CAE 464/517 HVAC Systems Design

Spring 2023

March 02, 2023

Air distribution systems: Pressure loss in ducts fittings

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ANNOUNCEMENTS

Announcements

- How many of you are attending the career fair today?

Announcements

Cyclone Energy Group | ASHRAE Illinois Institute of Technology Student Branch

Commissioning Skills

to Improve Building Performance

SPEAKER

Commissioning Team Technical Leader

Jed Starner

WHEN

March 2nd, 2023

12:40 pm – 1:40 pm

WHERE

John T. Rettaliata Engineering Center, RE 242

TALK ABOUT

- ✓ Careers in Commissioning Services
- ✓ Work Experiences

For more information, feel free to contact ASHRAE official email ashrae_iit@iit.edu

Interested in Joining

Lunch will be provided!

HOMEWORK / PROJECT / EXAM

Homework / Project / Exam

- Next class we have the first midterm exam:
  - ❑ Exam starts at 8:35 am (be on-time)
  - ❑ Covers the materials before March 2, 2023 (last class)
  - ❑ Open book (Fundamentals) and open notes
  - ❑ Past exams are posted

Homework / Project / Exam

- Project is posted
  - Follow the timeline closely:
  - No extension will be granted
  - Next submission is by the end of next week before the spring break
  - Highly recommend to start working on that ASAP
  - No group composition changes for Part 1 is allowed

RECAP

Recap

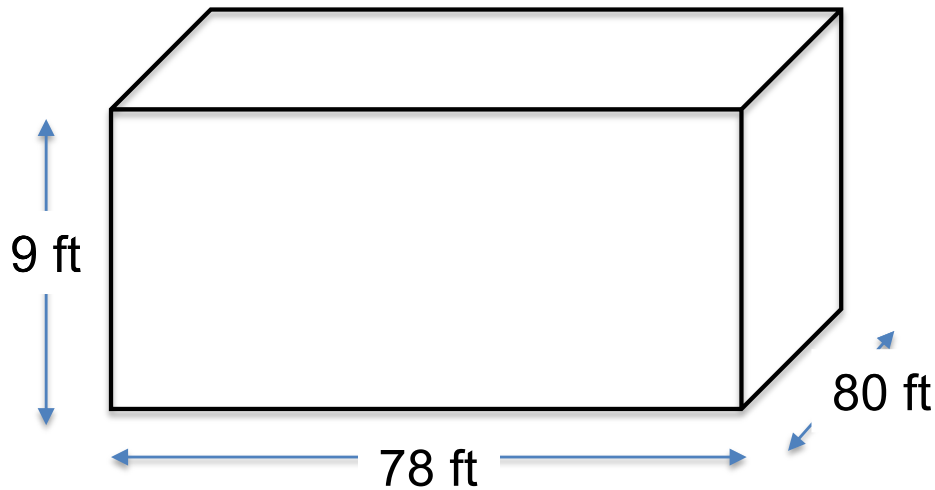
Recap

Performance Data — Models 510, 520 / 610, 620 / 710, 720 / 910, 920

								NC 20	30			40	
	Core Velocity fpm		300	400	500	600	700	800	1000	1200	1400	1600	1800
	Velocity Pressure		.006	.010	.016	.022	.030	.040	.062	.090	.122	.159	.202
Size	Total	0°	.014	.024	.038	.052	.071	.094	.146	.212	.287	.374	.475
	Pressure	22½°	.017	.028	.045	.063	.085	.114	.176	.256	.347	.452	.574
		45°	.025	.042	.067	.093	.126	.168	.261	.379	.514	.669	.850
Ac = **0.15** ft² 7 x 4, 6 x 5	cfm		45	60	75	90	105	120	150	180	210	240	270
	NC		—	—	—	—	15	19	26	31	36	40	44
		0°	4-6-12	5-8-14	7-10-16	8-12-17	9-13-19	11-14-20	13-16-22	14-17-24	15-19-26	16-20-28	17-22-30
	Throw	22½°	3-5-10	4-6-11	6-8-13	6-10-14	7-10-15	9-11-16	10-13-18	11-14-19	12-15-21	13-16-22	14-18-24
	ft	45°	2-3-6	3-4-7	3-5-8	4-6-9	5-7-9	5-7-10	6-8-11	7-9-12	8-9-13	8-10-14	9-11-15
Ac = **0.18** ft² 8 x 4, 7 x 5, 6 x 6	cfm		55	70	90	110	125	145	180	215	250	290	325
	NC		—	—	—	—	16	20	27	32	37	41	45
		0°	4-7-13	6-8-15	7-11-17	9-13-19	10-15-20	11-16-22	14-17-24	15-19-26	17-21-29	18-22-31	19-24-33
	Throw	22½°	3-6-10	5-6-12	6-9-14	7-10-15	8-12-16	9-13-18	11-14-19	12-15-21	14-17-23	14-18-25	15-19-26
	ft	45°	2-3-7	3-4-8	4-5-9	4-7-10	5-7-10	6-8-11	7-9-12	8-10-13	8-10-14	9-11-15	10-12-16
Ac = **0.22** ft² 10 x 4, 8 x 5, 7 x 6	cfm		65	90	110	130	155	175	220	265	310	350	395
	NC		—	—	—	—	17	21	27	33	38	42	45
		0°	4-7-14	7-10-17	8-12-19	9-15-21	11-16-23	13-17-24	16-19-27	17-21-29	19-23-32	20-25-34	21-26-36
	Throw	22½°	3-6-11	6-8-14	6-10-15	7-12-17	9-13-18	10-14-19	13-15-22	14-17-23	15-18-26	16-20-27	17-21-29
	ft	45°	2-4-7	3-5-9	4-6-10	5-7-10	6-8-11	6-9-12	8-10-13	9-11-15	9-12-16	10-12-17	11-13-18
Ac = **0.26** ft² 12 x 4, 10 x 5, 8 x 6	cfm		80	105	130	155	180	210	260	310	365	415	470
	NC		—	—	—	—	17	21	28	34	38	42	46
		0°	5-8-16	7-11-19	9-13-21	10-16-23	12-17-24	14-19-26	17-21-29	19-23-32	20-25-35	22-26-37	23-27-40
	Throw	22½°	4-6-13	6-9-15	7-10-17	8-13-18	10-14-19	11-15-21	14-17-23	15-18-26	16-20-28	18-21-30	18-22-32
	ft	45°	3-4-8	4-5-9	4-7-10	5-8-11	6-9-12	7-9-13	8-11-15	9-12-16	10-13-17	11-13-18	12-14-20
Ac = **0.30** ft² 14 x 4	cfm		90	120	150	180	210	240	300	360	420	480	540
	NC		—	—	—	—	18	22	29	34	39	43	47
		0°	5-9-17	8-11-20	9-14-22	11-17-24	13-19-26	15-20-28	18-23-31	20-25-34	22-27-37	24-29-40	25-30-42
	Throw	22½°	4-7-14	6-9-16	7-11-18	9-14-19	10-15-21	12-16-22	14-18-25	16-20-27	18-22-30	19-23-32	20-24-34
	ft	45°	3-4-8	4-6-10	5-7-11	6-8-12	7-9-13	8-10-14	9-11-16	10-12-17	11-13-19	12-14-20	12-15-21
Ac = **0.34** ft² 16 x 4, 12 x 5, 10 x 6	cfm		100	135	170	205	240	270	340	410	475	545	610
	NC		—	—	—	—	19	23	29	35	40	44	47
		0°	5-9-18	8-12-21	10-15-24	12-19-26	14-20-28	16-22-30	20-24-33	22-26-37	23-28-40	25-30-42	26-32-45
	Throw	22½°	4-7-14	6-10-17	8-12-19	10-15-21	11-16-22	13-18-24	16-19-26	18-21-30	18-22-32	20-24-34	21-26-36
	ft	45°	3-4-9	4-6-11	5-8-12	6-9-13	7-10-14	8-11-15	10-12-17	11-13-18	12-14-20	12-15-21	13-16-22

Recap

- Design of supply diffuser layout



INTRO TO PRESSURE LOSS IN DUCTS AND FITTINGS

Intro to Pressure Loss in Ducts and Fittings

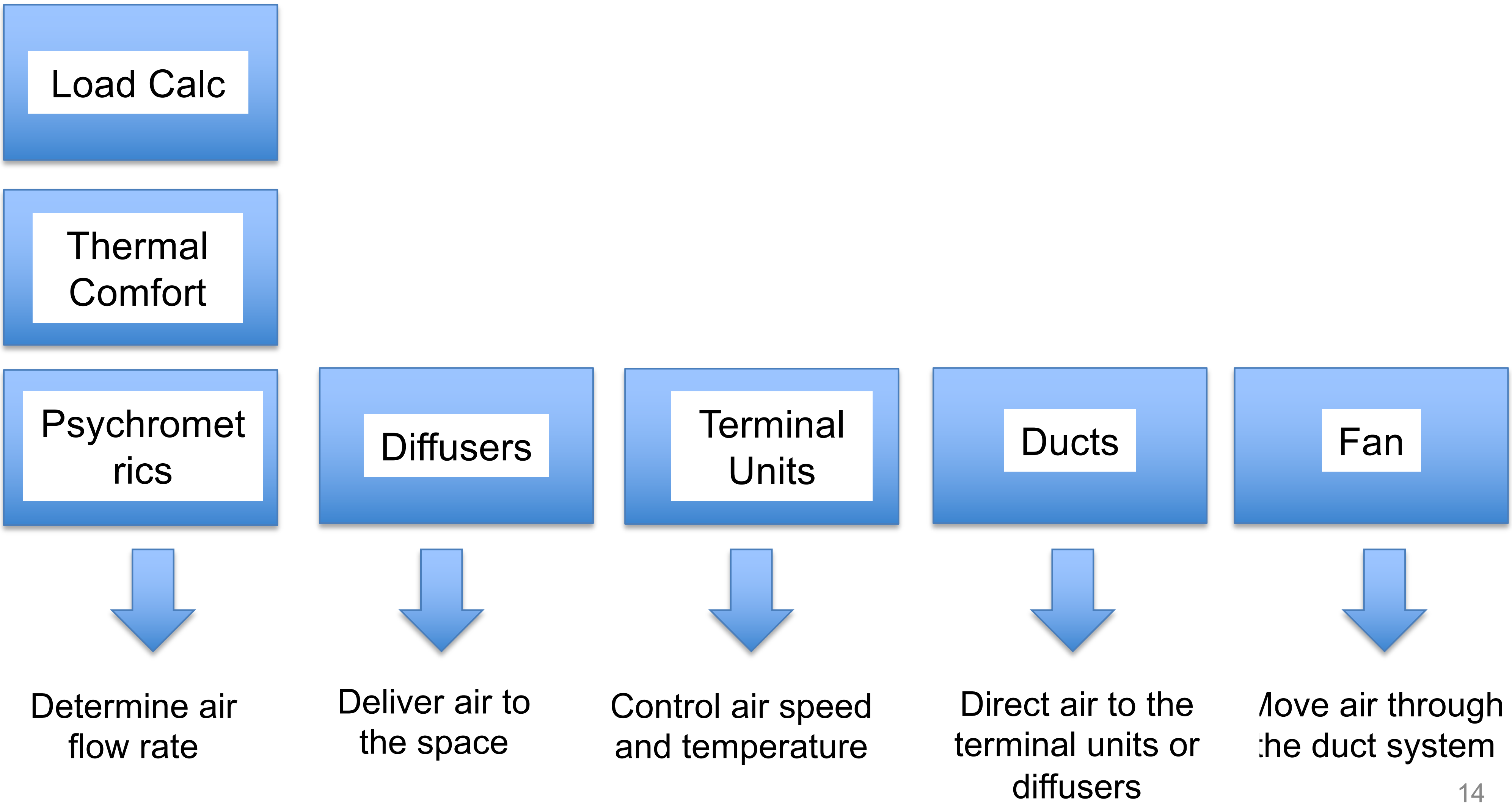
- Most of the materials are from our Fundamentals Chapter 21

CHAPTER 21

DUCT DESIGN

Intro to Pressure Loss in Ducts and Fittings

- There are a couple of components required for the design of an air distribution



Intro to Pressure Loss in Ducts and Fittings

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + H_M - H_L = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

Static head

Lost head (L)

$$P_1 + \frac{\rho V_1^2}{2} + \rho z_1 + \rho H_M - \rho L_h = P_2 + \frac{\rho V_2^2}{2} + \rho z_2$$

Static pressure

Lost pressure

Intro to Pressure Loss in Ducts and Fittings

- No change in the elevation

$$P_1 + \frac{\rho V_1^2}{2} = P_2 + \frac{\rho V_2^2}{2} + \rho L_h$$

- Total pressure in the duct section

$$P_{total,1} = P_{total,2} + \Delta P_f$$

Intro to Pressure Loss in Ducts and Fittings

- We define system requirements

$$P_{total} = \sum_{i \epsilon F_{up}} \Delta \mathrm{p}_{\mathrm{t_i}} + \sum_{i \epsilon F_{down}} \Delta \mathrm{p}_{\mathrm{t_i}}$$

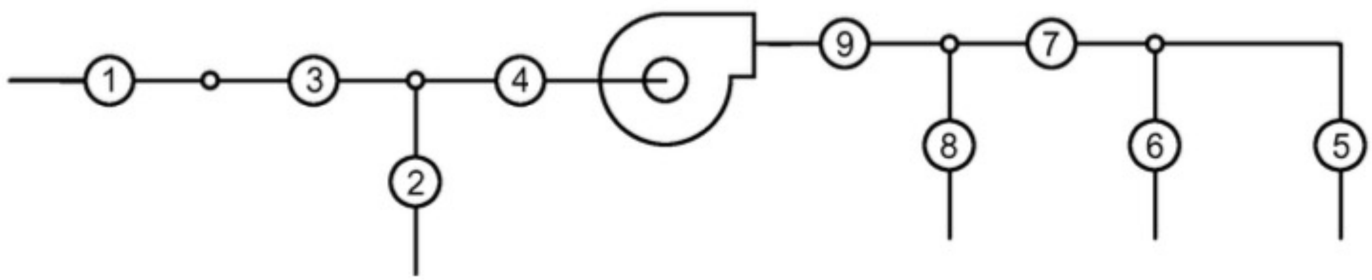
$$i = 1,2, \ldots n_{up}, n_{down}$$

- ❑ F_{up} and F_{down} : Sets of duct sections returns and downstream of fan
- ❑ ϵ: Symbol that ties duct sections into system paths from exhaust/return air terminals to supply terminals

CLASS ACTIVITY

Class Activity

- What is the pressure requirement for balancing airflow in this configuration?



Class Activity

- Solution: The following equations must be satisfied to attain pressure balancing for design airflow

$$P_{total} = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5$$

$$P_{total} = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_6$$

$$P_{total} = \Delta p_1 + \Delta p_3 + \Delta p_4 + \Delta p_9 + \Delta p_8$$

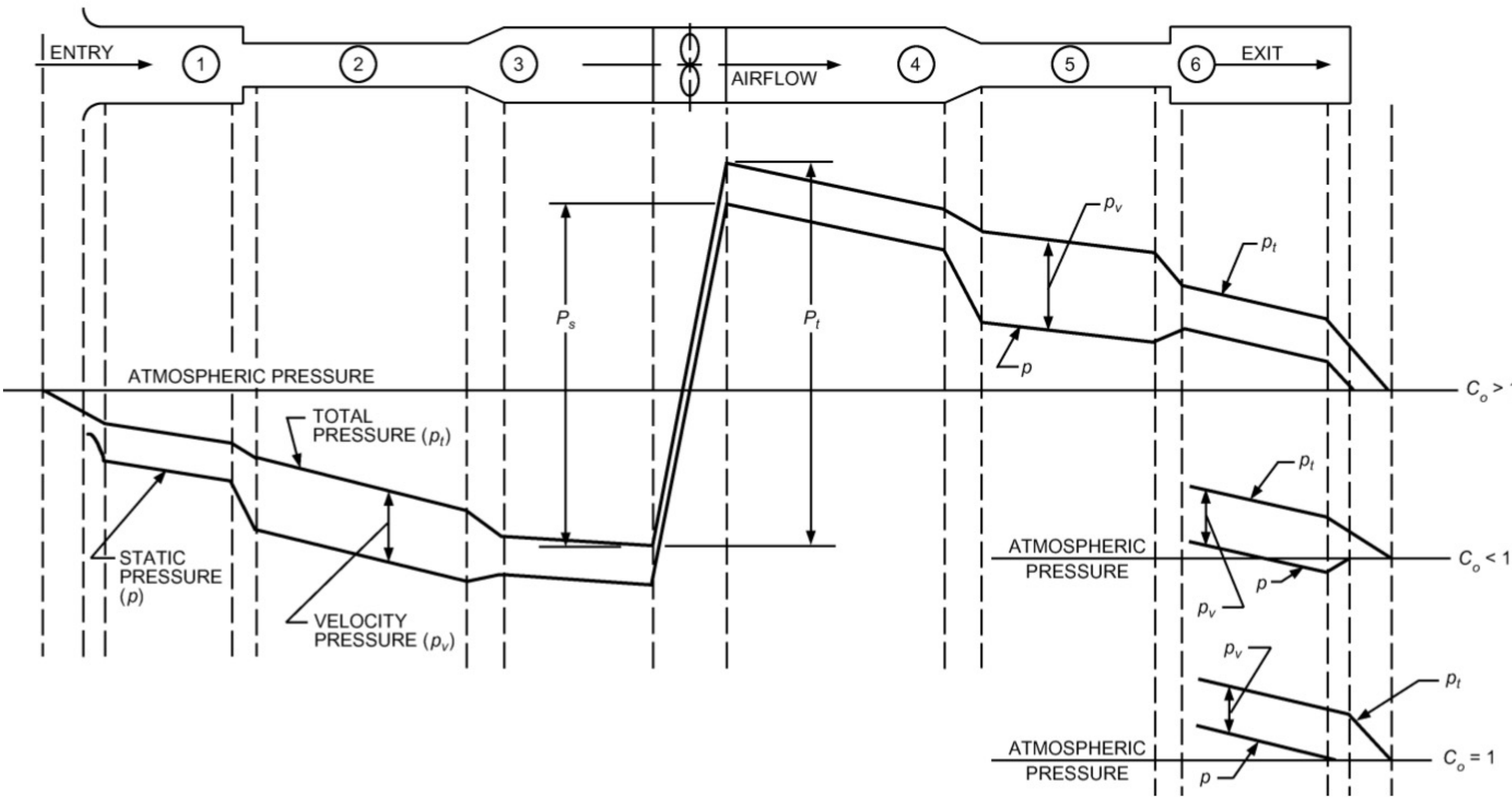
$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_5$$

$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_7 + \Delta p_6$$

$$P_{total} = \Delta p_2 + \Delta p_4 + \Delta p_9 + \Delta p_8$$

TOTAL FAN PRESSURE

Total Fan Pressure



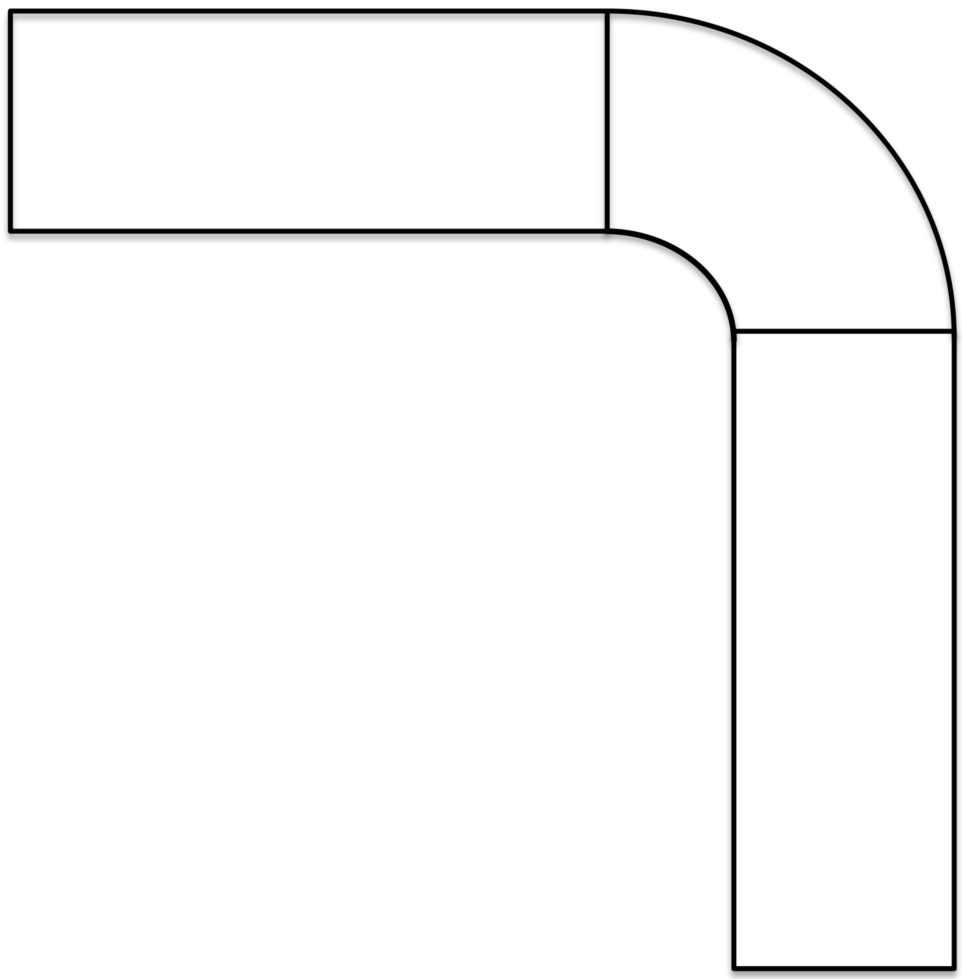
Total Fan Pressure

- The airflow system principals are:
  - ❑ The measure of the amount of energy required to move air from one location to another is the change (decrease) in the total pressure within the system
  - ❑ The total pressure (P_{total}) at any location within a system is a measure of the total mechanical energy at that location. It is the sum of the static pressure and the velocity pressure
  - ❑ In any duct system, the total pressure always decreases in the direction of airflow
  - ❑ In any system having two or more branches, the losses in total pressure between the fan and the end of each branch are the same
  - ❑ Static pressure and velocity pressure are mutually convertible and can either increase or decrease in the direction of flow

PRESSURE LOSSES IN DUCTS AND FITTINGS

Pressure Losses in Ducts and Fittings

- How do we calculate the pressure loss here:



Pressure Losses in Ducts and Fittings

- Consider loss coefficient (K) for fittings as:

$$Loss\ of\ section = K\left(\frac{V^2}{2g}\right)$$

- Adding them together, the total losses in the pipe is:

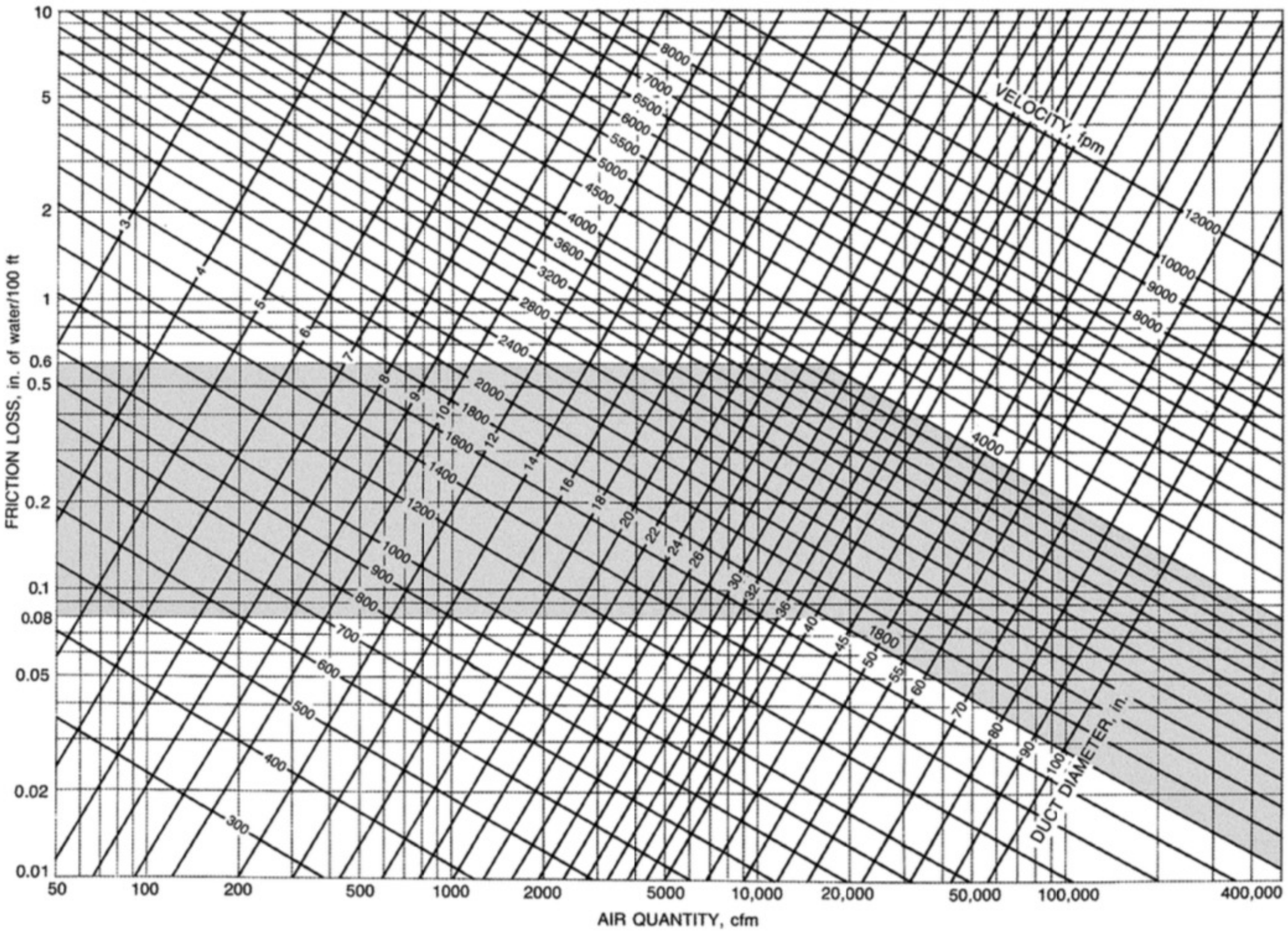
$$H_{Lf} = \left[K + f\left(\frac{L}{D}\right)\right]\left(\frac{V^2}{2g}\right)$$

Pressure Losses in Ducts and Fittings

Table 1 Duct Roughness Factors

1	2	3
	Absolute Roughness ε, ft	
Duct Type/Material	**Range**	**Roughness Category**
Drawn tubing (Madison and Elliot 1946)	0.0000015	Smooth 0.0000015
PVC plastic pipe (Swim 1982)	0.00003 to 0.00015	Medium smooth 0.00015
Commercial steel or wrought iron (Moody 1944)	0.00015	
Aluminum, round, longitudinal seams, crimped slip joints, 3 ft spacing (Hutchinson 1953)	0.00012 to 0.0002	
Friction chart:		
Galvanized steel, round, longitudinal seams, variable joints (Vanstone, drawband, welded. Primarily beaded coupling), 4 ft joint spacing (Griggs et al. 1987)	0.00016 to 0.00032	Average 0.0003
Galvanized steel, spiral seams, 10 ft joint spacing (Jones 1979)	0.0002 to 0.0004	
Galvanized steel, spiral seam with 1, 2, and 3 ribs, beaded couplings, 12 ft joint spacing (Griggs et al. 1987)	0.00029 to 0.00038	
Galvanized steel, rectangular, various type joints (Vanstone, drawband, welded. Beaded coupling), 4 ft spacing[a] (Griggs and Khodabakhsh-Sharifabad 1992)	0.00027 to 0.0005	
Wright Friction Chart:		
Galvanized steel, round, longitudinal seams, 2.5 ft joint spacing, ε = 0.0005 ft	Retained for historical purposes [See Wright (1945) for development of friction chart]	
Flexible duct, nonmetallic and wire, fully extended (Abushakra et al. 2004; Culp 2011)	0.0003 to0.003	Medium rough 0.003
Galvanized steel, spiral, corrugated,[b] Beaded slip couplings, 10 ft spacing (Kulkarni et al. 2009)	0.0018 to 0.0030	
Fibrous glass duct, rigid (tentative)[c]	—	
Fibrous glass duct liner, air side with facing material (Swim 1978)	0.005	
Fibrous glass duct liner, air side spray coated (Swim 1978)	0.015	Rough 0.01
Flexible duct, metallic corrugated, fully extended	0.004 to 0.007	
Concrete (Moody 1944)	0.001 to 0.01	

Pressure Losses in Ducts and Fittings



Pressure Losses in Ducts and Fittings

- Based on:
  - ❑ Standard air
  - ❑ Round galvanized sheet metal with 4 ft joints
  - ❑ Absolute roughness of 0.0003 ft
- No correction for:
  - ❑ Medium roughness
  - ❑ Temperature range 40 ºF to 100 ºF
  - ❑ Elevations to 1,500 ft
  - ❑ Duct pressure range -20 to 20 in w.c
- Variation of +/- 5%

Pressure Losses in Ducts and Fittings

- We define circular equivalent of rectangular ducts as:

$$D_e = 1.30\,\frac{(ab)^{0.625}}{(a+b)^{0.25}}$$

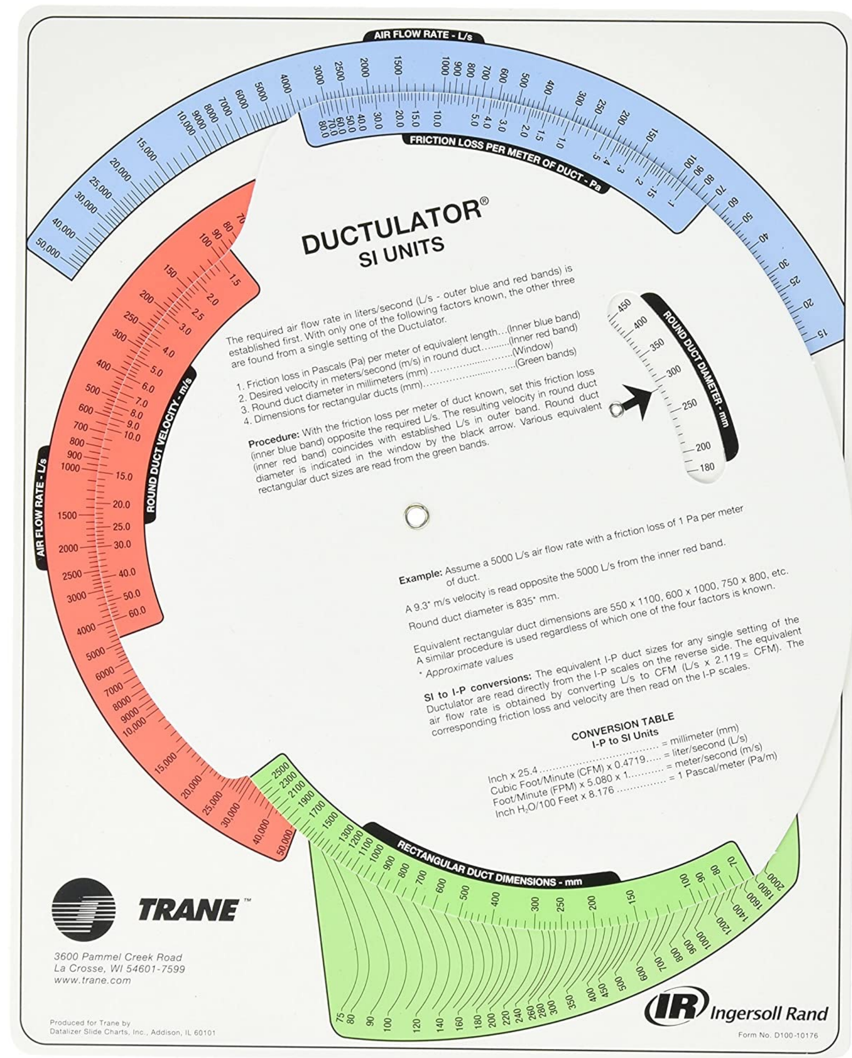
- Where:
  - ❑ D_e: Circular equivalent of a rectangular duct (in)
  - ❑ a: Height of duct (in)
  - ❑ b: Width of duct (in)

Pressure Losses in Ducts and Fittings

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										

Pressure Losses in Ducts and Fittings

- Ductulator options exist



CLASS ACTIVITY

Class Activity

- Example: For a duct of 12 in by 12 in delivers 1,000 cfm. Find equivalent duct size and the friction loss per 100 ft of duct length

Class Activity

- Solution:

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									

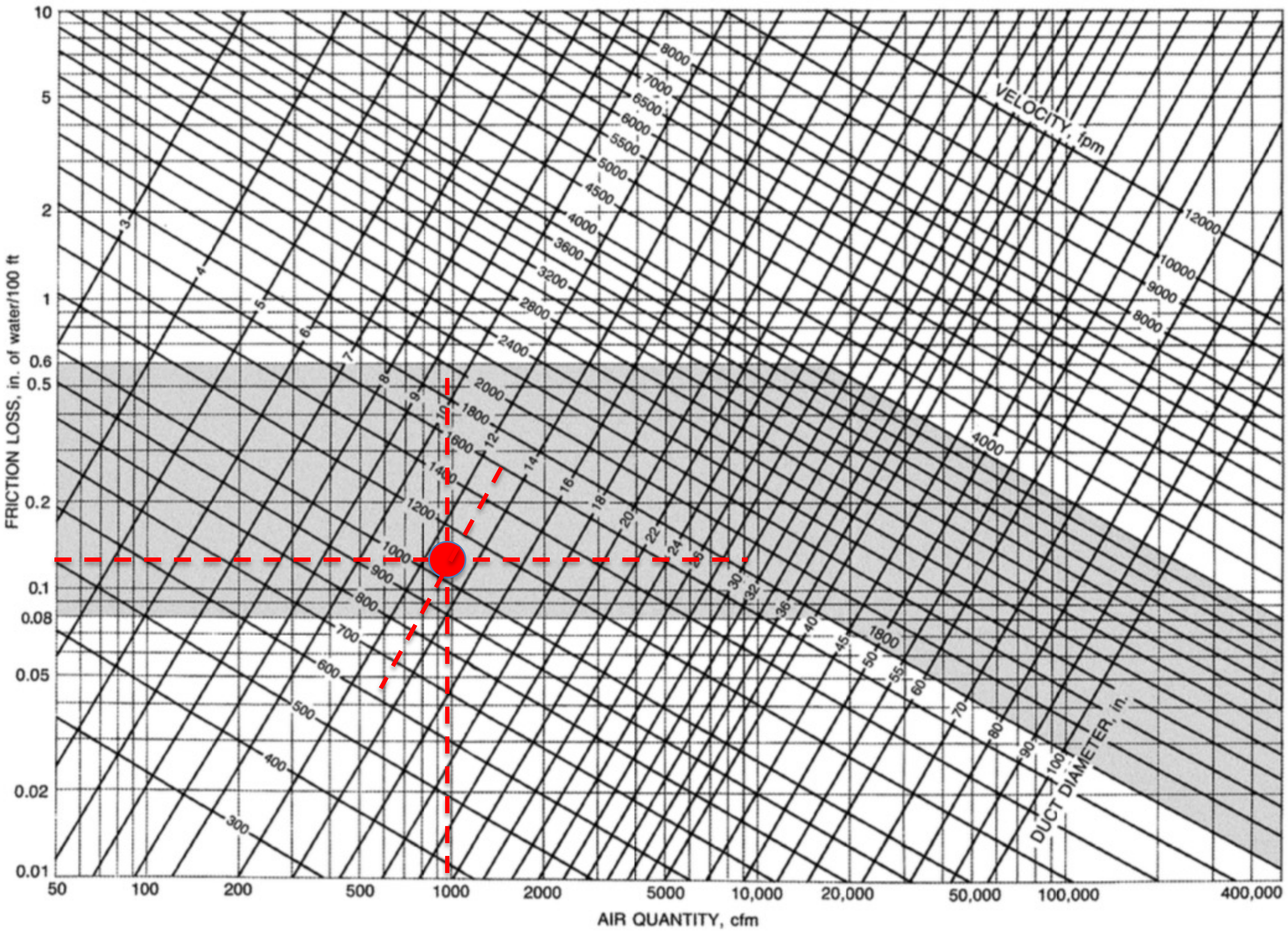
Class Activity

$$D_e = 1.30\,\frac{(ab)^{0.625}}{(a+b)^{0.25}}$$

$$D_e = 1.30\,\frac{(12\times 12)^{0.625}}{(12+12)^{0.25}}$$

$$D_e = 13.1\ in$$

Class Activity



PRESSURE LOSS IN FITTINGS

Pressure Loss in Fittings

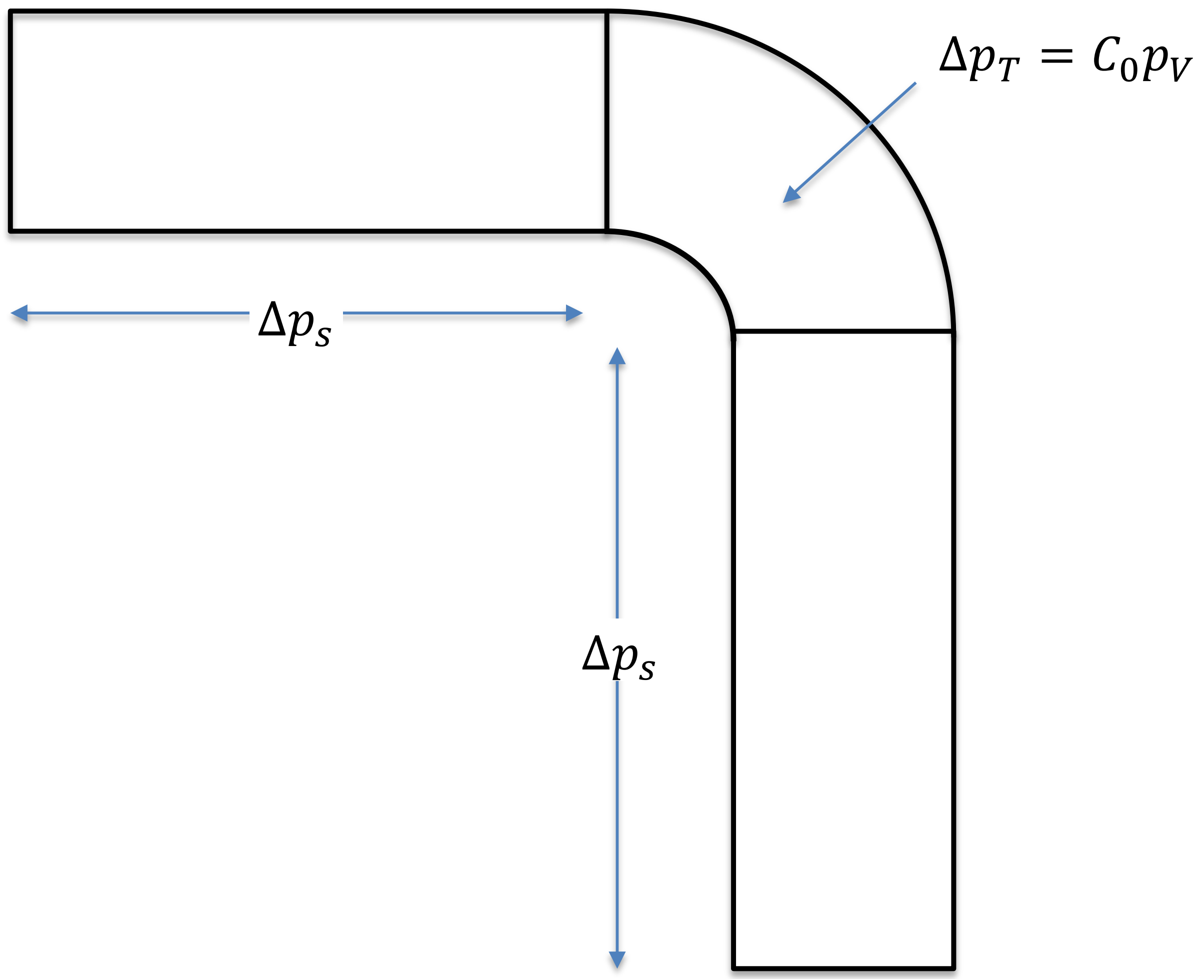
- For all fittings except junctions, the pressure loss in a fitting can be written as

$$\Delta p_{total} = C_o \, p_{v,0}$$

- ❑ C_o: Local loss coefficient of fitting (dimensionless)
- ❑ Δp_{total}: Fitting total pressure loss (in w.c.)
- ❑ $p_{v,o}$: Velocity pressure at section “o" of fitting (in w.c.)
- ❑ $p_{v,o} = \left(\frac{V_o}{4,005}\right)^2$
- ❑ V_o: Velocity in section of fitting

Pressure Loss in Fittings

- Pressure drop calculations (elbows and transitions)



Pressure Loss in Fittings

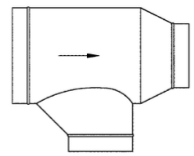
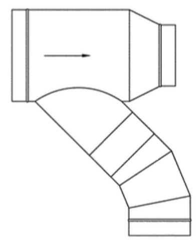
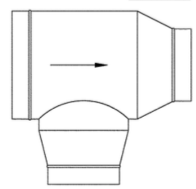
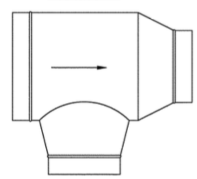
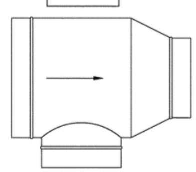
$$p_{v,o} = \left(\frac{V_o}{4{,}005}\right)^2$$

Duct velocity V_o (fpm)	Duct pressure p_v (in w.c.)
4,000	1.00
3,000	0.56
2,000	0.25
1,000	0.06

Pressure Loss in Fittings

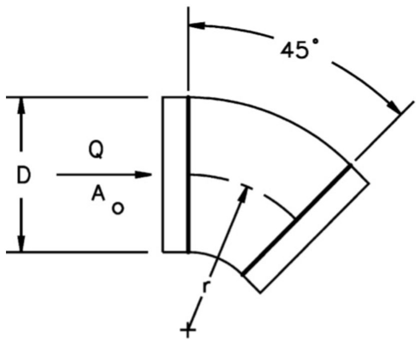
- Pressure drop calculations for converging and diverging fittings are documents in the Handbook:

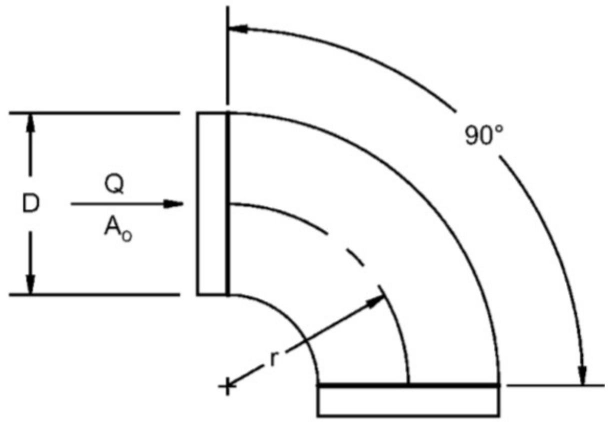
Table 10 Options for Selecting 90° Takeoff

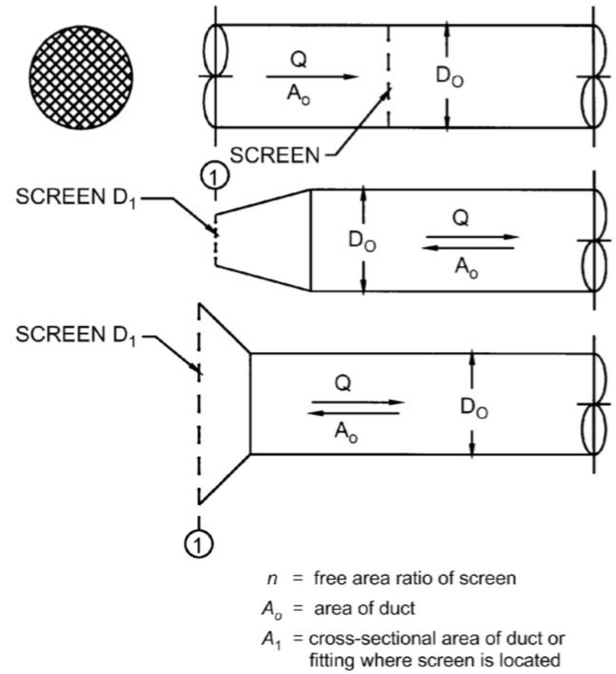
Code	Description		Efficiency	Loss Coefficient	
				Main[a]	Branch[b]
SD5-12	Tee, 45° entry branch		Highest	0.15	0.64
SD5-4	Wye, 45°, Straight body branch with 45° elbow, 90° to main		—	0.15	0.74
SD5-11	Tee, Conical branch		—	0.15	0.87
SD5-10	Tee, Conical branch tapered into body		—	0.15	1.10
SD5-9	Tee		Lowest	0.15	1.80

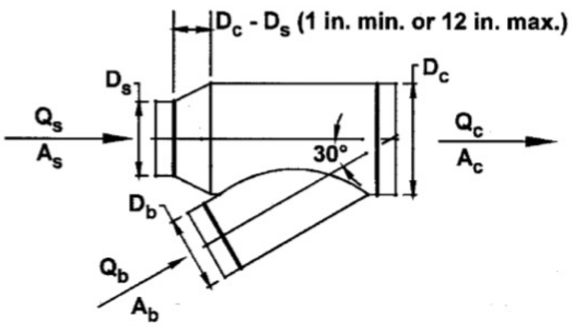
[a] $Q_s/Q_c = 0.8$; $A_s/A_c = 0.69$
[b] $Q_b/Q_c = 0.2$; $A_b/A_c = 0.25$

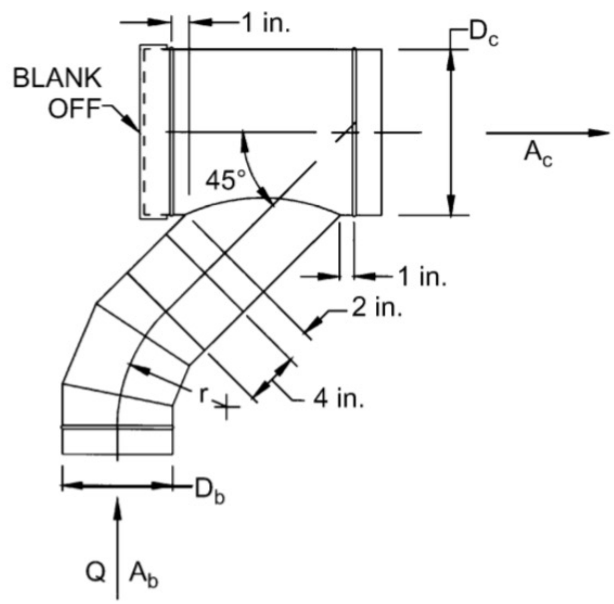
Pressure Loss in Fittings

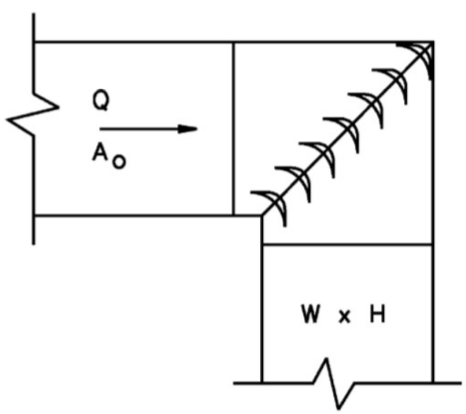






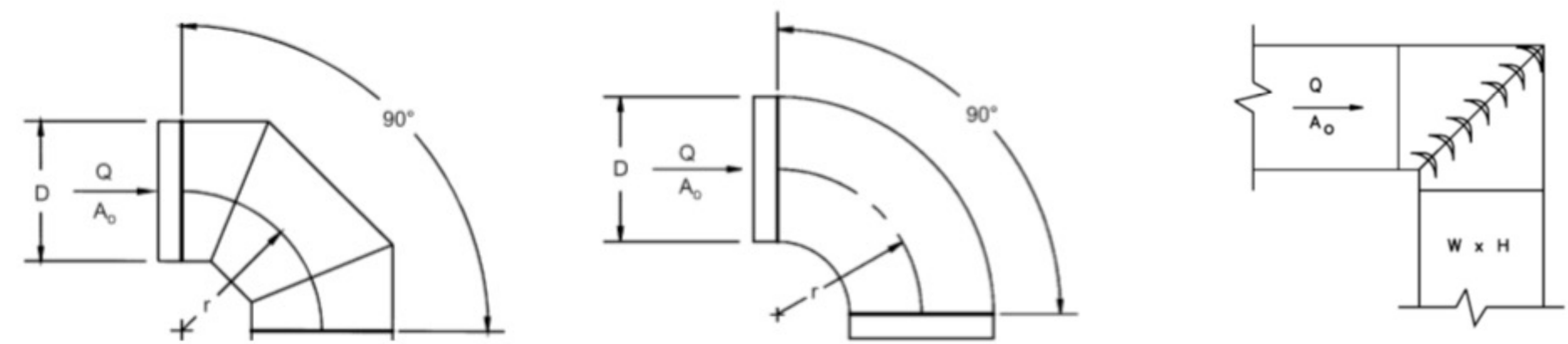






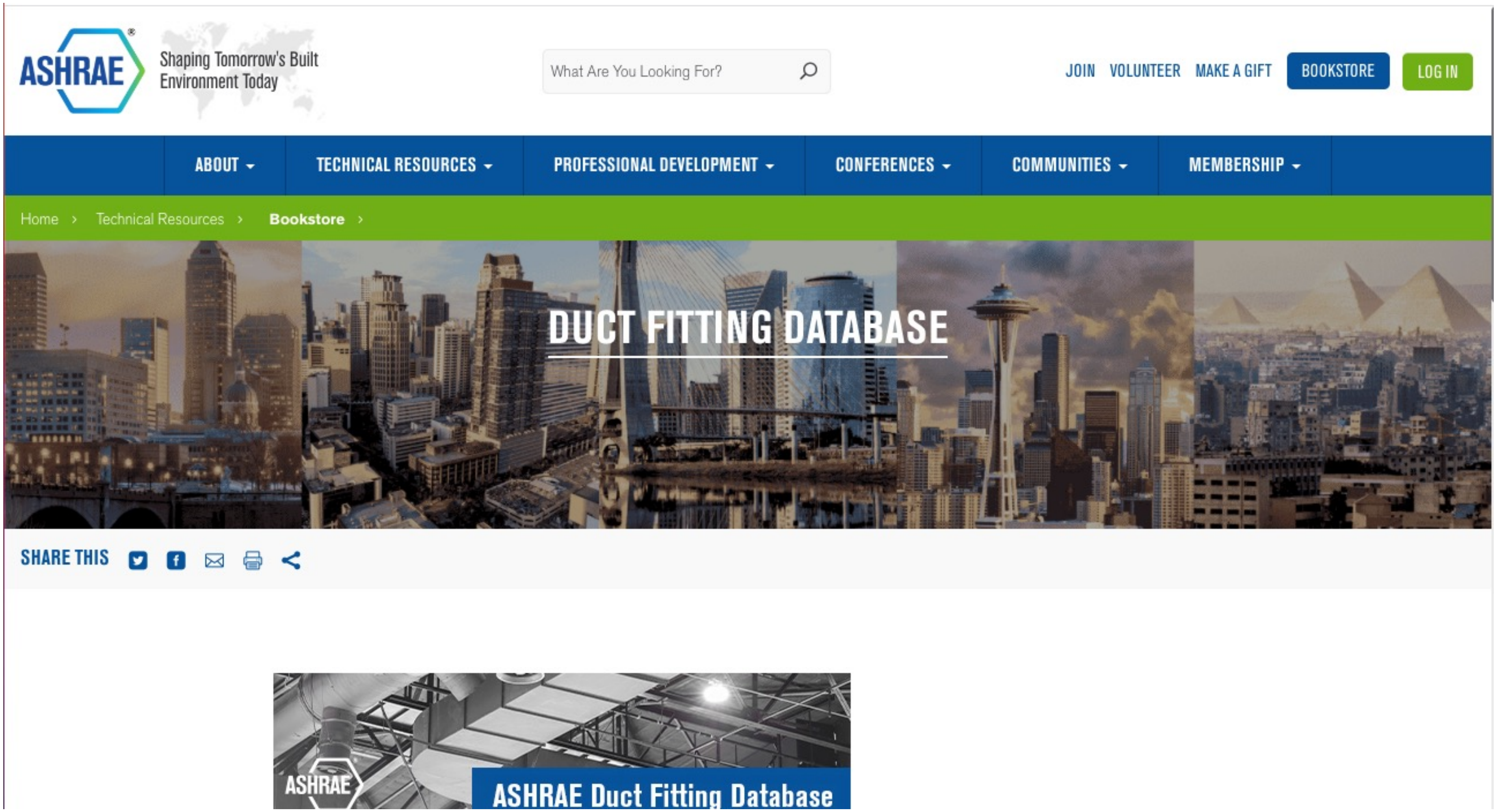
Pressure Loss in Fittings

- Local loss coefficient in elbow is a function of:
  - ❑ Turning angle of elbow
  - ❑ Relative radius of curvature of throat radius to width of duct
  - ❑ Installation of vanes
  - ❑ Shape of the cross section of the duct



Pressure Loss in Fittings

- ASHRAE or SMACNA have different apps and documents for providing these losses



https://www.ashrae.org/technical-resources/bookstore/duct-fitting-database

Pressure Loss in Fittings

- You can use other resources (e.g., Chapter 8 of the Price Industries Handbook)
- Older version of ASHRAE Handbook

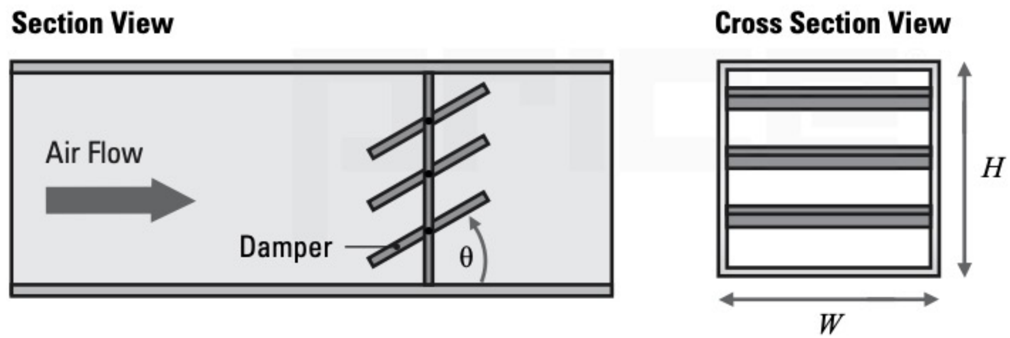
https://utahashrae.org/images/meeting/011119/Slides/smacna_duct_design_fundamentals.pdf

http://ftp.demec.ufpr.br/disciplinas/TM184/VENTILACAO_LOCAL_EXAUSTORA/DUCT_DESIGN.pdf

Pressure Loss in Fittings

- Dampers (e.g., parallel blade):

$$C_0 = \frac{\Delta p_0}{p_v}$$



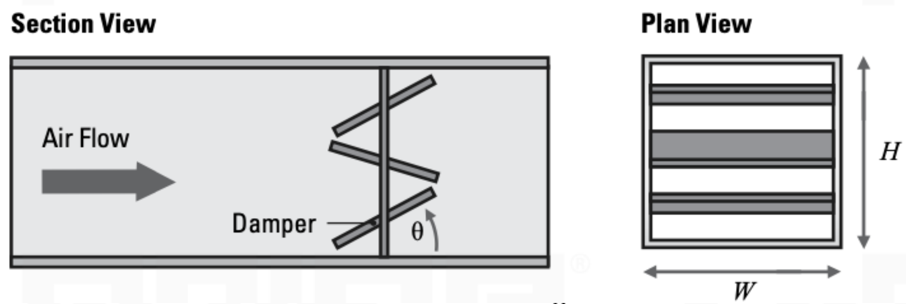
Coefficient C									
L/R	θ								
	80°	70°	60°	50°	40°	30°	20°	10°	0° fully open
0.3	116	32	14	9.0	5.0	2.3	1.4	0.79	0.52
0.4	152	38	16	9.0	6.0	2.4	1.5	0.85	0.52
0.5	188	45	18	9.0	6.0	2.4	1.5	0.92	0.52
0.6	245	45	21	9.0	5.4	2.4	1.5	0.92	0.52
0.8	284	55	22	9.0	5.4	2.5	1.5	0.92	0.52
1.0	361	65	24	10	5.4	2.6	1.6	1.0	0.52
1.5	576	102	28	10	5.4	2.7	1.6	1.0	0.52

Price Industries Engineering Handbook

Pressure Loss in Fittings

- Dampers (e.g., opposed blade):

$$C_0 = \frac{\Delta p_0}{p_v}$$



Abrupt Exit - Coefficient *C*									
L/R	θ								
	80°	70°	60°	50°	40°	30°	20°	10°	0° fully open
0.3	807	284	73	21	9.0	4.1	2.1	0.85	0.52
0.4	915	332	100	28	11	5.0	2.2	0.92	0.52
0.5	1045	377	122	33	13	5.4	2.3	1.0	0.52
0.6	1121	411	148	38	14	6.0	2.3	1.0	0.52
0.8	1299	495	188	54	18	6.6	2.4	1.1	0.52
1.0	1521	547	245	65	21	7.3	2.7	1.2	0.52
1.5	1654	677	361	107	28	9.0	3.2	1.4	0.52

$$\frac{L}{R} = \frac{NW}{2(H+W)}$$

Price Industries Engineering Handbook

Pressure Loss in Fittings

- Supply outlets (from the same performance data tables):

PDF/PDN/PDC/PDMC/PDSP

Perforated Face Supply Diffuser

PERFORMANCE DATA

PDF/PDFE - 16 in. x 16 in.

Inlet Size	Neck Velocity (fpm) / Velocity Pressure (in. w.g.)		300 / .006	400 / .010	500 / .016	600 / .022	700 / .031	800 / .040	900 / .050	1000 / .062	1200 / .090	1400 / .122
6 Ø	Total Pressure (in. w.g.)		.012	.021	.033	.047	.064	.084	.106	.131	.189	.257
	Flow Rate (cfm)		59	78	98	118	137	157	176	196	235	274
	Sound (NC)		-	-	-	19	24	28	32	35	41	46
	Throw (ft.)	4 Way	0-1-4	1-2-6	1-3-7	2-4-8	3-5-9	4-6-10	4-7-10	5-7-11	6-8-12	7-9-13
		3 Way	1-1-5	1-2-7	2-4-9	2-5-10	3-6-11	4-7-11	5-8-12	6-9-13	7-10-14	8-11-15
		2 Way	1-2-7	1-3-10	2-5-12	3-7-13	4-8-14	6-10-15	7-11-16	8-12-17	10-13-19	11-14-20
		1 Way	1-2-9	2-4-12	3-6-15	4-9-17	5-10-18	7-12-19	9-13-20	10-15-21	12-17-23	14-18-25
6 x 6	Total Pressure (in. w.g.)		.013	.024	.037	.054	.073	.096	.121	.150	.215	.293
	Flow Rate (cfm)		75	100	125	150	175	200	225	250	300	350
	Sound (NC)		-	-	17	22	27	31	35	38	44	48
	Throw (ft.)	4 Way	1-1-5	1-2-7	2-4-9	2-5-9	3-6-10	4-7-11	5-8-11	6-9-12	7-9-13	8-10-14
		3 Way	1-2-6	1-3-8	2-5-10	3-6-11	4-7-12	5-8-13	6-9-14	7-10-14	8-11-16	10-12-17
		2 Way	1-2-8	2-4-11	3-6-14	4-8-15	5-10-16	7-11-17	8-13-18	9-14-19	11-15-21	13-16-23
		1 Way	1-3-11	2-5-14	3-8-17	5-11-19	7-12-20	9-14-22	11-16-23	12-17-24	14-19-26	16-20-29
8 Ø	Total Pressure (in. w.g.)		.017	.029	.046	.066	.090	.118	.149	.184	.265	.360
	Flow Rate (cfm)		105	140	175	209	244	279	314	349	419	489
	Sound (NC)		-	-	21	26	31	35	39	42	48	52
	Throw (ft.)	4 Way	1-2-7	2-3-9	2-5-10	3-7-11	5-8-12	6-9-13	7-10-14	7-10-14	9-11-16	10-12-17
		3 Way	1-2-8	2-4-11	3-7-12	4-8-13	6-9-14	7-11-15	8-11-16	9-12-17	11-13-19	12-14-20
		2 Way	1-3-11	2-6-14	4-9-16	6-11-18	8-12-19	9-14-20	11-15-22	12-16-23	14-18-25	16-19-27
		1 Way	2-4-13	3-7-18	5-11-20	7-13-22	10-15-24	12-18-26	13-19-27	15-20-29	18-22-31	19-24-34
	Total Pressure (in. w.g.)		.019	.034	.053	.076	.104	.136	.172	.212	.305	.415

Can you calculate the static and dynamic pressure drops?

https://www.priceindustries.com/content/uploads/assets/literature/catalogs/performance-data/section%20c/pdf-perforated-face-supply-diffuser-performance-data.pdf

Pressure Loss in Fittings

- Any other components in the duct system to consider?
  - ❑ Heating coil
  - ❑ Cooling coil
  - ❑ Outdoor air louvers

Pressure Loss in Fittings

- Although they often account for a major portion of the total pressure loss, the additional losses due to entries and exits, fittings and dampers are traditionally referred to as minor losses

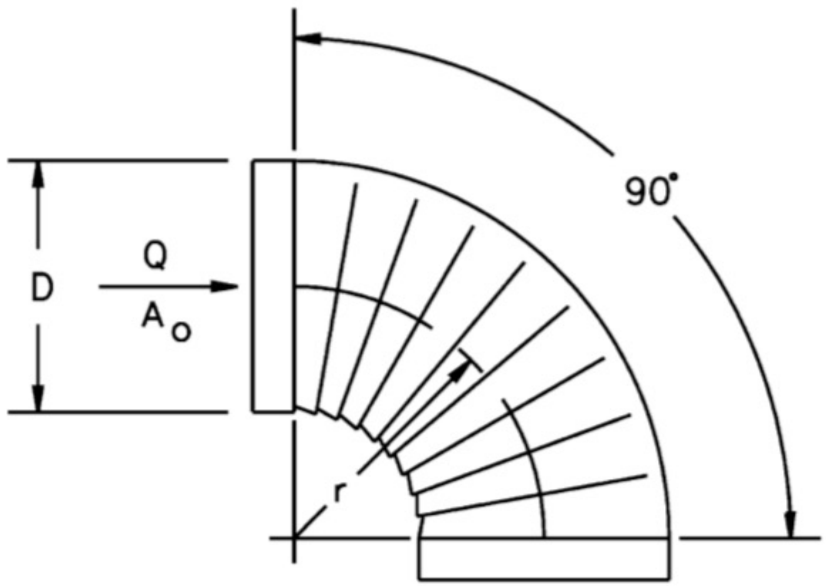
- These losses represent additional energy dissipation in the flow, usually caused by secondary flows induced by curvature or recirculation

- The minor losses are any total pressure loss present in addition to the total pressure loss for the same length of straight pipe

CLASS ACTIVITY

Class Activity

- Problem:
  - Compute the lost pressure in a 6 in, 90-degree plated elbow that has 150 cfm of airflow through it
  - The ratio of turning radius to diameter is 1.5



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

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

Class Activity

- Solution (IP Unit):

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

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

- Calculate velocity

$$V = \frac{Q}{A} = \frac{Q}{\left(\frac{\pi}{4}\right) D^2} = \frac{150 \times 4 \times 144}{\pi \times 36} = 764\ fpm$$

Class Activity

- Calculate pressure (IP Unit):

$$p_v = \left(\frac{V}{4{,}005}\right)^2 = \left(\frac{746}{4{,}005}\right)^2 = 0.036\ in\ w.c.$$

- Calculate fitting total pressure loss:

$$\Delta p_T = C_0 p_v = 0.43 \times 0.036 = 0.016\ in\ w.c.$$

Class Activity

- Solution (SI Unit):

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

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

- Calculate velocity

$$V = \frac{Q}{A} = \frac{Q}{\left(\frac{\pi}{4}\right) D^2} = \frac{(4.25\,\frac{m^3}{min})\times 4}{\pi\times(0.1524)^2(60\,\frac{s}{min})} = 3.88\,\frac{m}{s}$$

- Calculate pressure

$$p_v = \left(\frac{V}{1.29}\right)^2 = \left(\frac{3.88}{1.29}\right)^2 = 3.89\ Pa$$

$$p_T = C_0 p_v = 0.43\times 3.89 = 1.627\ Pa$$

DESIGN RULES

Design Rules

- The most important is that the duct fitting loss is a function of the velocity pressure in the duct, and that duct velocity pressure is a function of the square of the flow rate:

  - ❑ In practical terms, it means that the pressure losses associated with a poor fitting in a low velocity duct system will be much less than the losses associated with the same fitting in a higher velocity duct system

Design Rules

- A second important rule is that the ratio of perimeter to cross sectional area for a large duct is generally much smaller than it is for a small duct:
  - In practical terms, the velocities in a large duct will be much higher than they are in a smaller duct when designed at equal friction rates
  - As a result, the potential for a poor fitting to cause a static pressure problem is much higher in the larger ducts associated with an air handling system

Design Rules

- Some common fitting terminology are:

Fitting Function	**Geometry**	**Category**	**Sequential Number**
S: **S**upply	D: Round (**D**iameter)	1. Entries	1, 2, 3, …
		2. Exits	
E: **E**xhaust / Return	R: **R**ectangular	3. Elbows	
		4. Transitions	
C: **C**ommon (supply/ return)	F: **F**lat oval	5. Junctions	
		6. Obstructions	
		7. Fan and system interactions	
		8. Duct-mounted equipment	
		9. Dampers	
		10. Hoods	

Design Rules

- A few items to consider are:
  - ❑ Space pressure relationships
  - ❑ Fire and smoke control
  - ❑ Duct insulation
  - ❑ Duct system leakage
  - ❑ System and duct noise
  - ❑ Testing and balancing

Design Rules

- See Table 12 for the recommended maximum airflow velocities:

Table 12 Recommended Maximum Airflow Velocities to Achieve Specified Acoustic Design Criteria*

Duct Location	NC or RC Rating in Adjoining Occupancy	Maximum Airflow Velocity, fpm	
		Rectangular Duct	Round Duct
1	2	3	4
In shaft or above solid drywall ceiling	45	3500	5000
	35	2500	3500
	25 or less	1500	2500
Above suspended acoustical ceiling	45	2500	4500
	35	1750	3000
	25 or less	1000	2000
Duct within occupied space	45	2000	3900
	35	1450	2600
	25 or less	950	1700

Design Rules

- Look at Table 9 for different design criterion for recommended duct velocity and diameter:

Table 9 Maximum Airflow of Round, Flat Oval and Rectangular Ducts as Function of Available Ceiling Space

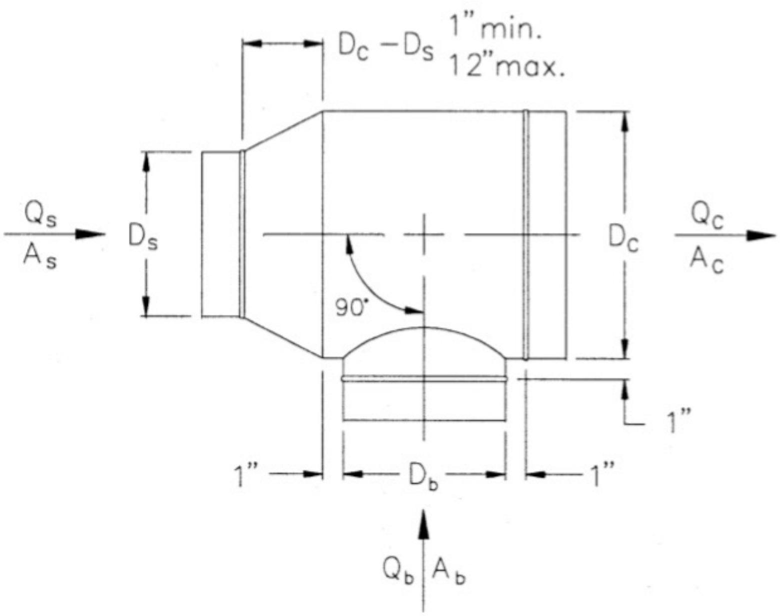
A. Design Criterion: 0.08 in. of water per 100 ft or 2500 fpm Maximum

Minimum Clearance for Duct, in.	**18**	**22**	**26**	**30**	**34**	**38**
Single Round Duct						
Duct diameter, in.	14	18	22	26	30	34
Airflow, cfm	950	1900	3200	4900	7300	10,000
Velocity, fpm	889	1075	1212	1329	1487	1586
Rectangular Duct with Aspect Ratio = 2						
Rectangular $W \times H$, in.	28 × 14	36 × 18	44 × 22	52 × 26	60 × 30	68 × 34
Airflow, cfm	2900	5500	9800	14,900	21,200	30,000
Velocity, fpm	1065	1222	1458	1587	1696	1869
Equivalent diameter D_e, in.	21.3	27.4	33.5	39.6	45.7	51.8
Flat Oval Duct with Aspect Ratio = 2						
Flat oval $A \times a$, in.	28 × 14	36 × 18	44 × 22	52 × 26	60 × 30	68 × 34
Airflow, cfm	2700	5400	9000	14,000	21,000	28,000
Velocity, fpm	1111	1344	1500	1670	1882	1954
Equivalent diameter D_e, in.	20.7	26.6	32.5	38.4	44.4	50.3
Two Round Ducts in Parallel						
Duct diameter, in.	Two 12	Two 16	Two 20	Two 24	Two 28	Two 32
Airflow, cfm	630 each	1350 each	2450 each	3950 each	5950 each	8500 each
Velocity, fpm	802	967	1123	1257	1391	1522

EXAMPLE

Example

- **Example:** Compute the loss in total pressure for a round 90-dgree 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 1,100 cfm. The branch flow rate is 250 cfm through a 6 in. duct.



	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

	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	0.16							
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

Example

- Solution:

- Calculate velocity in each section:

$$V_c = \frac{Q_c}{A_c} = \frac{Q_c}{\left(\frac{\pi}{4}\right) D_c^2} = \frac{1{,}100}{\frac{\pi}{4} \times \left(\frac{12}{12}\right)^2} = 1{,}400\ fpm$$

$$V_b = \frac{Q_b}{A_b} = \frac{Q_b}{\left(\frac{\pi}{4}\right) D_b^2} = \frac{250}{\frac{\pi}{4} \times \left(\frac{6}{12}\right)^2} = 1{,}273\ fpm$$

$$V_s = \frac{Q_s}{A_s} = \frac{Q_s}{\left(\frac{\pi}{4}\right) D_s^2} = \frac{850}{\frac{\pi}{4} \times \left(\frac{10}{12}\right)^2} = 1{,}558\ fpm$$

Example

- Solution:

- The ratio of the branch to the common flow rate is:

$$\frac{Q_b}{Q_c} = \frac{250}{1,100} = 0.23$$

- The ratio of the main to the common flow rate is:

$$\frac{Q_s}{Q_c} = \frac{850}{1,100} = 0.77$$

Example

- Solution:

- The ratio of the branch to the common are is:

$$\frac{A_b}{A_c} = \left(\frac{6}{12}\right)^2 = 0.25$$

- The ratio of the main to the common are is:

$$\frac{A_s}{A_c} = \left(\frac{10}{12}\right)^2 = 0.69$$

Example

- Solution:

- Using the loss coefficient for the branch, we have

$$\Delta p_{0b} = C_b \left(\frac{V_b}{4{,}005}\right)^2 = 1.55\left(\frac{1{,}273}{4{,}005}\right)^2 = 0.16\ in\ w.c.$$

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

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

	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

Example

- Solution:

- Using the loss coefficient for the branch, we have

$$\Delta p_{0s} = C_s \left(\frac{V_s}{4{,}005}\right)^2 = 0.14 \left(\frac{1{,}558}{4{,}005}\right)^2 = 0.021\ in\ w.c.$$

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

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

C_s Values

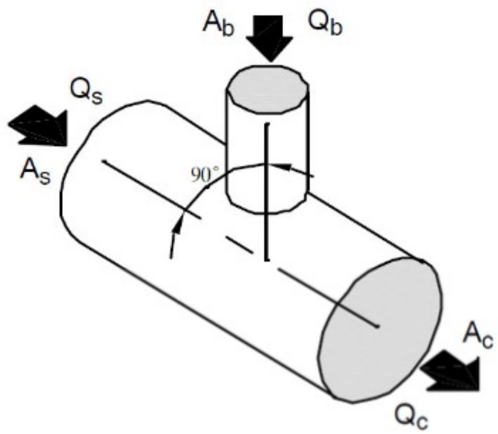
	Q_s/Q_c								
A_s/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.13	0.16							
0.2	0.20	0.13	0.15	0.16	0.28				
0.3	0.90	0.13	0.13	0.14	0.15	0.16	0.20		
0.4	2.88	0.20	0.14	0.13	0.14	0.15	0.15	0.16	0.34
0.5	6.25	0.37	0.17	0.14	0.13	0.14	0.14	0.15	0.15
0.6	11.88	0.90	0.20	0.13	0.14	0.13	0.14	0.14	0.15
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

EXAMPLE

Example

- Example: Converging Tee 90° Round Main and Branch. Main is 10”, Branch is 7”. Air flow Main is 1000 cfm. Air flow Branch is 500 cfm.

B. CONVERGING TEE, 90°, ROUND



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

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

Example

- Solution

$$A_c = \frac{\left(\frac{\pi \times 10^2}{4}\right)}{144} = 0.55\ ft^2$$

$$A_b = \frac{\left(\frac{\pi \times 7^2}{4}\right)}{144} = 0.24\ ft^2$$

$$V_c = \frac{1{,}000}{0.55} = 1818\ fpm$$

$$V_b = \frac{2{,}083}{0.24} = 2083\ fpm$$

Example

- Solution

$$p_{v,c} = \left(\frac{1818}{4005}\right)^2 = 0.21\ in\ w.c.$$

$$p_{v,b} = \left(\frac{2083}{4005}\right)^2 = 0.27\ in\ w.c.$$

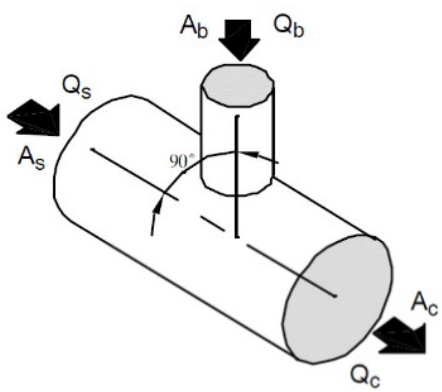
$$\frac{Q_b}{Q_c} = \frac{500}{1000} = 0.50$$

$$\frac{A_b}{A_c} = \frac{0.24}{0.5} = 0.44$$

Example

- Solution

B. CONVERGING TEE, 90°, ROUND



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

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

$C_b = 1.0$

$$\Delta p_{t,b-c} = 1 \times 0.21 = 0.21\ in\ w.c.$$

$$\Delta p_{t,b-c} = 053 \times 0.27 = 0.14\ in\ w.c.$$