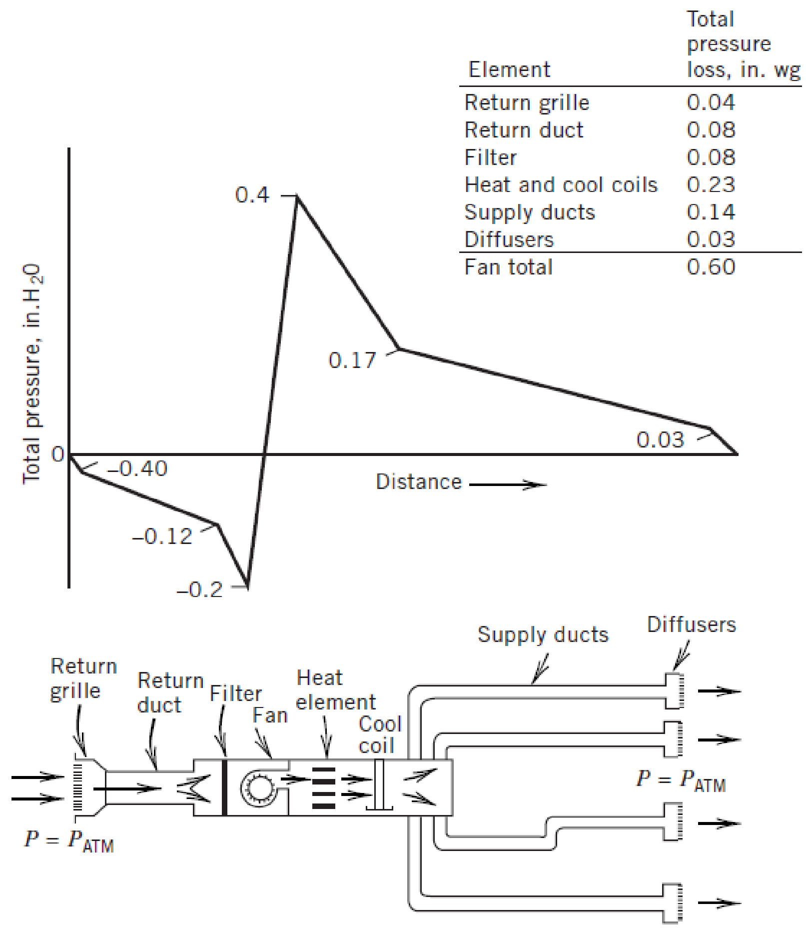
Duct Design

MSYS4480

Duct design

1. Air flow in ducts
2. Major and Minor Losses in Ducts
3. Loss coefficient for some fittings
4. Equivalent length for a fittings
5. Duct accessories
6. Pressure diagram
7. Duct design
    1. Equal friction method
    2. Balanced Capacity method
8. Flex Ducts
9. In-Slab Ducts
10. Avoiding Bullhead Tees
11. Return Air Boots
12. Pressurized Plenums with Home Run Ducts

Air Flow in Ducts



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

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

Internal, External, and Total Static Pressure Drop

Internal Static Pressure losses occur within mechanical equipment and are usually calculated by the manufacturer Examples include

- Dampers
- Filters
- Coils
- Heat exchangers
- Heat recovery devices (such as wheels, heat pipes)

External Static Pressure (ESP) losses occur within the system outside of the mechanical equipment and are usually calculated by the mechanical consultant. Examples include

- Louvers
- Dampers (motorized, balancing, backdraft…)
- Duct fittings
- Duct transitions and elbows
- Air terminals
- Air valves and VAV boxes
- Filters

Total Static Pressure (TSP) loss is the sum of the internal and external losses in the system.

Velocity air pressure, P_v

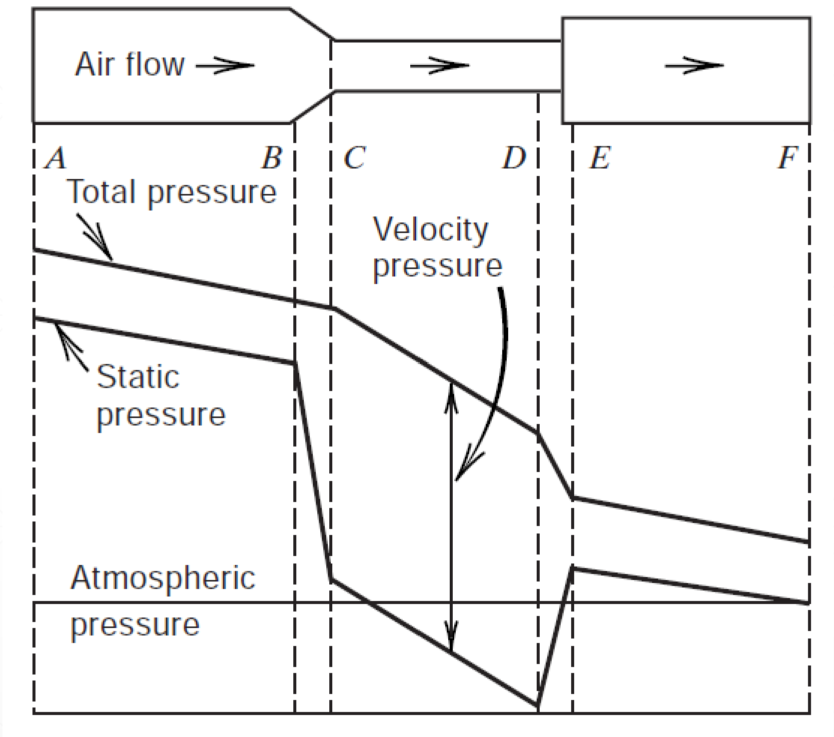
$$P_v = \rho\left(\frac{V^2}{1097}\right) = \left(\frac{V}{4005}\right)^2$$

Pv in in water and V in ft/min

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

Pv in Pa and V in m/s

Mass Density ρ
62.4 lbm/ft3 and 999 kg/



Pressure changes during flow in ducts.

Friction Loss

- Tedious task to solve by equations
- Pressure Loss Charts have been prepared.

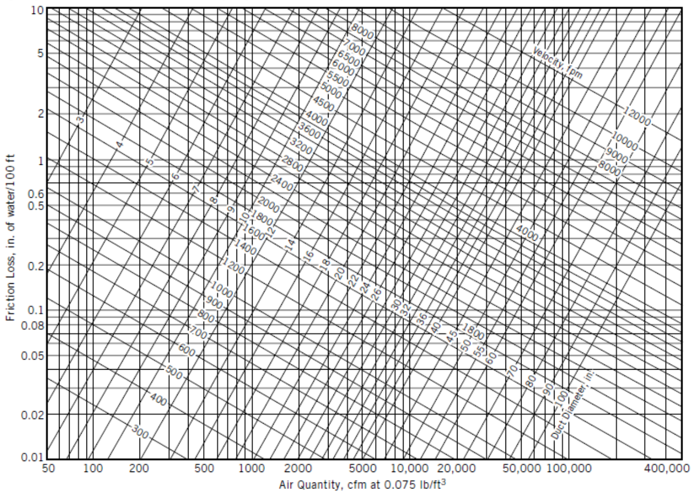
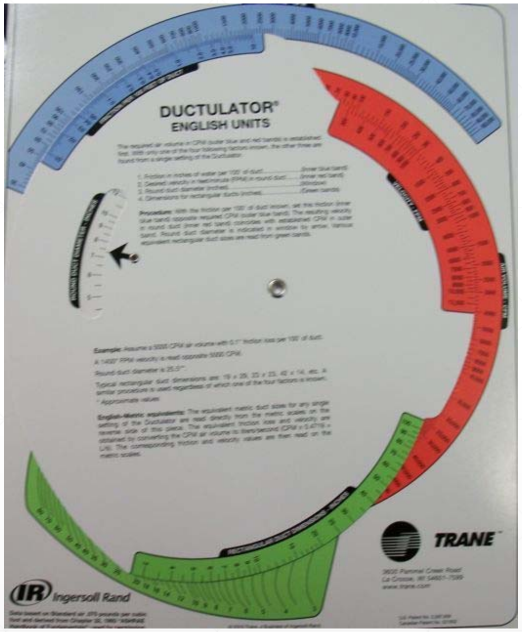


Figure 12-21 Pressure loss due to friction for galvanized steel ducts, IP units. (Reprinted by permission from *ASHRAE Handbook, Fundamentals Volume IP,* 1997.)



Friction Loss

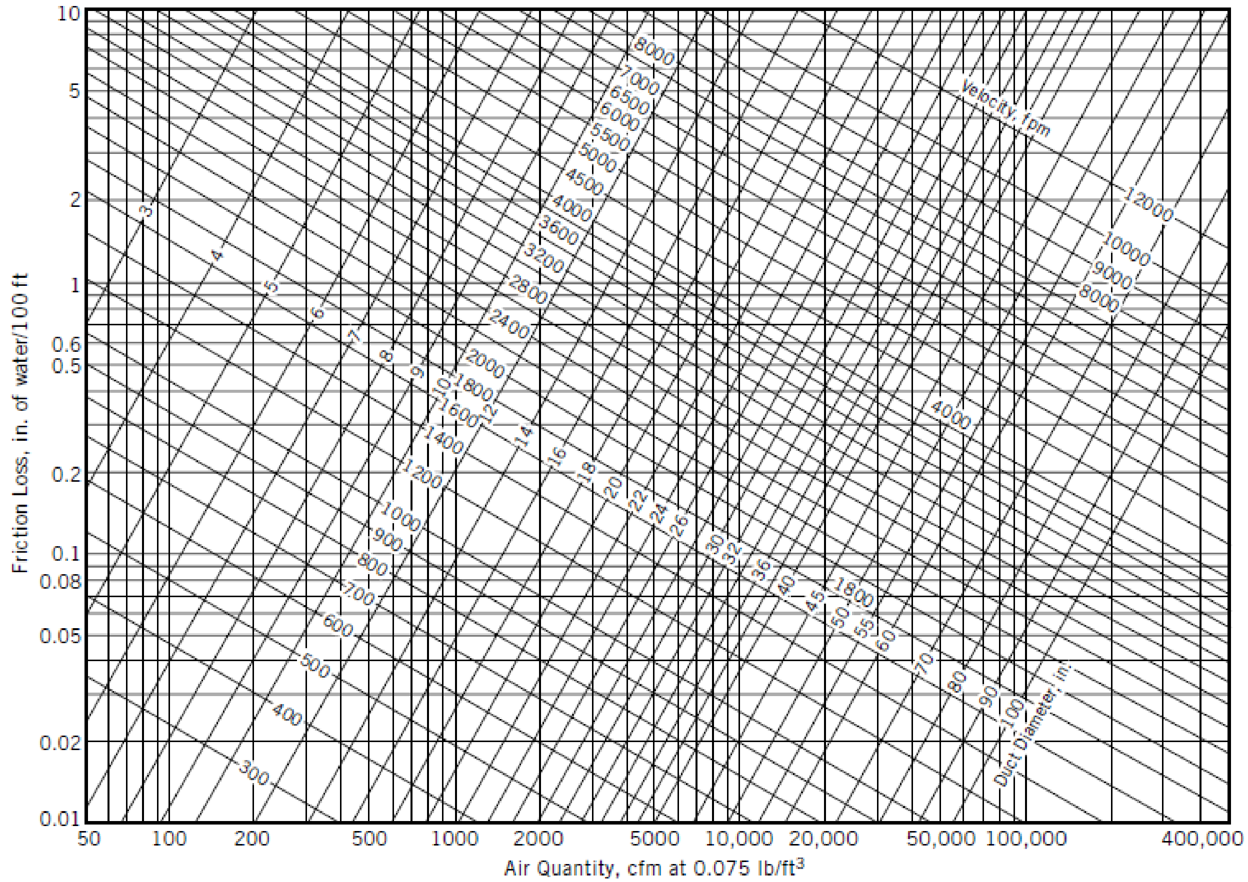


Figure 12-21 Pressure loss due to friction for galvanized steel ducts, IP units. (Reprinted by permission from *ASHRAE Handbook, Fundamentals Volume IP*, 1997.)

Friction Loss

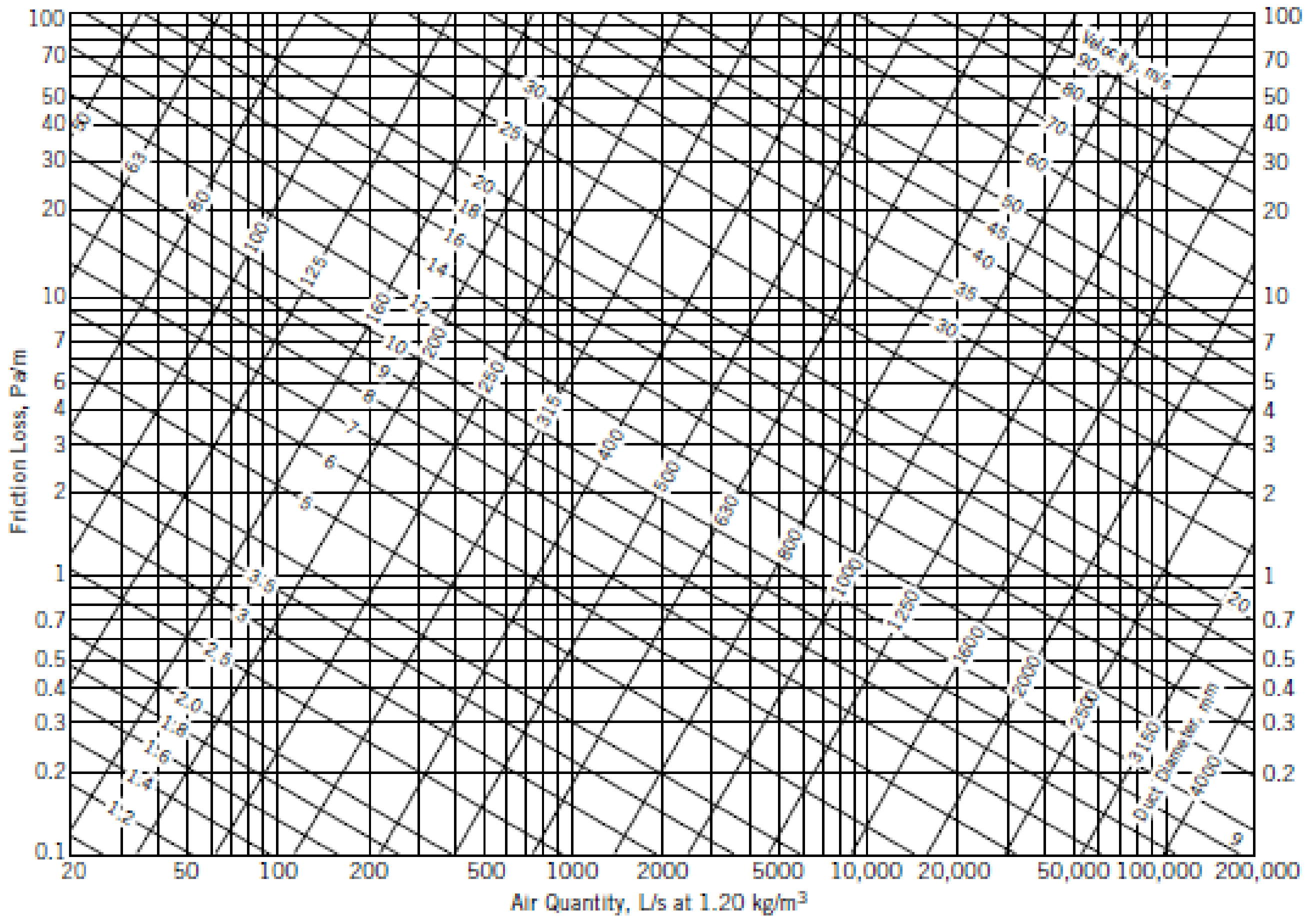


Figure 12-22 Pressure loss due to friction for galvanized steel ducts, SI units. (Reprinted by permission from *ASHRAE Handbook, Fundamentals Volume SI*, 1997.)

Equivalent of a circular duct

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

D_h = Hydraulic diameter
a and b are the dimension of a rectangular duct

Equivalent of a circular duct

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

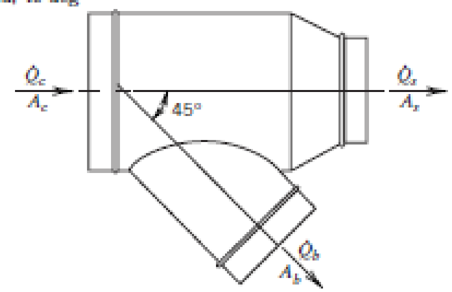
Side *a* of Rectangular Duct	Diameter D_e of Circular Duct																
	b = 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24
6	6.6																
7	7.1	7.7															
8	7.5	8.2	8.8														
9	8.0	8.6	9.3	9.9													
10	8.4	9.1	9.8	10.4	10.9												
11	8.8	9.5	10.2	10.8	11.4	12.0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

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

Friction Loss Fitting Table

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

A. Diverging Wye, Round, 45 deg



Branch, C_b

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

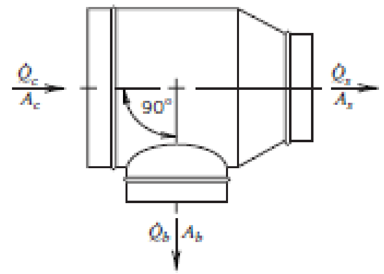
Main, C_s

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

Friction Loss Fitting Table

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

B. Diverging Tee, Round



Branch, C_b

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

Main, C_s

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

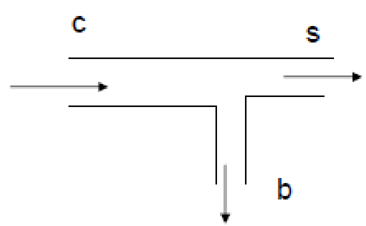
Source: Reprinted by permission from *ASHRAE Duct Fitting Database*, 1992.

Example: Pressure Loss

Compute the loss in total pressure for a round 90-degree branch and straight-through section, a tee.

The common section is 12 in. in diameter, and the straight-through section has a 10 in. diameter with a flow rate of 1100 cfm.

The branch flow rate is 250 cfm through a 6 in. duct.



Straight section

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

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

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

Branch section

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

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

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

From fig. 12.11B

C_s=0.14

C_b =1.55

$$\Delta P_{0s} = C_s \left[\frac{V_s}{4005}\right]^2 = 0.021 \text{ in } H_2O$$

$$\Delta P_{0b} = C_b \left[\frac{V_b}{4005}\right]^2 = 0.16'' \, H_2O$$

Equivalent lengths

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

Table 12-13 Friction Factors for Various Galvanized Steel Ducts

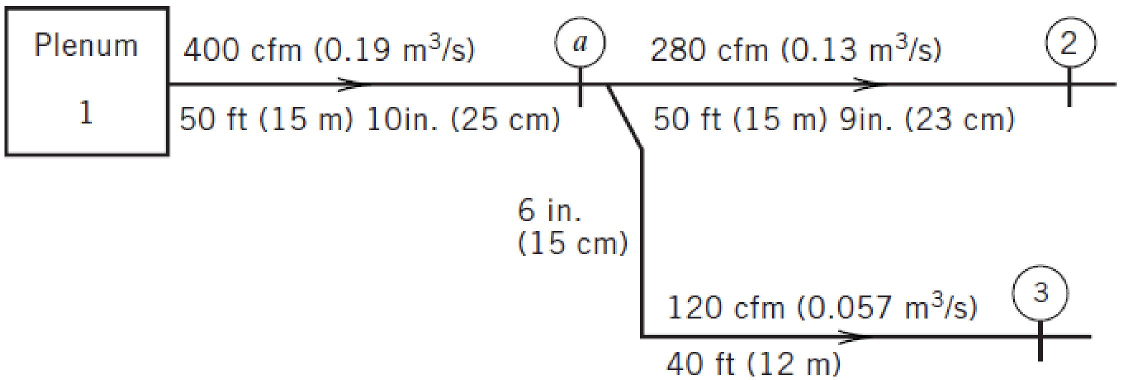
Diameter in.	Diameter mm	Darcy Friction Factor
4	10	0.035
6	15	0.028
8	20	0.023
10	25	0.022
12	30	0.019
14	36	0.017
16	40	0.016
20	50	0.015
24	60	0.014

Friction Loss Example

Example:
Compute the equivalent lengths for the fittings in the duct system of Fig. 12-24. The fittings are an entrance, a 45-degree wye, the straight-through section of the wye fitting, a 45-degree elbow, and a 90-degree elbow.

Table 12-13 Friction Factors for Various Galvanized Steel Ducts

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



SOLUTION

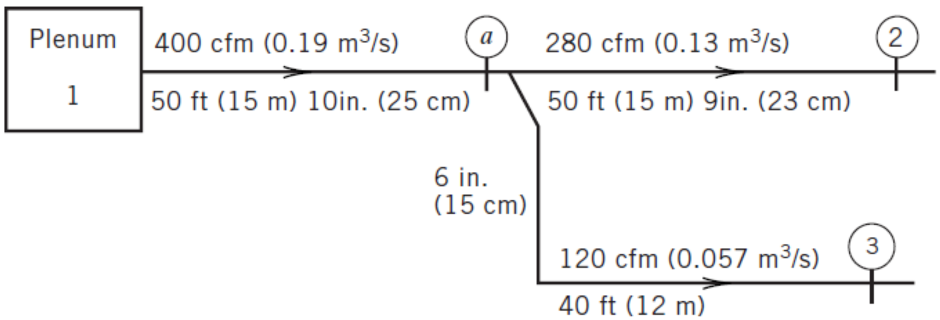
Table 12-10A gives the loss coefficient for an entrance. In this case, θ is either 0 or 180 degrees and C_0 is 0.5. Then using Eq. 12-20, Table 12-13 for f, and a 10 in. diameter, we have

$$\frac{L_t}{D} = \frac{0.5}{0.022} = 22.7 \quad \text{and} \quad L_t = 22.7\left(\frac{10}{12}\right) = 19 \text{ ft}$$

Table 12-11A gives the loss coefficients for the branch of a wye. For this case

$$\frac{\dot{Q}_b}{\dot{Q}_c} = \frac{120}{400} = 0.3 \quad \text{and} \quad \frac{A_b}{A_c} = \left(\frac{6}{10}\right)^2 = 0.36$$

Friction Loss Example



Example:
What is the total pressure loss on the critical path?

Path 1: 1-a-2

$L_e = L_i + 50 + L_{wye,S} + 50$
$= 19 + 50 + 4.4 + 50$
$=$ **123.4 ft**

Path 2: 1-a-3

$L_e = L_i + 50 + L_{wye,Br} + L_{elbow\text{-}90} + 40$
$= 19 + 50 + 11 + 7.7 + 40$
$=$ **127.4 ft**

Critical Path: 1-a-3 with Equivalent length of 127.4 ft

We pick average pressure (friction) loss for duct and calculate the total pressure loss for the system.

Friction loss to be designed for = 0.08"/100ft

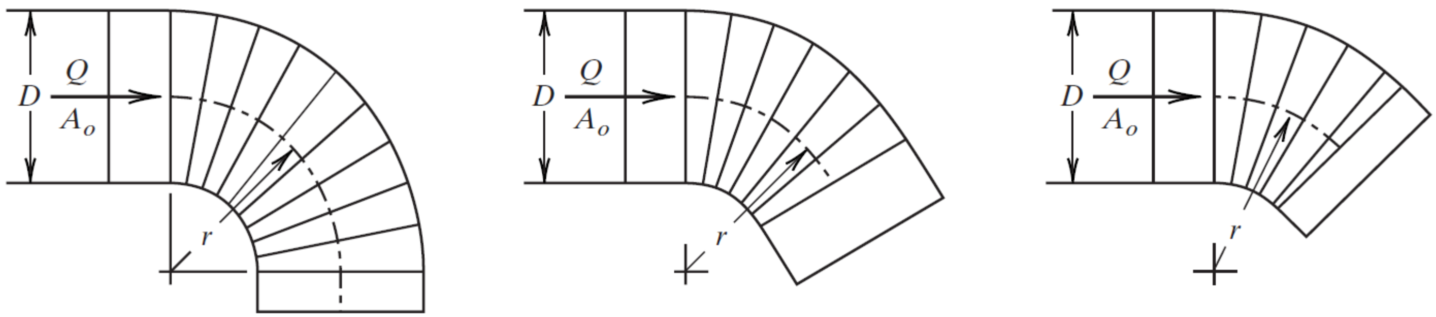
P = 127.4 ft x 0.08"/100ft = **0.102"**

Duct Accessories

1. Turning vanes
   - Linear
   - Airfoil (More efficient)
2. Dampers
   - Parallel blades (open/close)
   - Opposed blades (modulate airflow)
   - Balancing
   - Motorized
   - Backdraft
3. Fire dampers
   - Type A (blades inside air stream)
   - Type B (blades outside air stream)
4. Electric duct heaters

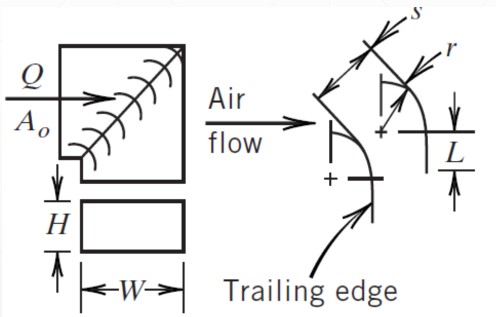
Turning Vanes

A. Elbow, Pleated, $r/D = 1.5$

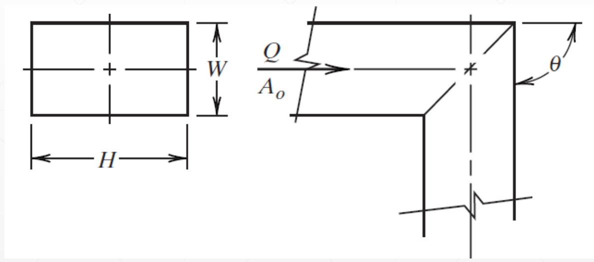


90 degree 60 degree 45 degree

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



C. Elbow, Mitered, Rectangular



Dampers

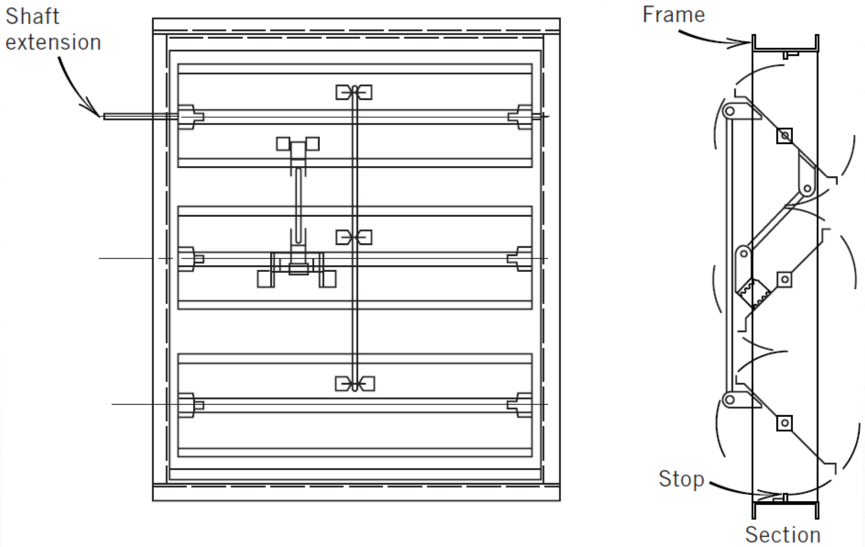


Figure 12-25 Typical opposed blade damper assembly.

Duct Design

Volume (Q) is a function of cross sectional area (A) and velocity (V)

$$Q=AV$$

however, momentum, friction and turbulence must also be accounted for in the sizing method

Air Flow in Ducts

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

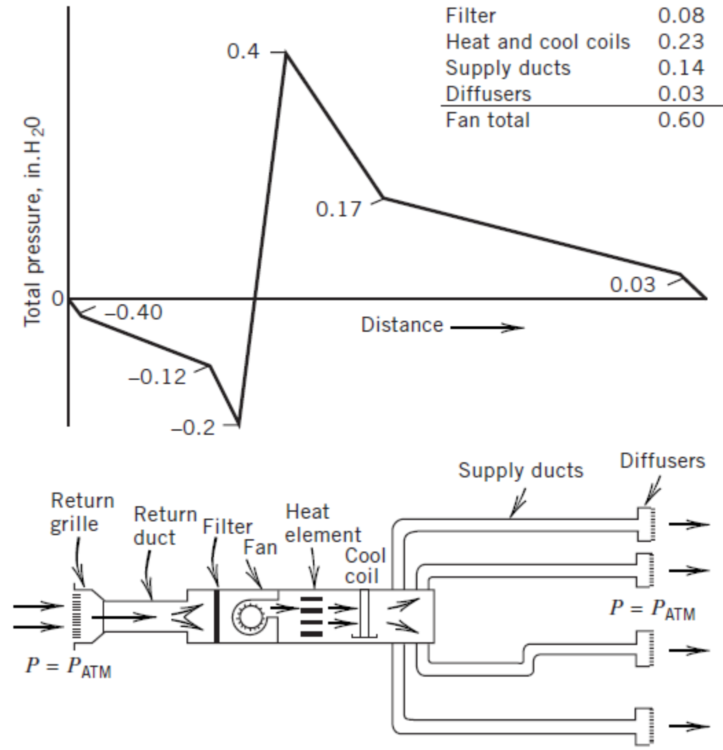


Figure 12-26 Total pressure profile for a simple unitary system.

Static Pressure

- Force required to overcome friction and loss of momentum due to turbulence
- As air encounters friction or turbulence, static pressure is reduced
- Fans add static pressure
- Static pressure is measured in Inches-water gauge
  - Positive pressure pushes air
  - Negative pressure draws air
- Straight ducts have a pressure loss of “w.g./100’

  based on diameter and velocity

Equivalent Length

- Describes the amount of static pressure lost in a fitting that would be comparable to a length of straight duct

Duct Construction

- **Round ductwork is the most efficient but requires greater depth**
- **Rectangular ductwork is the least efficient but can be reduced in depth to accommodate smaller clearances**
- **Avoid aspect ratios greater than 5:1**

Equal Friction Method

- **Presumes that friction in ductwork can be balanced to allow uniform friction loss through all branches**

1. Find effective length (EL) of longest run

2. Establish allowed static pressure loss/100'

$$\Delta P = 100(SP)/E_L$$

3. Size ducts

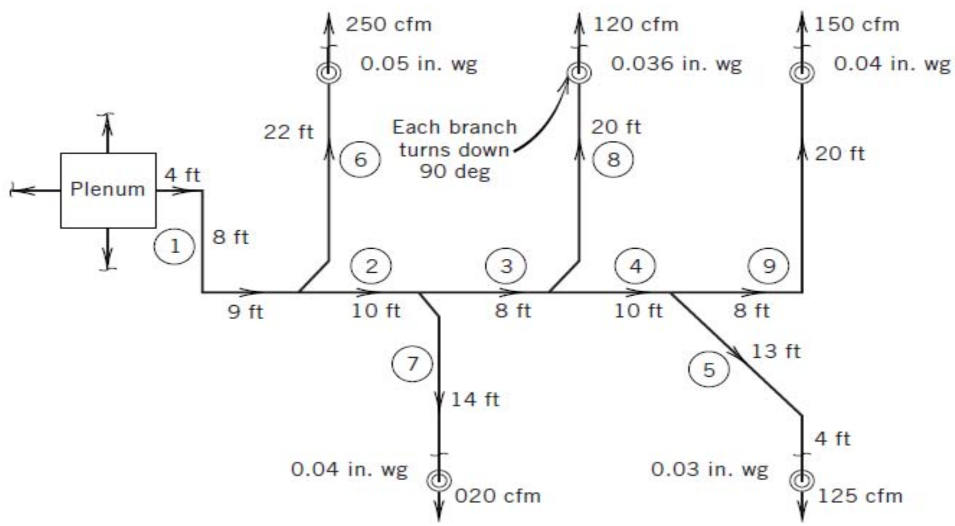
4. Repeat for each branch

Note: velocity must be higher in each upstream section

Equal Friction Method - Example

Given:

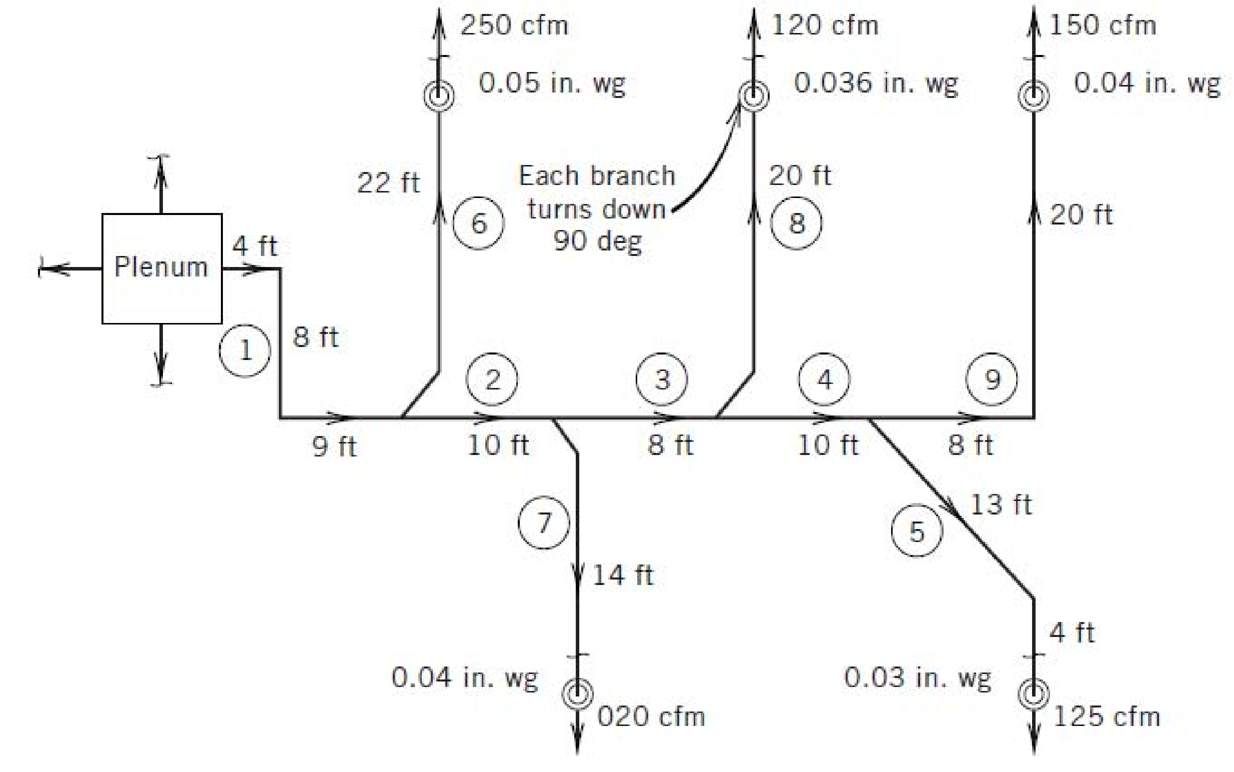
- The system shown is supplied air by a rooftop unit that develops 0.25 in. wg total pressure external to the unit.
- The return air system requires 0.10 in. wg.
- The ducts are to be of round cross section, and the maximum velocity in the main run is 850 ft/min, whereas the branch velocities must not exceed 650 ft/min.



Size:

- The ducts using the equal-friction method.
- Show the location of any required dampers. Compute the total pressure loss for the system.

Equal Friction Method - Example

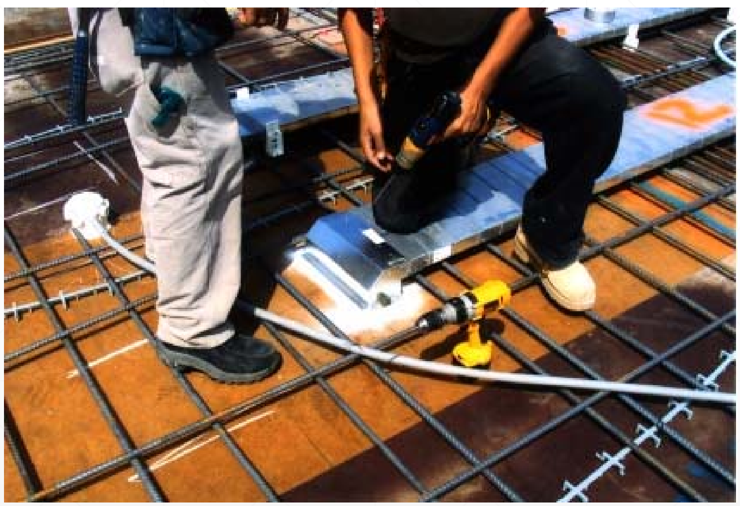


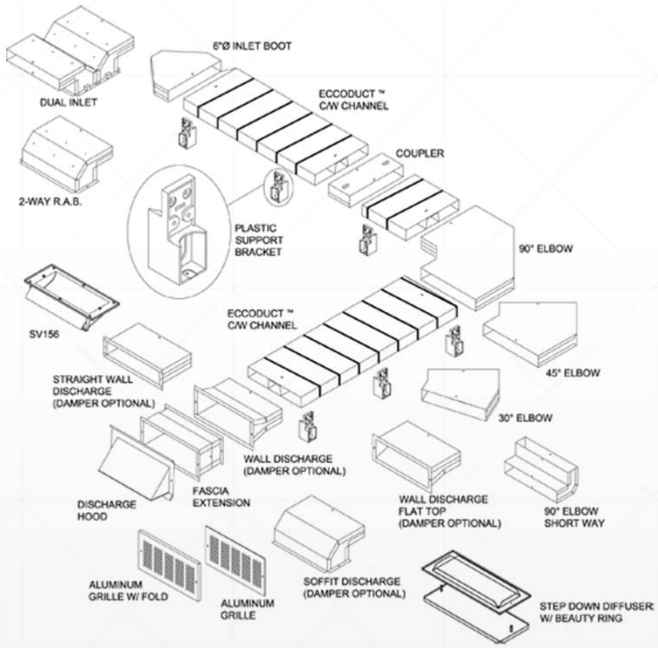
Flex Ducts

- Used to dampen noise when connecting to air terminals or mechanical equipment (i.e. bathroom fans)
- Typically only used for a max 5 foot length.
- Long runs of flex duct and elbows create large pressure drops in your system.

In-Slab Ducts

- Typically seen in high rise buildings were no dropped ceilings are given near building exterior.
- Used to vent oven ranges, dryers, and sometimes bathroom fans.
- Can handle little airflow (approx. 50 CFM) due to size.
- Elbows always shown as two 45° joints to minimize pressure drop.
- Must be minimum of 2’-0” from structural bearing entities (columns, walls).

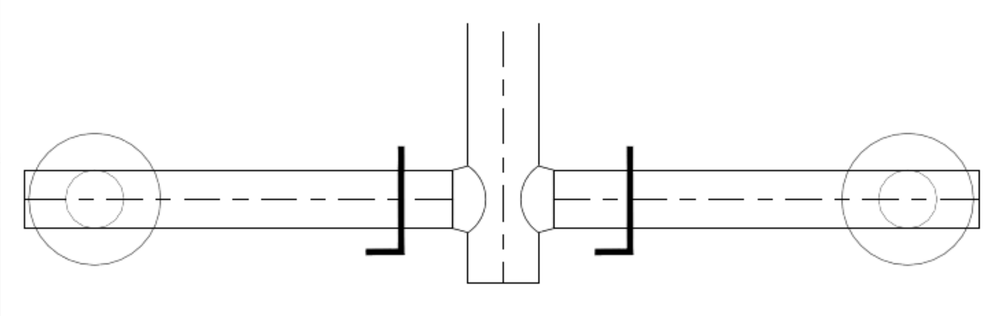


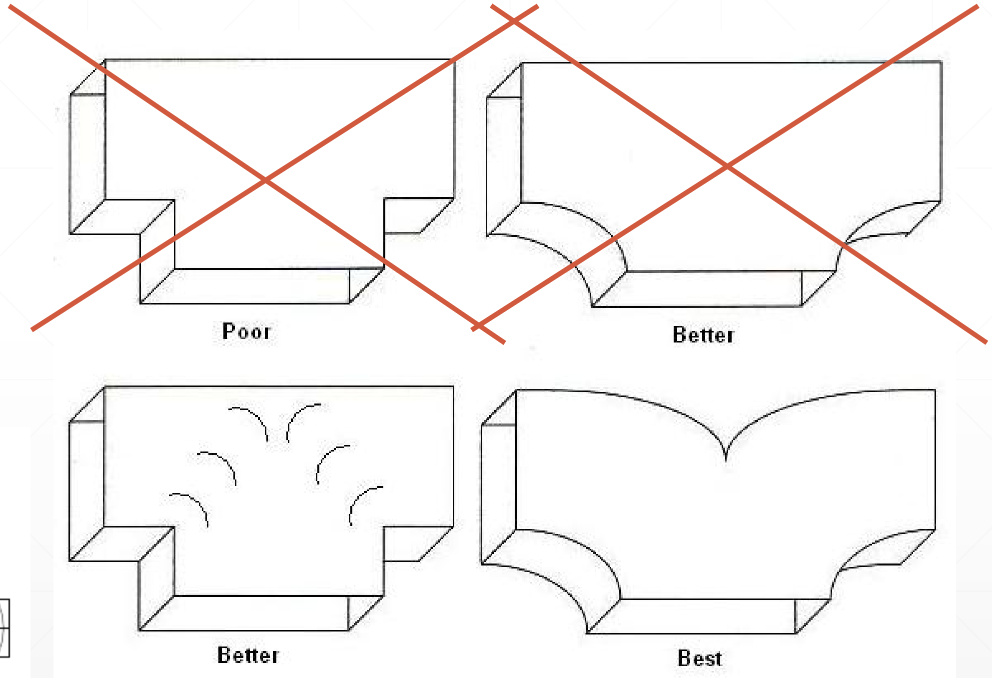


No “Bull Head” Tees

Airflow does not travel well when there is no clear path to follow. Instead

- show the duct continuing onward past the branch (as shown below),
- add turning vanes.
- use “pant leg” or wye type fitting (best option but most expensive)





Rectangular double 90 degree tees

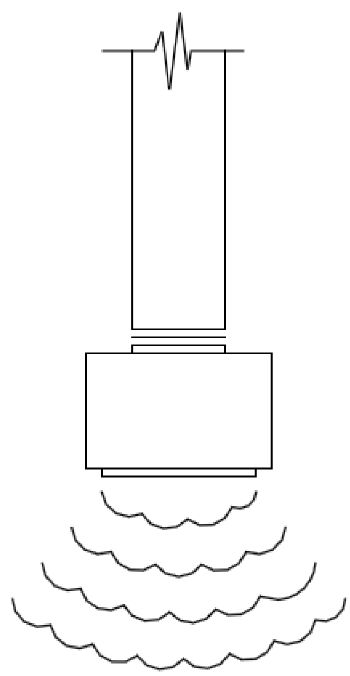
Return Air Boot

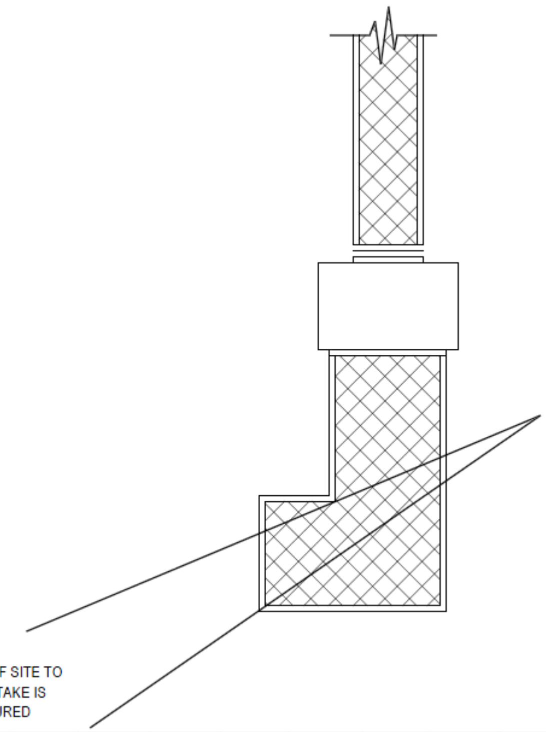
Used to reduce noise emanating from mechanical equipment in and adjacent to occupied spaces.

Should completely obscure line of sight to the air inlet. This forces the sound to bounce

Specified with 1” acoustic insulation.

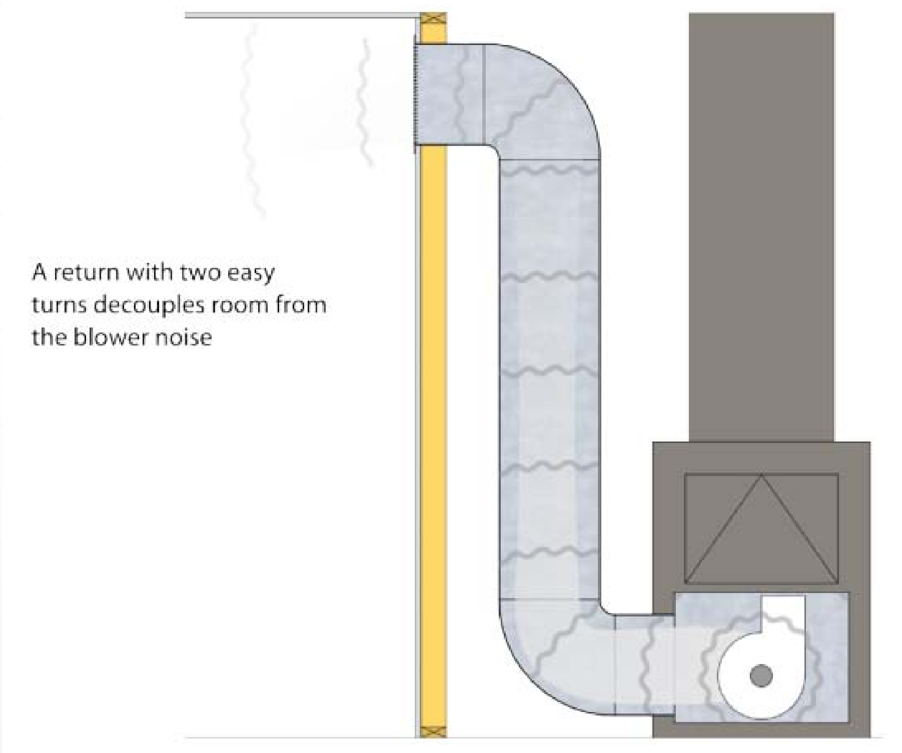
Typical “L” shaped boot is shown to the right.

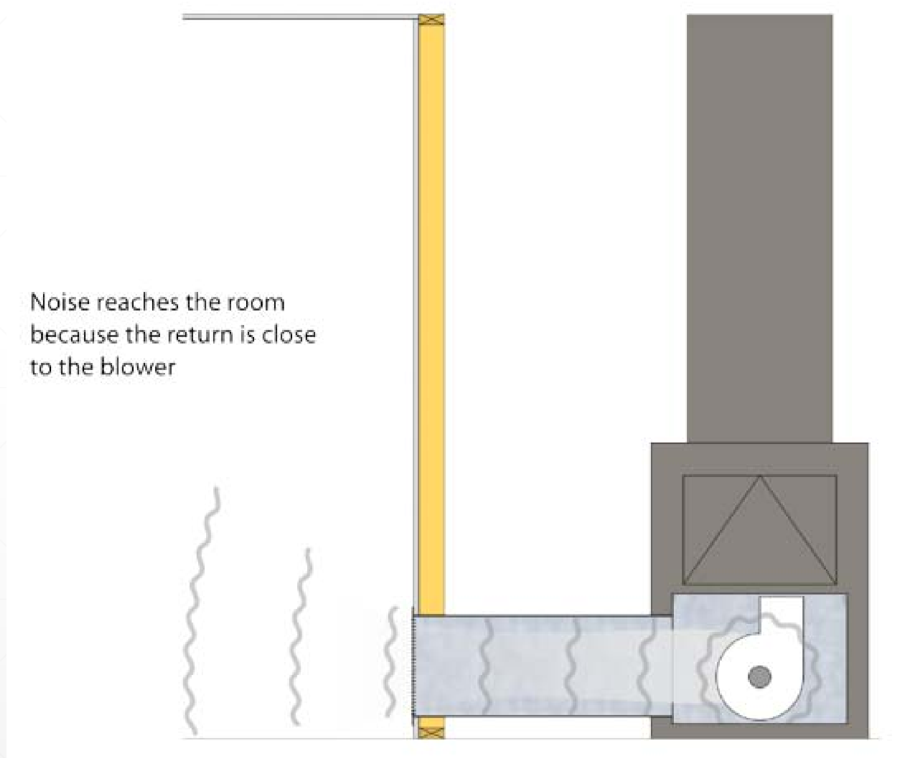




Z-Shape Return Air Boot

Less common but more effective.





Pressurized Plenum with Home Run Ducting

Can be used where there are multiple duct diffusers with similar airflow requirements.

Each "home run" should be approximately the same length with the same pressure drop.

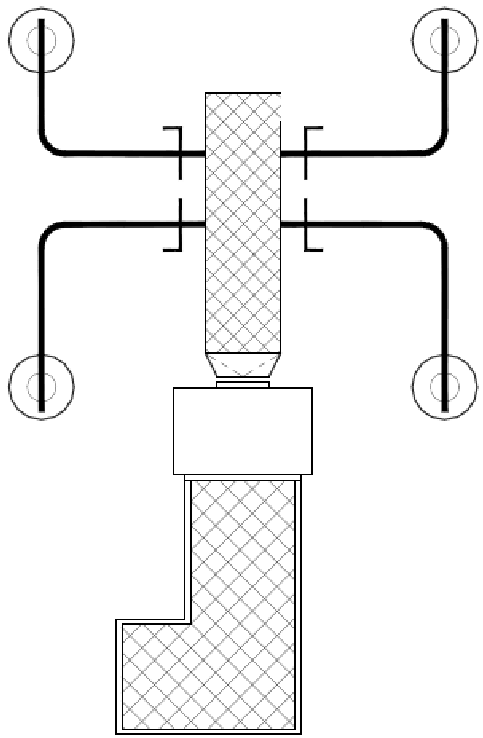
Do not take off ducts close to fan coil or at end of plenum.

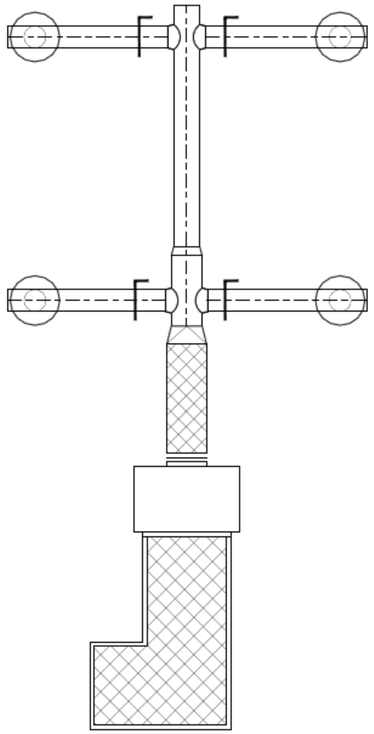
Advantages:

- Can be used where there is very little ceiling height (i.e. running four 6"ø ducts as opposed to one 10"ø / 10"x8")
- Requires less overall space

Disadvantages

- Cannot handle large pressure drops





Questions?