35	4.39	4.35	3.20	2.86	2.55	
1.0	0.0	0.62	0.90	1.61	2.63	3.61	4.01	4.18	4.22	4.18	3.08	2.75	2.45	
1.5	0.0	0.59	0.86	1.53	2.50	3.43	3.81	3.97	4.01	3.97	2.93	2.61	2.33	
2.0	0.0	0.56	0.81	1.45	2.37	3.25	3.61	3.76	3.80	3.76	2.77	2.48	2.21	
3.0	0.0	0.51	0.75	1.34	2.18	3.00	3.33	3.47	3.50	3.47	2.56	2.28	2.03	
4.0	0.0	0.48	0.70	1.26	2.05	2.82	3.13	3.26	3.29	3.26	2.40	2.15	1.91	
6.0	0.0	0.45	0.65	1.16	1.89	2.60	2.89	3.01	3.04	3.01	2.22	1.98	1.76	
8.0	0.0	0.43	0.63	1.13	1.84	2.53	2.81	2.93	2.95	2.93	2.16	1.93	1.72	

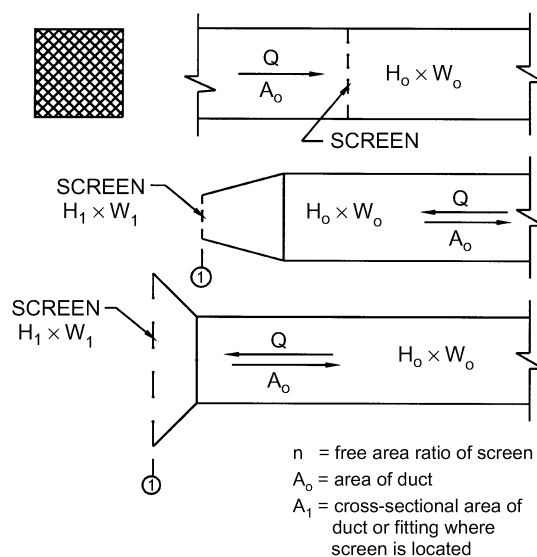
Reynolds Number Correction Factor K_r									
Re/1000	10	20	30	40	60	80	100	140	500
K_r	1.40	1.26	1.19	1.14	1.09	1.06	1.04	1.00	1.00



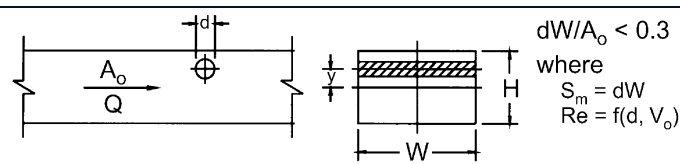
$C_o = K_r C_p$
 where K_r = Reynolds number correction factor

CR6-1 Screen (Only)

		C_o Values													
		n													
A_1/A_o		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.90	1.0	
0.2	155.0	103.0	75.00	55.00	41.25	31.50	24.25	18.75	14.50	11.00	8.00	3.50	0.0	0.0	
0.3	68.89	45.56	33.33	24.44	18.33	14.00	10.78	8.33	6.44	4.89	3.56	1.56	0.0	0.0	
0.4	38.75	25.63	18.75	13.75	10.31	7.88	6.06	4.69	3.63	2.75	2.00	0.88	0.0	0.0	
0.5	24.80	16.40	12.00	8.80	6.60	5.04	3.88	3.00	2.32	1.76	1.28	0.56	0.0	0.0	
0.6	17.22	11.39	8.33	6.11	4.58	3.50	2.69	2.08	1.61	1.22	0.89	0.39	0.0	0.0	
0.7	12.65	8.37	6.12	4.49	3.37	2.57	1.98	1.53	1.18	0.90	0.65	0.29	0.0	0.0	
0.8	9.69	6.40	4.69	3.44	2.58	1.97	1.52	1.17	0.91	0.69	0.50	0.22	0.0	0.0	
0.9	7.65	5.06	3.70	2.72	2.04	1.56	1.20	0.93	0.72	0.54	0.40	0.17	0.0	0.0	
1.0	6.20	4.10	3.00	2.20	1.65	1.26	0.97	0.75	0.58	0.44	0.32	0.14	0.0	0.0	
1.2	4.31	2.85	2.08	1.53	1.15	0.88	0.67	0.52	0.40	0.31	0.22	0.10	0.0	0.0	
1.4	3.16	2.09	1.53	1.12	0.84	0.64	0.49	0.38	0.30	0.22	0.16	0.07	0.0	0.0	
1.6	2.42	1.60	1.17	0.86	0.64	0.49	0.38	0.29	0.23	0.17	0.13	0.05	0.0	0.0	
1.8	1.91	1.27	0.93	0.68	0.51	0.39	0.30	0.23	0.18	0.14	0.10	0.04	0.0	0.0	
2.0	1.55	1.03	0.75	0.55	0.41	0.32	0.24	0.19	0.15	0.11	0.08	0.04	0.0	0.0	
2.5	0.99	0.66	0.48	0.35	0.26	0.20	0.16	0.12	0.09	0.07	0.05	0.02	0.0	0.0	
3.0	0.69	0.46	0.33	0.24	0.18	0.14	0.11	0.08	0.06	0.05	0.04	0.02	0.0	0.0	
4.0	0.39	0.26	0.19	0.14	0.10	0.08	0.06	0.05	0.04	0.03	0.02	0.01	0.0	0.0	
6.0	0.17	0.11	0.08	0.06	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.00	0.0	0.0	



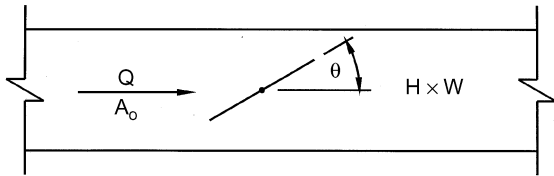
CR6-4 Obstruction, Smooth Cylinder in Rectangular Duct



C _o Values							C _o Values						
		S _m /A _o							S _m /A _o				
y/H	Re/1000	0.0	0.05	0.10	0.15	0.20	y/H	Re/1000	0.0	0.05	0.10	0.15	0.20
0.00	0.1	0.0	0.10	0.21	0.35	0.47	0.25	400	0.0	0.04	0.10	0.16	0.21
	0.5	0.0	0.08	0.17	0.28	0.38		500	0.0	0.03	0.07	0.12	0.16
	200	0.0	0.08	0.17	0.28	0.38		600	0.0	0.02	0.04	0.06	0.09
	300	0.0	0.07	0.16	0.26	0.35		1000	0.0	0.02	0.04	0.07	0.09
	400	0.0	0.05	0.11	0.19	0.25		0.1	0.0	0.08	0.17	0.28	0.38
	500	0.0	0.04	0.09	0.14	0.19	0.25	0.5	0.0	0.06	0.14	0.22	0.30
	600	0.0	0.02	0.05	0.07	0.10		200	0.0	0.06	0.14	0.22	0.30
0.05	1000	0.0	0.02	0.05	0.08	0.11		300	0.0	0.06	0.12	0.20	0.28
	0.1	0.0	0.10	0.21	0.34	0.46		400	0.0	0.04	0.09	0.15	0.20
	0.5	0.0	0.08	0.17	0.27	0.37	0.30	500	0.0	0.03	0.07	0.11	0.15
	200	0.0	0.08	0.17	0.27	0.37		600	0.0	0.02	0.04	0.06	0.08
	300	0.0	0.07	0.15	0.25	0.34		1000	0.0	0.02	0.04	0.06	0.09
	400	0.0	0.05	0.11	0.18	0.24		0.1	0.0	0.07	0.16	0.26	0.35
	500	0.0	0.04	0.08	0.13	0.18	0.35	0.5	0.0	0.06	0.13	0.21	0.28
	600	0.0	0.02	0.04	0.07	0.10		200	0.0	0.06	0.13	0.21	0.28
0.10	1000	0.0	0.02	0.05	0.08	0.11		300	0.0	0.05	0.12	0.19	0.26
	0.1	0.0	0.09	0.20	0.32	0.44		400	0.0	0.04	0.08	0.14	0.19
	0.5	0.0	0.07	0.16	0.26	0.35	0.40	500	0.0	0.03	0.06	0.10	0.14
	200	0.0	0.07	0.16	0.26	0.35		600	0.0	0.02	0.03	0.05	0.07
	300	0.0	0.07	0.15	0.24	0.32		1000	0.0	0.02	0.04	0.06	0.08
	400	0.0	0.05	0.11	0.17	0.23		0.1	0.0	0.07	0.14	0.23	0.32
	500	0.0	0.04	0.08	0.13	0.18	0.40	0.5	0.0	0.05	0.11	0.19	0.25
0.15	600	0.0	0.02	0.04	0.07	0.09		200	0.0	0.05	0.11	0.19	0.25
	1000	0.0	0.02	0.05	0.08	0.10		300	0.0	0.05	0.11	0.17	0.23
	0.1	0.0	0.09	0.19	0.31	0.42		400	0.0	0.04	0.08	0.12	0.17
	0.5	0.0	0.07	0.15	0.25	0.34		500	0.0	0.03	0.06	0.09	0.13
	200	0.0	0.07	0.15	0.25	0.34	0.40	600	0.0	0.01	0.03	0.05	0.07
	300	0.0	0.06	0.14	0.23	0.31		1000	0.0	0.02	0.03	0.05	0.07
	400	0.0	0.05	0.10	0.17	0.22		0.1	0.0	0.06	0.13	0.20	0.28
0.20	500	0.0	0.04	0.08	0.12	0.17		0.5	0.0	0.05	0.10	0.16	0.22
	600	0.0	0.02	0.04	0.07	0.09		200	0.0	0.05	0.10	0.16	0.22
	1000	0.0	0.02	0.04	0.07	0.10		300	0.0	0.04	0.09	0.15	0.20
	0.1	0.0	0.08	0.18	0.29	0.40		400	0.0	0.03	0.07	0.11	0.15
	0.5	0.0	0.07	0.14	0.24	0.32		500	0.0	0.02	0.05	0.08	0.11
	200	0.0	0.07	0.14	0.24	0.32		600	0.0	0.01	0.03	0.04	0.06
	300	0.0	0.06	0.13	0.22	0.29		1000	0.0	0.01	0.03	0.05	0.06

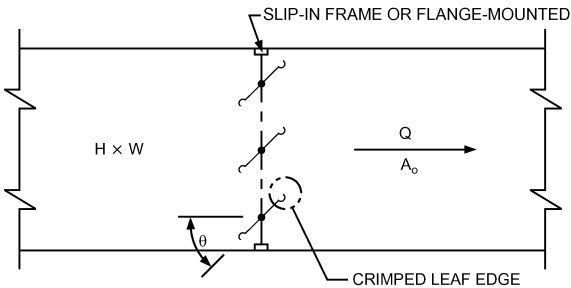
CR9-1 Damper, Butterfly

C _o Values										
		θ								
H/W	0	10	20	30	40	50	60	65	70	90
0.10	0.04	0.30	1.10	3.0	8.0	23.0	60.	100.	190.	9999
0.50	0.04	0.30	1.10	3.0	8.0	23.0	60.	100.	190.	9999
1.0	0.04	0.30	1.10	3.0	8.0	23.0	60.	100.	190.	9999
1.5	0.04	0.35	1.25	3.6	10.0	29.0	80.	155.	230.	9999
2.0	0.04	0.35	1.25	3.6	10.0	29.0	80.	155.	230.	9999



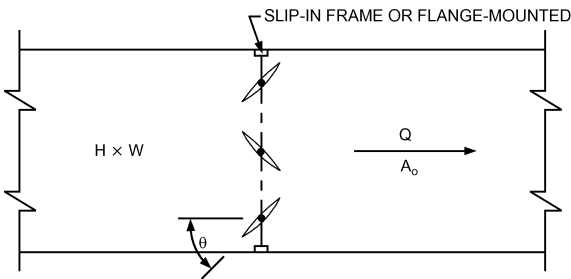
CR9-3 Damper, Parallel and Opposed 3V Blades, Open

$C_o = 0.37$



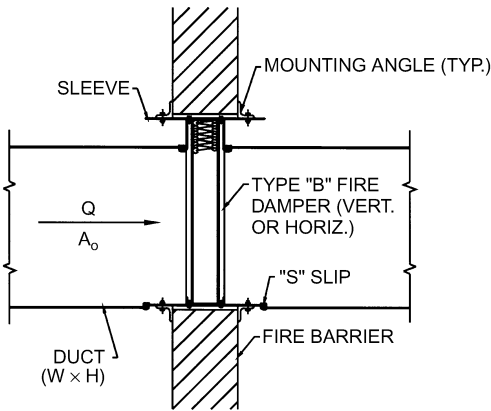
CR9-4 Damper, Parallel and Opposed Airfoil Blades, Open

$C_o = 0.18$



CR9-6 Fire Damper, Curtain Type, Type B, Horizontal Duct

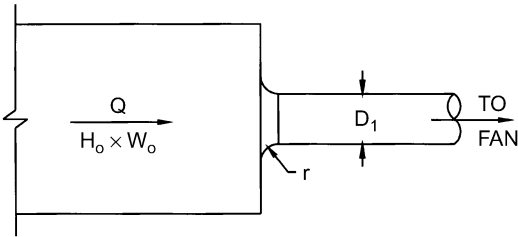
$C_o = 0.19$



ER2-1 Bellmouth, Plenum to Round, Exhaust/Return Systems

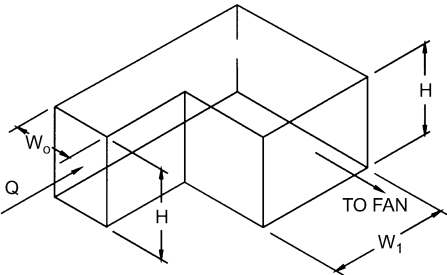
r/D_1	0.0	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.16	0.20	10.0
C_l	0.50	0.44	0.37	0.31	0.26	0.22	0.20	0.15	0.12	0.09	0.06	0.03	0.03

$C_o = C_l \left(\frac{A_o}{A_1} \right)^2$



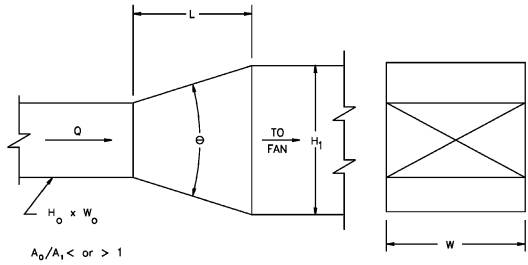
ER3-1 Elbow, 90 Degree, Variable Inlet/Outlet Areas, Exhaust/Return Systems

C_o Values							
H/W_o	W_1/W_o						
	0.6	0.8	1.0	1.2	1.4	1.6	2.0
0.25	1.76	1.43	1.24	1.14	1.09	1.06	1.06
1.00	1.70	1.36	1.15	1.02	0.95	0.90	0.84
4.00	1.46	1.10	0.90	0.81	0.76	0.72	0.66
100.00	1.50	1.04	0.79	0.69	0.63	0.60	0.55



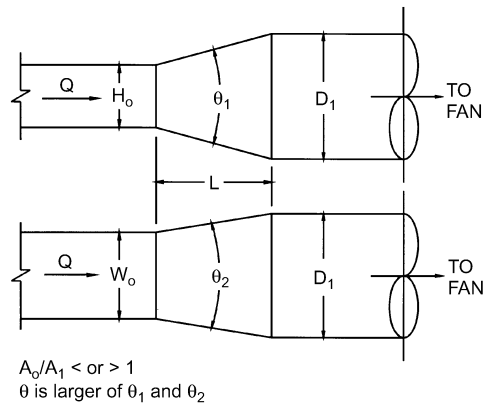
ER4-1 Transition, Rectangular, Two Sides Parallel, Symmetrical, Exhaust/Return Systems

C_o Values													
θ													
A_o/A_1	0	3	5	10	15	20	30	45	60	90	120	150	180
0.063	0.0	0.44	0.27	0.25	0.27	0.36	0.56	0.71	0.86	0.99	0.99	0.98	0.98
0.10	0.0	0.41	0.27	0.23	0.25	0.34	0.53	0.69	0.83	0.94	0.94	0.92	0.91
0.167	0.0	0.34	0.28	0.21	0.23	0.30	0.48	0.65	0.76	0.83	0.83	0.82	0.80
0.25	0.0	0.26	0.29	0.17	0.19	0.25	0.42	0.60	0.68	0.70	0.70	0.68	0.66
0.50	0.0	0.16	0.24	0.14	0.13	0.15	0.24	0.35	0.37	0.38	0.37	0.36	0.35
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.0	0.30	0.38	0.25	0.17	0.17	0.17	0.23	0.29	0.49	0.66	0.81	0.88
4.00	0.0	1.66	1.25	0.77	0.70	0.70	0.70	0.90	1.09	2.84	4.36	5.69	6.57
6.00	0.0	4.05	3.14	1.76	1.58	1.58	1.58	2.12	2.66	6.71	10.11	13.13	15.20
10.00	0.0	12.01	9.39	5.33	5.00	5.00	5.00	6.45	7.93	19.10	28.60	36.79	42.79



ER4-3 Transition, Rectangular to Round, Exhaust/Return Systems

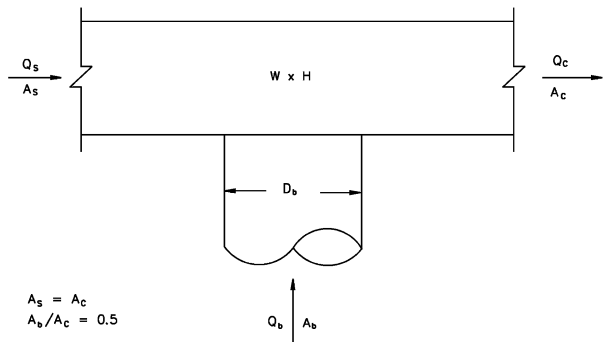
C_o Values													
θ													
A_o/A_1	0	3	5	10	15	20	30	45	60	90	120	150	180
0.063	0.0	0.17	0.19	0.30	0.46	0.53	0.64	0.77	0.88	0.95	0.95	0.94	0.93
0.10	0.0	0.17	0.19	0.30	0.45	0.53	0.64	0.75	0.84	0.89	0.89	0.89	0.88
0.167	0.0	0.18	0.19	0.30	0.44	0.53	0.63	0.72	0.78	0.79	0.79	0.79	0.79
0.25	0.0	0.16	0.18	0.25	0.36	0.45	0.52	0.58	0.62	0.64	0.64	0.64	0.64
0.50	0.0	0.14	0.14	0.15	0.22	0.25	0.30	0.33	0.33	0.33	0.32	0.31	0.30
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.0	0.30	0.27	0.26	0.28	0.25	0.19	0.23	0.27	0.52	0.75	0.91	0.95
4.00	0.0	1.60	1.14	0.84	0.85	0.86	0.76	0.90	1.09	2.78	4.30	5.65	6.55
6.00	0.0	3.89	3.04	1.84	1.77	1.78	1.73	2.18	2.67	6.67	10.07	13.09	15.18
10.00	0.0	11.80	9.31	5.40	5.18	5.15	5.05	6.44	7.94	19.06	28.55	36.75	42.75



ER5-2 Tee, Round Tap to Rectangular Main, Converging

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_b	-14.00	-2.38	0.50	0.65	1.03	1.17	1.19	1.33	1.51	1.44

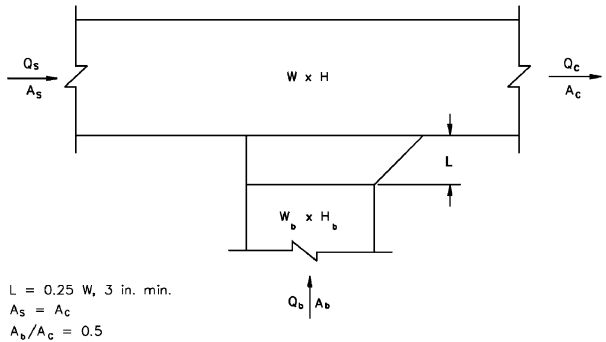
Q_s/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_s	22.15	11.91	6.54	3.74	2.23	1.33	0.76	0.38	0.10	0.0



ER5-3 Tee, 45 Degree Entry Branch, Converging

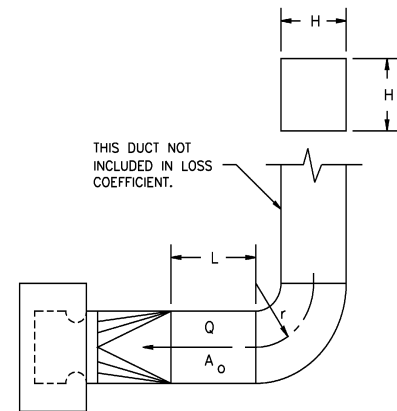
Q_b/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_b	-19.38	-3.75	-0.74	0.48	0.66	0.75	0.85	0.77	0.83	0.83

Q_s/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_s	22.15	11.91	6.54	3.74	2.23	1.33	0.76	0.38	0.10	0.0



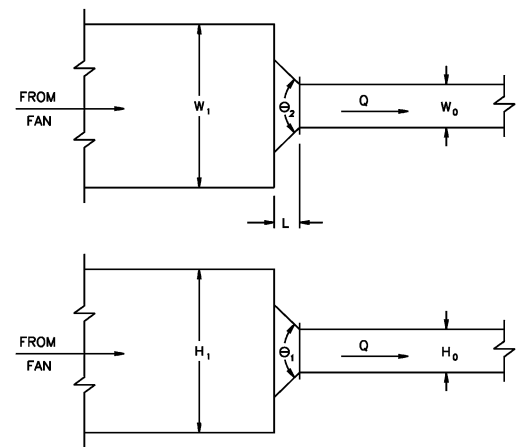
**ER7-1 Fan Inlet, Centrifugal, SWSI,
90 Degree Smooth Radius Elbow (Square)**

r/H	C_o Values			
	L/H			
	0.0	2.0	5.0	10.0
0.50	2.50	1.60	0.80	0.80
0.75	2.00	1.20	0.67	0.67
1.00	1.20	0.67	0.33	0.33
1.50	1.00	0.57	0.30	0.30
2.00	0.80	0.47	0.26	0.26



**SR1-1 Conical Bellmouth/Sudden Contraction, Plenum to Rectangular,
Supply Air Systems**

L/D_h	C_o Values									
	θ									
	0	10	20	30	40	60	100	140	180	
0.000	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.025	0.50	0.47	0.45	0.43	0.41	0.40	0.42	0.45	0.50	0.50
0.050	0.50	0.45	0.41	0.36	0.33	0.30	0.35	0.42	0.50	0.50
0.075	0.50	0.42	0.35	0.30	0.26	0.23	0.30	0.40	0.50	0.50
0.100	0.50	0.39	0.32	0.25	0.22	0.18	0.27	0.38	0.50	0.50
0.150	0.50	0.37	0.27	0.20	0.16	0.15	0.25	0.37	0.50	0.50
0.600	0.50	0.27	0.18	0.13	0.11	0.12	0.23	0.36	0.50	0.50

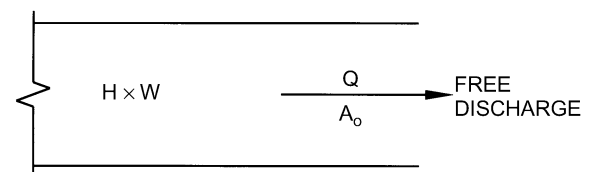


$$D_h = \frac{2 H_o w_o}{(H_o + w_o)}$$

θ IS LARGER OF θ_1 AND θ_2

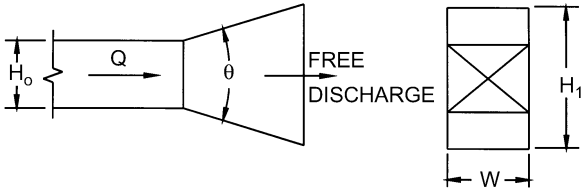
SR2-1 Abrupt Exit

Laminar Flow										
H/W	0.1	0.2	0.9	0.999	1.0	1.001	1.1	4.0	5.0	10.0
C_o	1.55	1.55	1.55	1.55	2.00	1.555	1.55	1.55	1.55	1.55
Turbulent Flow										
$C_o = 1.0$										



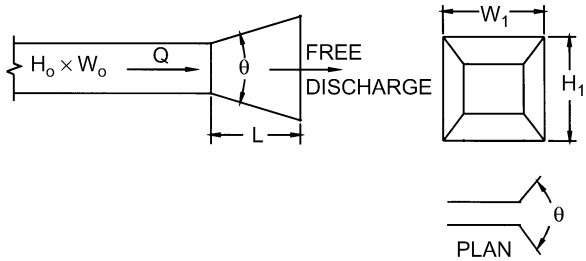
SR2-3 Plain Diffuser (Two Sides Parallel), Free Discharge

		<i>C_o</i> Values									
		θ									
<i>A₁/A_o</i>	Re/1000	4	8	10	14	20	30	45	60	90	120
1	50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	50	0.51	0.50	0.51	0.56	0.63	0.80	0.96	1.04	1.09	1.09
	100	0.48	0.48	0.50	0.56	0.63	0.80	0.96	1.04	1.09	1.09
	200	0.42	0.44	0.47	0.53	0.63	0.74	0.93	1.02	1.08	1.08
	400	0.38	0.40	0.42	0.50	0.62	0.74	0.93	1.02	1.08	1.08
	2000	0.38	0.40	0.42	0.50	0.62	0.74	0.93	1.02	1.08	1.08
4	50	0.35	0.34	0.38	0.48	0.63	0.76	0.91	1.03	1.07	1.07
	100	0.31	0.31	0.36	0.45	0.59	0.72	0.88	1.02	1.07	1.07
	200	0.27	0.26	0.31	0.41	0.53	0.67	0.83	0.96	1.06	1.06
	400	0.21	0.22	0.27	0.39	0.53	0.67	0.83	0.96	1.06	1.06
	2000	0.21	0.22	0.27	0.39	0.53	0.67	0.83	0.96	1.06	1.06
6	50	0.36	0.32	0.34	0.41	0.56	0.70	0.84	0.96	1.08	1.08
	100	0.32	0.27	0.30	0.41	0.56	0.70	0.84	0.96	1.08	1.08
	200	0.26	0.24	0.27	0.36	0.52	0.67	0.81	0.94	1.06	1.06
	400	0.21	0.20	0.24	0.36	0.52	0.67	0.81	0.94	1.06	1.06
	2000	0.21	0.20	0.24	0.36	0.52	0.67	0.81	0.94	1.06	1.06



SR2-5 Pyramidal Diffuser, Free Discharge

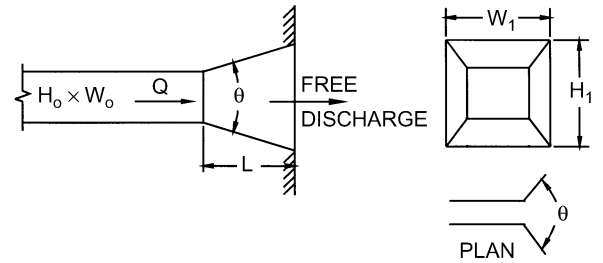
		<i>C_o</i> Values									
		θ									
<i>A₁/A_o</i>	Re/1000	4	8	10	14	20	30	45	60	90	120
1	50	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	100	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	200	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	400	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	2000	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	50	0.55	0.65	0.68	0.74	0.82	0.92	1.05	1.10	1.08	1.08
	100	0.51	0.61	0.66	0.73	0.81	0.90	1.04	1.09	1.08	1.08
	200	0.47	0.57	0.61	0.70	0.79	0.89	1.04	1.09	1.08	1.08
	400	0.42	0.50	0.56	0.64	0.76	0.88	1.02	1.07	1.08	1.08
	2000	0.42	0.50	0.56	0.64	0.76	0.88	1.02	1.07	1.08	1.08
4	50	0.38	0.53	0.60	0.69	0.78	0.90	1.02	1.07	1.09	1.09
	100	0.33	0.49	0.55	0.66	0.78	0.90	1.02	1.07	1.09	1.09
	200	0.27	0.42	0.50	0.62	0.74	0.87	1.00	1.06	1.08	1.08
	400	0.22	0.36	0.44	0.56	0.70	0.84	0.99	1.06	1.08	1.08
	2000	0.22	0.36	0.44	0.56	0.70	0.84	0.99	1.06	1.08	1.08
6	50	0.34	0.50	0.57	0.66	0.77	0.91	1.02	1.07	1.08	1.08
	100	0.30	0.47	0.54	0.63	0.76	0.98	1.02	1.07	1.08	1.08
	200	0.24	0.42	0.48	0.60	0.73	0.88	1.00	1.06	1.08	1.08
	400	0.18	0.34	0.44	0.56	0.73	0.86	0.98	1.06	1.08	1.08
	2000	0.18	0.34	0.44	0.56	0.73	0.86	0.98	1.06	1.08	1.08
10	50	0.30	0.45	0.53	0.64	0.74	0.85	0.97	1.10	1.12	1.12
	100	0.25	0.40	0.48	0.62	0.73	0.85	0.97	1.10	1.12	1.12
	200	0.20	0.34	0.44	0.56	0.69	0.82	0.95	1.10	1.11	1.11
	400	0.16	0.28	0.40	0.55	0.67	0.80	0.93	1.09	1.11	1.11
	2000	0.16	0.28	0.40	0.55	0.67	0.80	0.93	1.09	1.11	1.11



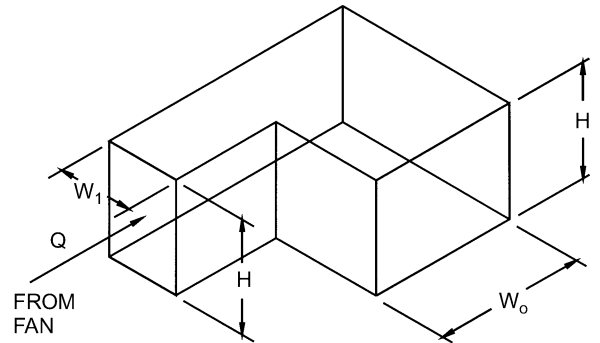
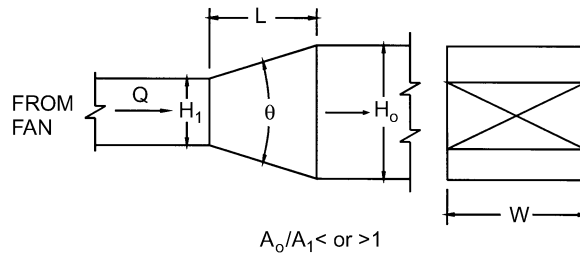
SR2-6 Pyramidal Diffuser, with Wall

L/D_h	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0
C_o	0.49	0.40	0.30	0.26	0.23	0.21	0.19	0.17	0.16	0.15	0.14
θ	26	19	13	11	9	8	7	6	6	5	5

θ is the optimum angle.

**SR3-1 Elbow, 90 Degree, Variable Inlet/Outlet Areas, Supply Air Systems**

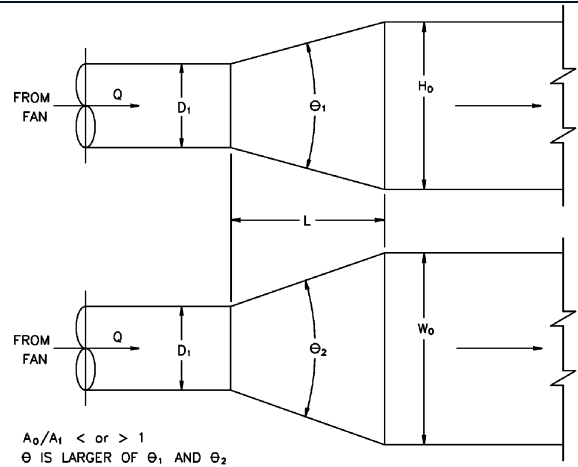
H/W_1	C_o Values						
	W_o/W_1						
	0.6	0.8	1.0	1.2	1.4	1.6	2.0
0.25	0.63	0.92	1.24	1.64	2.14	2.71	4.24
1.00	0.61	0.87	1.15	1.47	1.86	2.30	3.36
4.00	0.53	0.70	0.90	1.17	1.49	1.84	2.64
100.	0.54	0.67	0.79	0.99	1.23	1.54	2.20

**SR4-1 Transition, Rectangular, Two Sides Parallel, Symmetrical, Supply Air Systems**

$A_o/A_1 < \text{or} > 1$

A_o/A_1	C_o Values												
	θ												
	0	3	5	10	15	20	30	45	60	90	120	150	180
0.10	0.0	0.12	0.09	0.05	0.05	0.05	0.05	0.06	0.08	0.19	0.29	0.37	0.43
0.167	0.0	0.11	0.09	0.05	0.04	0.04	0.04	0.06	0.07	0.19	0.28	0.36	0.42
0.25	0.0	0.10	0.08	0.05	0.04	0.04	0.04	0.06	0.07	0.18	0.27	0.36	0.41
0.50	0.0	0.08	0.09	0.06	0.04	0.04	0.04	0.06	0.07	0.12	0.17	0.20	0.27
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
2.00	0.0	0.64	0.96	0.54	0.52	0.62	0.94	1.40	1.48	1.52	1.48	1.44	1.40
4.00	0.0	4.16	4.64	2.72	3.09	4.00	6.72	9.60	10.88	11.20	11.20	10.88	10.56
6.00	0.0	12.24	10.08	7.38	8.10	10.80	17.28	23.40	27.36	29.88	29.88	29.34	28.80
10.00	0.0	40.50	27.20	23.30	25.10	34.00	52.84	69.00	82.50	93.50	93.50	92.40	91.30
16.00	0.0	112.64	68.35	63.74	67.84	92.93	142.13	182.53	220.16	254.21	254.21	251.90	249.60

SR4-3 Transition, Round to Rectangular, Supply Air Systems



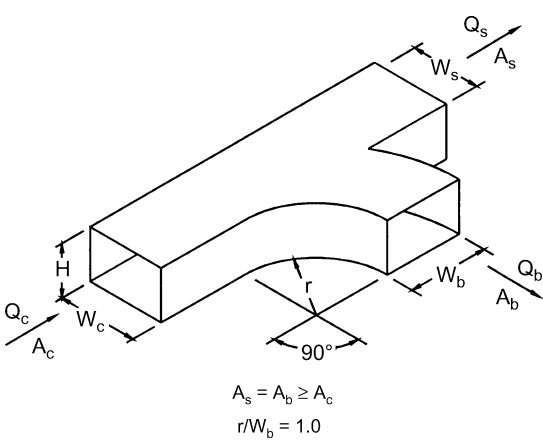
$A_0/A_1 < \text{or} > 1$
 θ IS LARGER OF θ_1 AND θ_2

C_o Values

A_0/A_1	θ												
	0	3	5	10	15	20	30	45	60	90	120	150	180
0.10	0.0	0.12	0.09	0.05	0.05	0.05	0.05	0.06	0.08	0.19	0.29	0.37	0.43
0.167	0.0	0.11	0.08	0.05	0.05	0.05	0.05	0.06	0.07	0.19	0.28	0.37	0.42
0.25	0.0	0.10	0.07	0.05	0.05	0.05	0.05	0.06	0.07	0.17	0.27	0.35	0.41
0.50	0.0	0.08	0.07	0.06	0.07	0.06	0.05	0.06	0.07	0.13	0.19	0.23	0.24
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.0	0.57	0.55	0.61	0.87	1.00	1.20	1.30	1.30	1.30	1.28	1.24	1.20
4.00	0.0	2.60	2.84	3.92	5.72	7.20	8.32	9.28	9.92	10.24	10.24	10.24	10.24
6.00	0.0	6.57	6.75	10.62	15.84	18.90	22.50	25.74	27.90	28.44	28.44	28.35	28.26
10.00	0.0	17.25	18.75	30.00	45.00	53.00	63.50	75.00	84.0	89.00	89.00	88.50	88.00
16.00	0.0	42.75	48.13	77.57	116.74	136.45	164.10	196.86	224.26	241.92	241.92	240.38	238.59

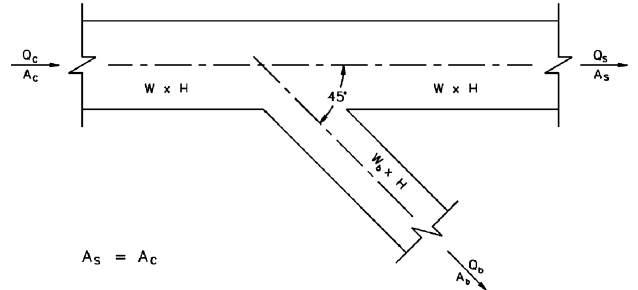
SR5-1 Smooth Wye of Type A_s + A_b ≥ A_c, Branch 90° to Main, Diverging

A_s/A_c A_b/A_c		C_b Values								
		Q_b/Q_c								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.50	0.25	2.25	0.48	0.25	0.18	0.17	0.16	0.17	0.17	0.17
	0.50	11.00	2.38	1.06	0.64	0.52	0.47	0.47	0.47	0.48
	1.00	60.00	13.00	4.78	2.06	0.96	0.47	0.31	0.27	0.26
0.75	0.25	2.19	0.55	0.35	0.31	0.33	0.35	0.36	0.37	0.39
	0.50	13.00	2.50	0.89	0.47	0.34	0.31	0.32	0.36	0.43
	1.00	70.00	15.00	5.67	2.63	1.36	0.78	0.53	0.41	0.36
1.00	0.25	3.44	0.78	0.42	0.33	0.30	0.31	0.40	0.42	0.46
	0.50	15.50	3.00	1.11	0.63	0.48	0.42	0.40	0.42	0.46
	1.00	67.00	13.75	5.11	2.31	1.28	0.81	0.59	0.47	0.46
A_s/A_c A_b/A_c		C_s Values								
		Q_s/Q_c								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.50	0.25	8.65	1.12	0.21	0.05	0.06	0.10	0.15	0.19	0.24
	0.50	7.50	0.98	0.19	0.06	0.06	0.10	0.14	0.18	0.22
	1.00	5.21	0.68	0.15	0.06	0.07	0.10	0.13	0.16	0.19
0.75	0.25	19.62	3.25	0.86	0.23	0.05	0.02	0.00	0.00	0.05
	0.50	20.62	3.24	0.76	0.14	-0.03	-0.07	-0.05	-0.01	0.03
	1.00	17.01	2.55	0.55	0.07	-0.05	-0.05	-0.02	0.02	0.06
1.00	0.25	46.00	9.50	3.22	1.31	0.52	0.14	-0.02	-0.05	-0.01
	0.50	35.34	6.49	1.98	0.69	0.22	0.00	-0.04	-0.05	-0.05
	1.00	38.95	7.10	2.15	0.74	0.23	0.03	-0.04	-0.05	-0.04

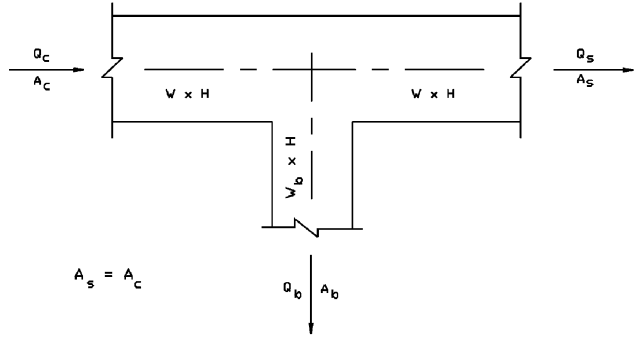


SR5-3 Wye of the Type $A_s + A_b > A_c$, $A_s = A_c$, 45 Degree, Diverging

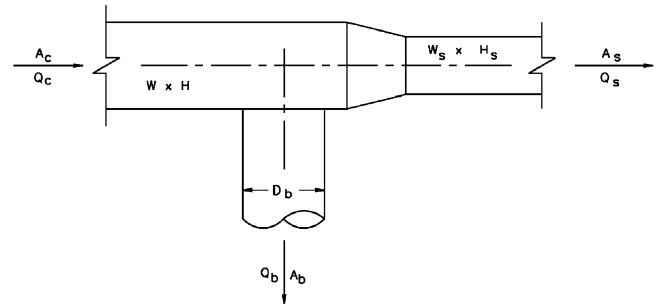
A_b/A_c	C_b Values								
	Q_b/Q_c								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.60	0.52	0.57	0.58	0.64	0.67	0.70	0.71	0.73
0.2	2.24	0.56	0.44	0.45	0.51	0.54	0.58	0.60	0.62
0.3	5.93	1.08	0.52	0.41	0.43	0.46	0.49	0.52	0.54
0.4	10.61	1.89	0.72	0.43	0.34	0.31	0.31	0.33	0.34
0.5	17.70	3.23	1.14	0.59	0.40	0.31	0.30	0.30	0.31
0.6	26.66	5.01	1.75	0.84	0.50	0.36	0.31	0.30	0.30
0.7	37.49	7.22	2.53	1.17	0.66	0.43	0.35	0.32	0.30
0.8	50.20	9.87	3.49	1.61	0.88	0.54	0.41	0.35	0.32
0.9	64.77	12.95	4.63	2.13	1.14	0.69	0.50	0.40	0.35
Q_s/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
C_s	32.40	6.40	2.18	0.90	0.40	0.18	0.07	0.03	0.00

**SR5-5 Tee of the Type $A_s + A_b > A_c$, $A_s = A_c$, Diverging**

A_b/A_c	C_b Values								
	Q_b/Q_c								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	2.06	1.20	0.99	0.87	0.88	0.87	0.87	0.86	0.86
0.2	5.15	1.92	1.29	1.03	0.99	0.94	0.92	0.90	0.89
0.3	10.30	3.12	1.78	1.28	1.16	1.06	1.01	0.97	0.94
0.4	15.90	4.35	2.24	1.48	1.11	0.88	0.80	0.75	0.72
0.5	24.31	6.31	3.04	1.90	1.35	1.03	0.91	0.83	0.78
0.6	34.60	8.70	4.03	2.41	1.65	1.22	1.04	0.94	0.87
0.7	46.75	11.53	5.19	3.01	2.00	1.44	1.20	1.06	0.96
0.8	60.78	14.79	6.53	3.70	2.40	1.69	1.38	1.20	1.07
0.9	76.67	18.49	8.05	4.49	2.86	1.98	1.59	1.36	1.20
Q_s/Q_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0
C_s	32.40	6.40	2.18	0.90	0.40	0.18	0.07	0.03	0.00

**SR5-11 Tee, Rectangular Main to Round Tap, Diverging**

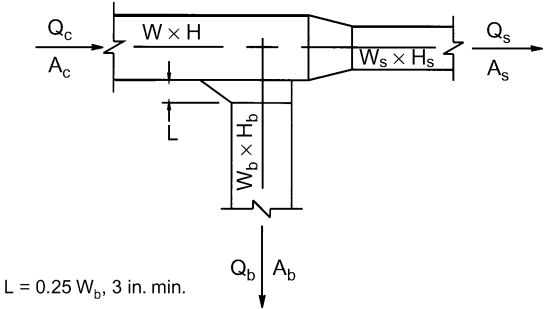
A_b/A_c	C_b Values								
	Q_b/Q_c								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	1.58	0.94	0.83	0.79	0.77	0.76	0.76	0.76	0.75
0.2	4.20	1.58	1.10	0.94	0.87	0.83	0.80	0.79	0.78
0.3	8.63	2.67	1.58	1.20	1.03	0.91	0.88	0.85	0.83
0.4	14.85	4.20	2.25	1.58	1.27	1.10	1.00	0.94	0.90
0.5	22.87	6.19	3.13	2.07	1.58	1.32	1.16	1.06	0.99
0.6	32.68	8.63	4.20	2.67	1.96	1.58	1.35	1.20	1.10
0.7	44.30	11.51	5.48	3.38	2.41	1.89	1.58	1.38	1.24
0.8	57.71	14.85	6.95	4.20	2.94	2.25	1.84	1.58	1.40
0.9	72.92	18.63	8.63	5.14	3.53	2.67	2.14	1.81	1.58
C_s Values									
A_s/A_c	Q_s/Q_c								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2	0.98	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.3	3.48	0.31	0.04	0.01	0.00	0.00	0.00	0.00	0.00
0.4	7.55	0.98	0.18	0.04	0.02	0.00	0.00	0.00	0.00
0.5	13.18	2.03	0.49	0.13	0.04	0.00	0.01	0.00	0.00
0.6	20.38	3.48	0.98	0.31	0.10	0.04	0.02	0.01	0.00
0.7	29.15	5.32	1.64	0.60	0.23	0.09	0.04	0.02	0.01
0.8	39.48	7.55	2.47	0.98	0.42	0.18	0.08	0.04	0.02
0.9	51.37	10.17	3.48	1.46	0.67	0.31	0.15	0.07	0.04



SR5-13 Tee, 45 Degree Entry Branch, Diverging

<i>C_b</i> Values									
<i>Q_b/Q_c</i>									
<i>A_b/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.32	0.33	0.32	0.34	0.32	0.37	0.38	0.39	0.40
0.2	0.31	0.32	0.41	0.34	0.32	0.32	0.33	0.34	0.35
0.3	1.86	1.65	0.73	0.47	0.37	0.34	0.32	0.32	0.32
0.4	3.56	3.10	1.28	0.73	0.51	0.41	0.36	0.34	0.32
0.5	5.74	4.93	2.07	1.12	0.73	0.54	0.44	0.38	0.35
0.6	8.48	7.24	3.10	1.65	1.03	0.73	0.56	0.47	0.41
0.7	11.75	10.00	4.32	3.31	1.42	0.98	0.73	0.58	0.49
0.8	15.57	13.22	5.74	3.10	1.90	1.28	0.94	0.73	0.60
0.9	19.92	16.90	7.38	4.02	2.46	1.65	1.19	0.91	0.73

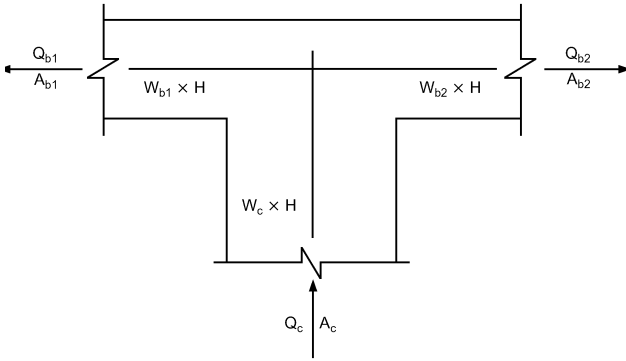
<i>C_s</i> Values									
<i>Q_s/Q_c</i>									
<i>A_s/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2	0.98	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.3	3.48	0.31	0.04	0.01	0.00	0.00	0.00	0.00	0.00
0.4	7.55	0.98	0.18	0.04	0.02	0.00	0.00	0.00	0.00
0.5	13.18	2.03	0.49	0.13	0.04	0.00	0.01	0.00	0.00
0.6	20.38	3.48	0.98	0.31	0.10	0.04	0.02	0.01	0.00
0.7	29.15	5.32	1.64	0.60	0.23	0.09	0.04	0.02	0.01
0.8	39.48	7.55	2.47	0.98	0.42	0.18	0.08	0.04	0.02
0.9	51.37	10.17	3.48	1.46	0.67	0.31	0.15	0.07	0.04



SR5-15 Bullhead Tee Without Vanes, Diverging

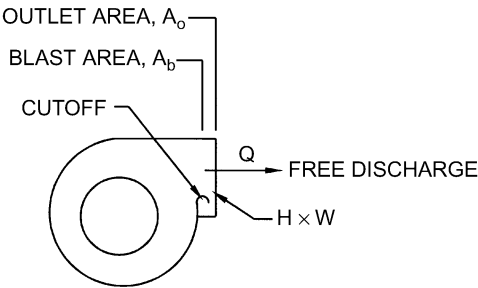
<i>C_{b1}</i> Values									
<i>Q_{b1}/Q_c</i>									
<i>A_{b1}/A_c</i>	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	1.34	0.53	0.37	0.30	0.29	0.28	0.27	0.27	0.27
0.2	4.43	1.25	0.66	0.45	0.39	0.35	0.32	0.31	0.30
0.3	9.58	2.45	1.16	0.71	0.56	0.47	0.41	0.37	0.35
0.4	16.87	4.17	1.88	1.09	0.73	0.53	0.38	0.33	0.30
0.5	26.19	6.35	2.79	1.56	1.01	0.71	0.49	0.41	0.37
0.6	37.57	9.02	3.89	2.14	1.35	0.92	0.62	0.52	0.45
0.7	51.03	12.17	5.20	2.82	1.75	1.18	0.78	0.64	0.54
0.8	66.55	15.81	6.71	3.61	2.22	1.48	0.96	0.78	0.65
0.9	84.15	19.93	8.42	4.50	2.74	1.81	1.17	0.94	0.78

For other branch, subscripts 1 and 2 change places.



SR7-1 Fan, Centrifugal, Without Outlet Diffuser, Free Discharge

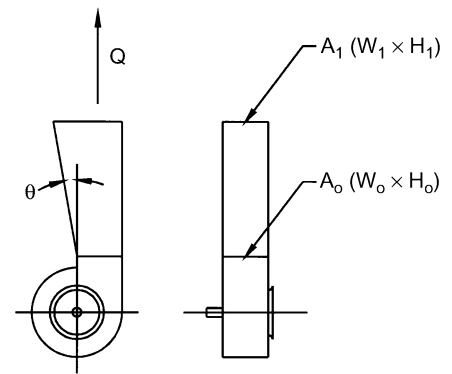
<i>A_b/A_o</i>	0.4	0.5	0.6	0.7	0.8	0.9	1.0
<i>C_o</i>	2.00	2.00	1.00	0.80	0.47	0.22	0.00



SR7-2 Plane Asymmetric Diffuser at Centrifugal Fan Outlet,
Free Discharge

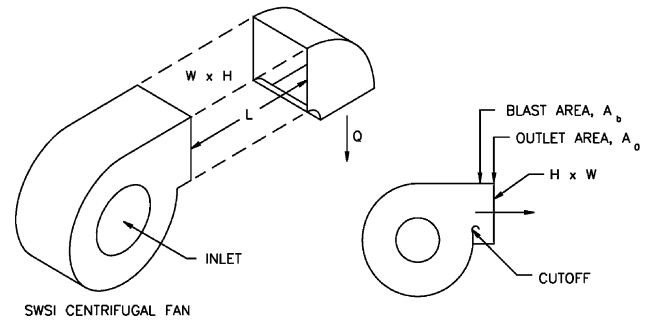
θ	C_o Values					
	A_1/A_o					
	1.5	2.0	2.5	3.0	3.5	4.0
10	0.51	0.34	0.25	0.21	0.18	0.17
15	0.54	0.36	0.27	0.24	0.22	0.20
20	0.55	0.38	0.31	0.27	0.25	0.24
25	0.59	0.43	0.37	0.35	0.33	0.33
30	0.63	0.50	0.46	0.44	0.43	0.42
35	0.65	0.56	0.53	0.52	0.51	0.50

FREE DISCHARGE



SR7-5 Fan Outlet, Centrifugal, SWSI, with Elbow (Position A)

A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	3.20	2.50	1.80	0.80	0.0	0.0
0.5	2.20	1.80	1.20	0.53	0.0	0.0
0.6	1.60	1.40	0.80	0.40	0.0	0.0
0.7	1.00	0.80	0.53	0.26	0.0	0.0
0.8	0.80	0.67	0.47	0.18	0.0	0.0
0.9	0.53	0.47	0.33	0.18	0.0	0.0
1.0	0.53	0.47	0.33	0.18	0.0	0.0



$$V_o > 2500 \text{ fpm: } L_e = \frac{V_o \sqrt{A_o}}{10,600}$$

$$V_o \leq 2500 \text{ fpm: } L_e = \frac{\sqrt{A_o}}{4.3}$$

where:

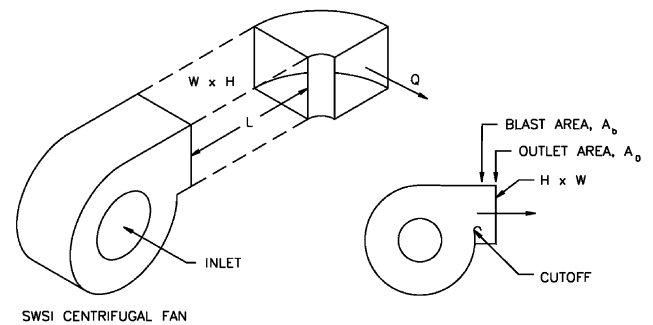
V_o = duct velocity, fpm

L_e = effective duct length, ft

A_o = duct area, in.²

SR7-6 Fan Outlet, Centrifugal, SWSI, with Elbow (Position B)

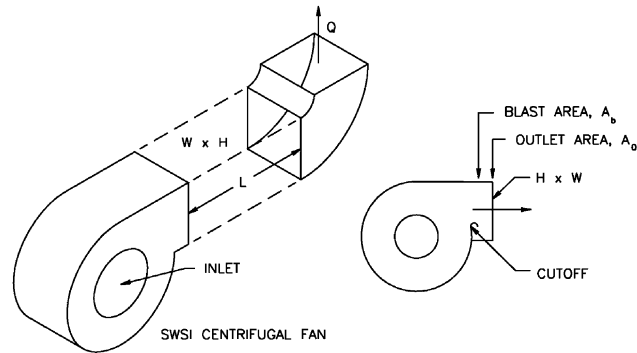
A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	3.80	3.20	2.20	1.00	0.0	0.0
0.5	2.90	2.20	1.60	0.67	0.0	0.0
0.6	2.00	1.60	1.20	0.53	0.0	0.0
0.7	1.40	1.00	0.67	0.33	0.0	0.0
0.8	1.00	0.80	0.53	0.26	0.0	0.0
0.9	0.80	0.67	0.47	0.18	0.0	0.0
1.0	0.67	0.53	0.40	0.18	0.0	0.0



To calculate L_e , see Fitting SR7-5.

SR7-7 Fan Outlet, Centrifugal, SWSI, with Elbow (Position C)

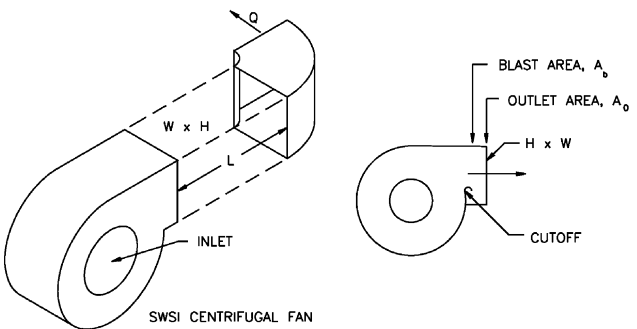
A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	5.50	4.50	3.20	1.60	0.0	0.0
0.5	3.80	3.20	2.20	1.00	0.0	0.0
0.6	2.90	2.50	1.60	0.80	0.0	0.0
0.7	2.00	1.60	1.00	0.53	0.0	0.0
0.8	1.40	1.20	0.80	0.33	0.0	0.0
0.9	1.20	0.80	0.67	0.26	0.0	0.0
1.0	1.00	0.80	0.53	0.26	0.0	0.0



To calculate L_e , see Fitting SR7-5.

SR7-8 Fan Outlet, Centrifugal, SWSI, with Elbow (Position D)

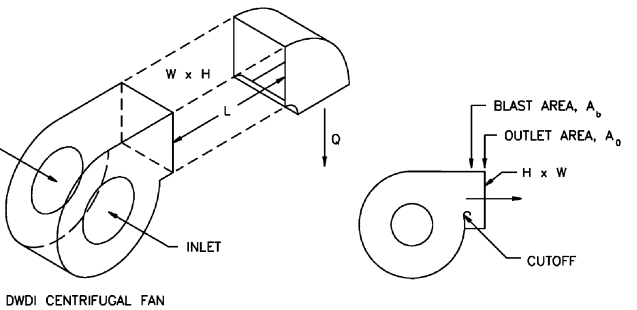
A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	5.50	4.50	3.20	1.60	0.0	0.0
0.5	3.80	3.20	2.20	1.00	0.0	0.0
0.6	2.90	2.50	1.60	0.80	0.0	0.0
0.7	2.00	1.60	1.00	0.53	0.0	0.0
0.8	1.40	1.20	0.80	0.33	0.0	0.0
0.9	1.20	0.80	0.67	0.26	0.0	0.0
1.0	1.00	0.80	0.53	0.26	0.0	0.0



To calculate L_e , see Fitting SR7-5.

SR7-9 Fan Outlet, Centrifugal, DWDI, with Elbow (Position A)

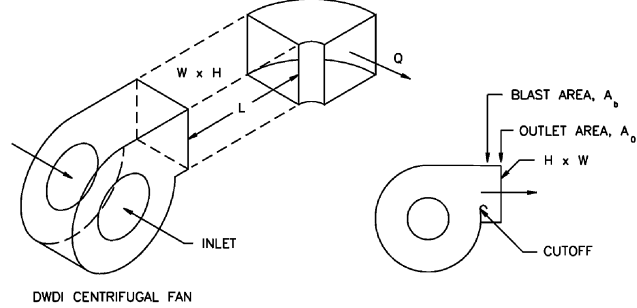
A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	3.20	2.50	1.80	0.80	0.0	0.0
0.5	2.20	1.80	1.20	0.53	0.0	0.0
0.6	1.60	1.40	0.80	0.40	0.0	0.0
0.7	1.00	0.80	0.53	0.26	0.0	0.0
0.8	0.80	0.67	0.47	0.18	0.0	0.0
0.9	0.53	0.47	0.33	0.18	0.0	0.0
1.0	0.53	0.47	0.33	0.18	0.0	0.0



To calculate L_e , see Fitting SR7-5.

SR7-10 Fan Outlet, Centrifugal, DWDI, with Elbow (Position B)

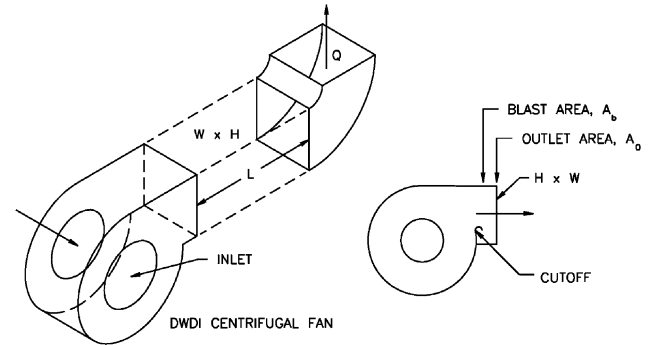
A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	4.80	4.00	2.90	1.30	0.0	0.0
0.5	3.60	2.90	2.00	0.84	0.0	0.0
0.6	2.50	2.00	1.50	0.66	0.0	0.0
0.7	1.80	1.30	0.84	0.41	0.0	0.0
0.8	1.25	1.00	0.66	0.33	0.0	0.0
0.9	1.00	0.84	0.59	0.23	0.0	0.0
1.0	0.84	0.66	0.50	0.23	0.0	0.0



To calculate L_e , see Fitting SR7-5.

SR7-11 Fan Outlet, Centrifugal, DWDI, with Elbow (Position C)

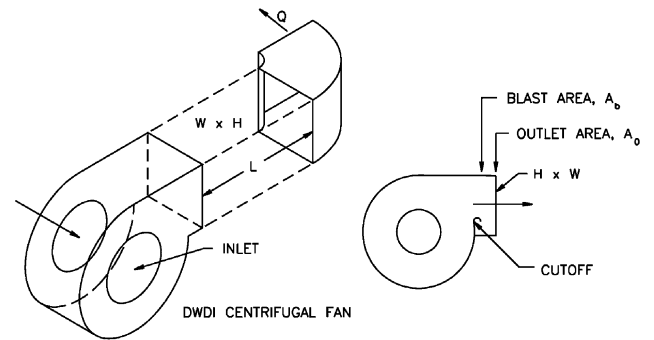
A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	5.50	4.50	3.20	1.60	0.0	0.0
0.5	3.80	3.20	2.20	1.00	0.0	0.0
0.6	2.90	2.50	1.60	0.80	0.0	0.0
0.7	2.00	1.60	1.00	0.53	0.0	0.0
0.8	1.40	1.20	0.80	0.33	0.0	0.0
0.9	1.20	0.80	0.67	0.26	0.0	0.0
1.0	1.00	0.80	0.53	0.26	0.0	0.0



To calculate L_e , see Fitting SR7-5.

SR7-12 Fan Outlet, Centrifugal, DWDI, with Elbow (Position D)

A_b/A_o	C_o Values					
	L/L_e					
	0.00	0.12	0.25	0.50	1.0	10.0
0.4	4.70	3.80	2.70	1.40	0.0	0.0
0.5	3.20	2.70	1.90	0.85	0.0	0.0
0.6	2.50	2.10	1.40	0.68	0.0	0.0
0.7	1.70	1.40	0.85	0.45	0.0	0.0
0.8	1.20	1.00	0.68	0.26	0.0	0.0
0.9	1.00	0.68	0.57	0.22	0.0	0.0
1.0	0.85	0.68	0.45	0.22	0.0	0.0

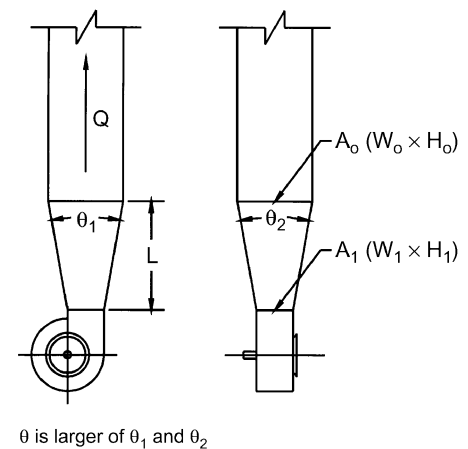


To calculate L_e , see Fitting SR7-5.

SR7-17 Pyramidal Diffuser at Centrifugal Fan Outlet with Ductwork

θ	C_1 Values						
	A_o/A_1						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.10	0.18	0.21	0.23	0.24	0.25
15	0.00	0.23	0.33	0.38	0.40	0.42	0.44
20	0.00	0.31	0.43	0.48	0.53	0.56	0.58
25	0.00	0.36	0.49	0.55	0.58	0.62	0.64
30	0.00	0.42	0.53	0.59	0.64	0.67	0.69

$$C_o = C_1 \left(\frac{A_o}{A_1} \right)^2$$



θ is larger of θ_1 and θ_2