CAE 464/517 HVAC Systems Design

Spring 2023

March 28, 2023

Air distribution systems: Fan selection example and air handling unit

Built
Environment
Research
@ IIT

Advancing energy, environmental, and sustainability research within the built environment

www.built-envi.com

Dr. Mohammad Heidarinejad, Ph.D., P.E.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
muh182@iit.edu

ANNOUNCEMENTS

Announcements

ASHRAE
Illinois Institute of Technology Student Branch

JLL

SEES IIT

Building Performance focusing on net zero design and energy modeling

SPEAKER
Senior Project Manager
Luis Lara

WHEN
March 30th, 2023
12:40 pm – 1:40 pm

WHERE
John T. Rettaliata Engineering Center, RE 104

TALK ABOUT
- ✓ Green building work
- ✓ Energy performance skill
- ✓ Sustainability consulting
- ✓ Energy conservation

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

Interested in Joining

Lunch will be provided!

Announcements

- Assignment 4 is due tonight (the solution will be posted tomorrow morning)

Announcements

- Project 1 will be graded, and feedback will be provided.

Announcements

- Midterm Exam 2
  - ❑ Exam will take place next Tuesday, 04/04/23 in class (all students are required to attend in person)
  - ❑ Open book / open notes (laptop is allowed)

How did you study for exam 1?

RECAP

Recap

Item	Backward	Radial	Forward
Efficiency	High (80% to 86%)	Medium (50% to 77%)	Medium (50% to 70%)
Space required	High	Medium	Small
Speed for a given pressure rise	High	Medium	Low
Noise	Good	Fair	Poor
Number of blades	10 to 16	6 to 10	24 to 64
Horsepower	Limiting	Rising	Rising

Recap

- Fan Laws ”or Affinity Laws”:
  - ❑ Q: Fan volume (cfm)
  - ❑ N: Rotational speed (rpm)
  - ❑ P: Total pressure (in. w.c.)
  - ❑ W: Brake Horsepower
  - ❑ ρ: Fan density (lb/ft^3)

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} . \frac{\rho_1}{\rho_2}$$

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^2 . \frac{\rho_1}{\rho_2}$$

$$\frac{W_1}{W_2} = \left(\frac{N_1}{N_2}\right)^3 . \frac{\rho_1}{\rho_2}$$

Recap

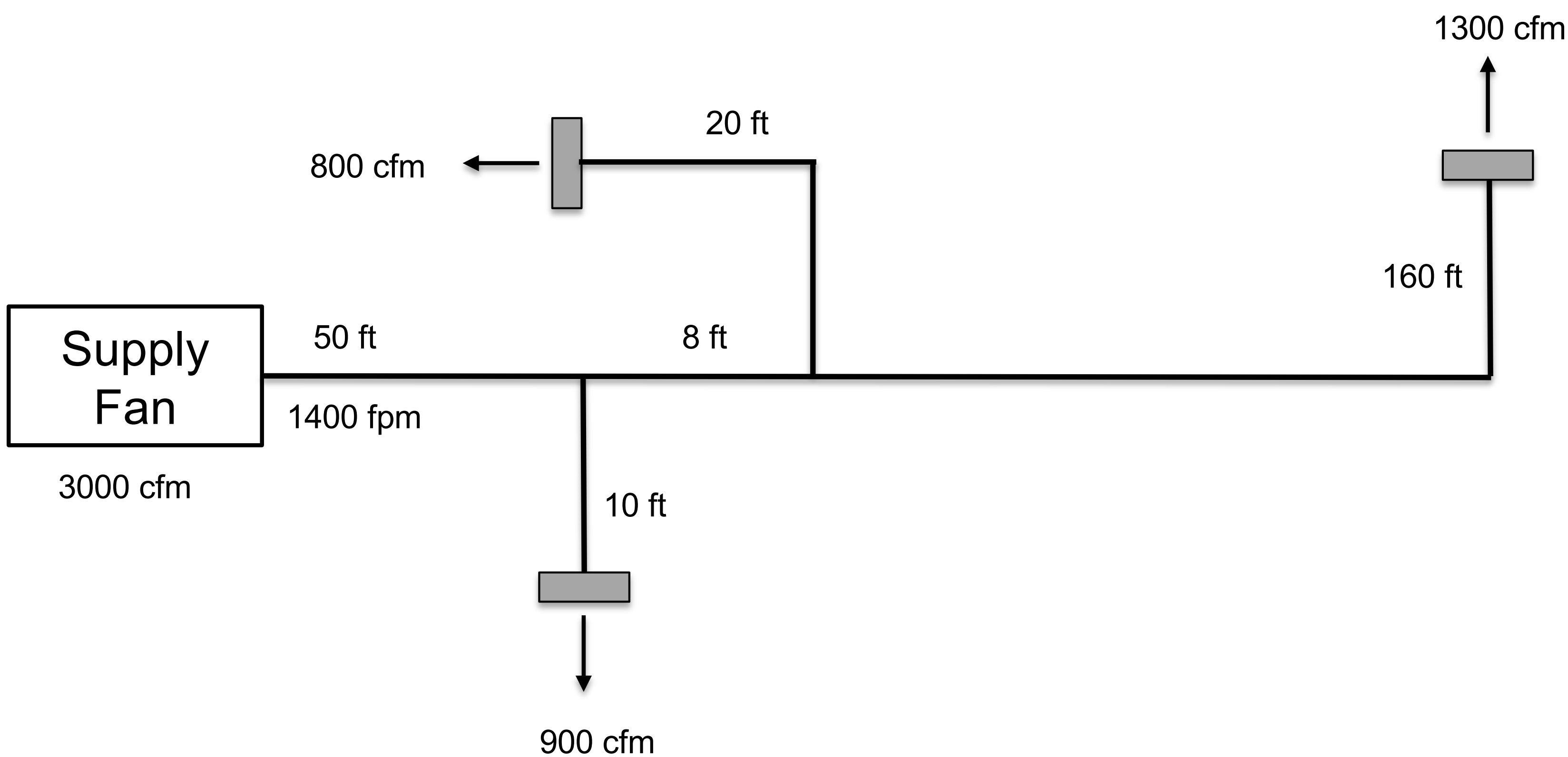
- The total fan power is defined as:

$$W_t = \frac{Q_s \times \Delta P_t}{6{,}356 \times \eta_f \times \eta_c \times \eta_m}$$

CLASS ACTIVITY

Class Activity

- The given information is given:
  - ❑ Ductwork needs to be rectangular at maximum depth of 12’’
  - ❑ All ductwork sizes are in even inches
  - ❑ Use tees with 45-degree entry branches (e.g., SR5-13)
  - ❑ Use elbow radius ratio of r/D = 1.5 (e.g., CR3-1)
  - ❑ Outlet losses in outlets are 0.10 in w.c.

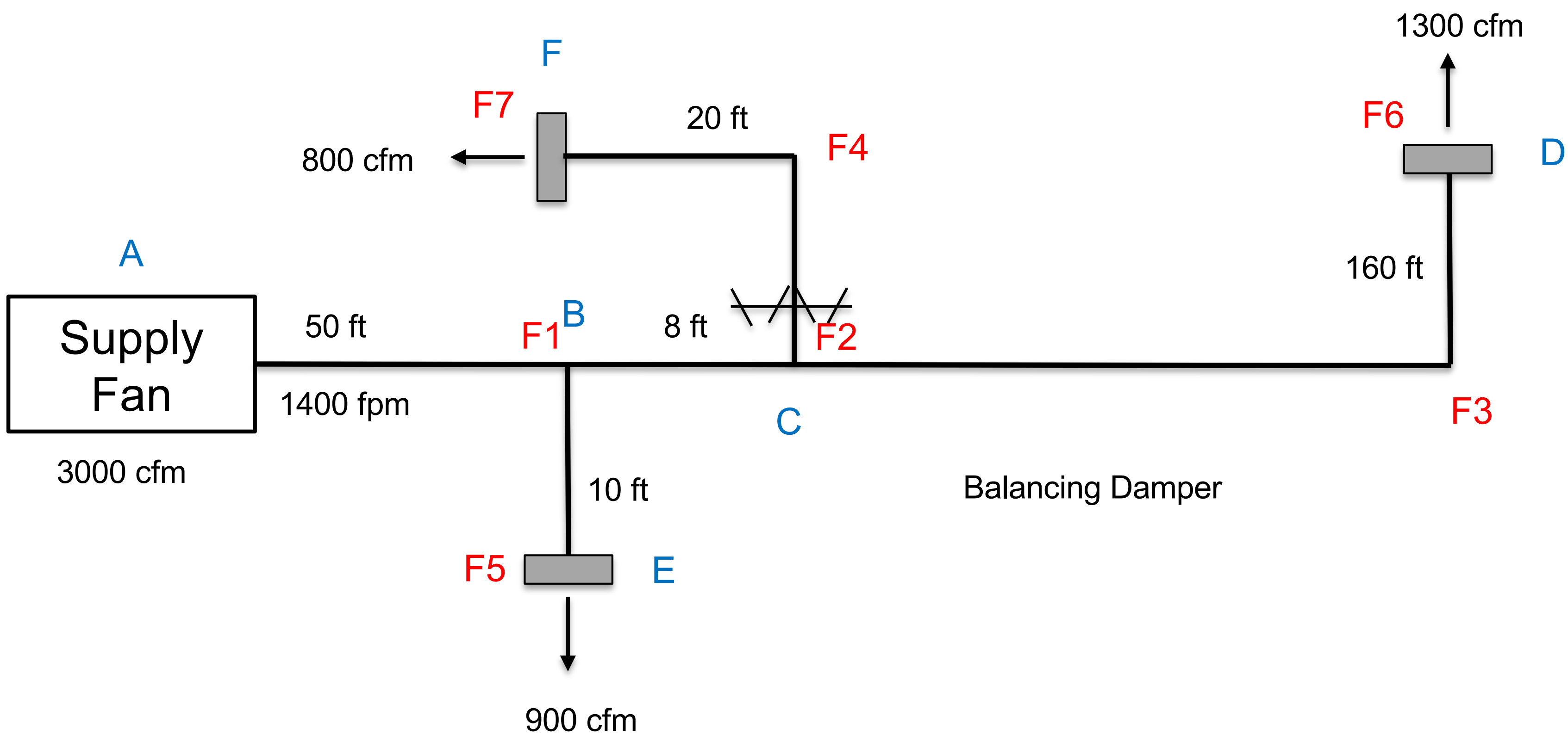


Class Activity

- Calculate the following information:
  - ❑ Pressure drop in each branch
  - ❑ Draw the system characteristics curve and the fan curve and select a fan option

Class Activity

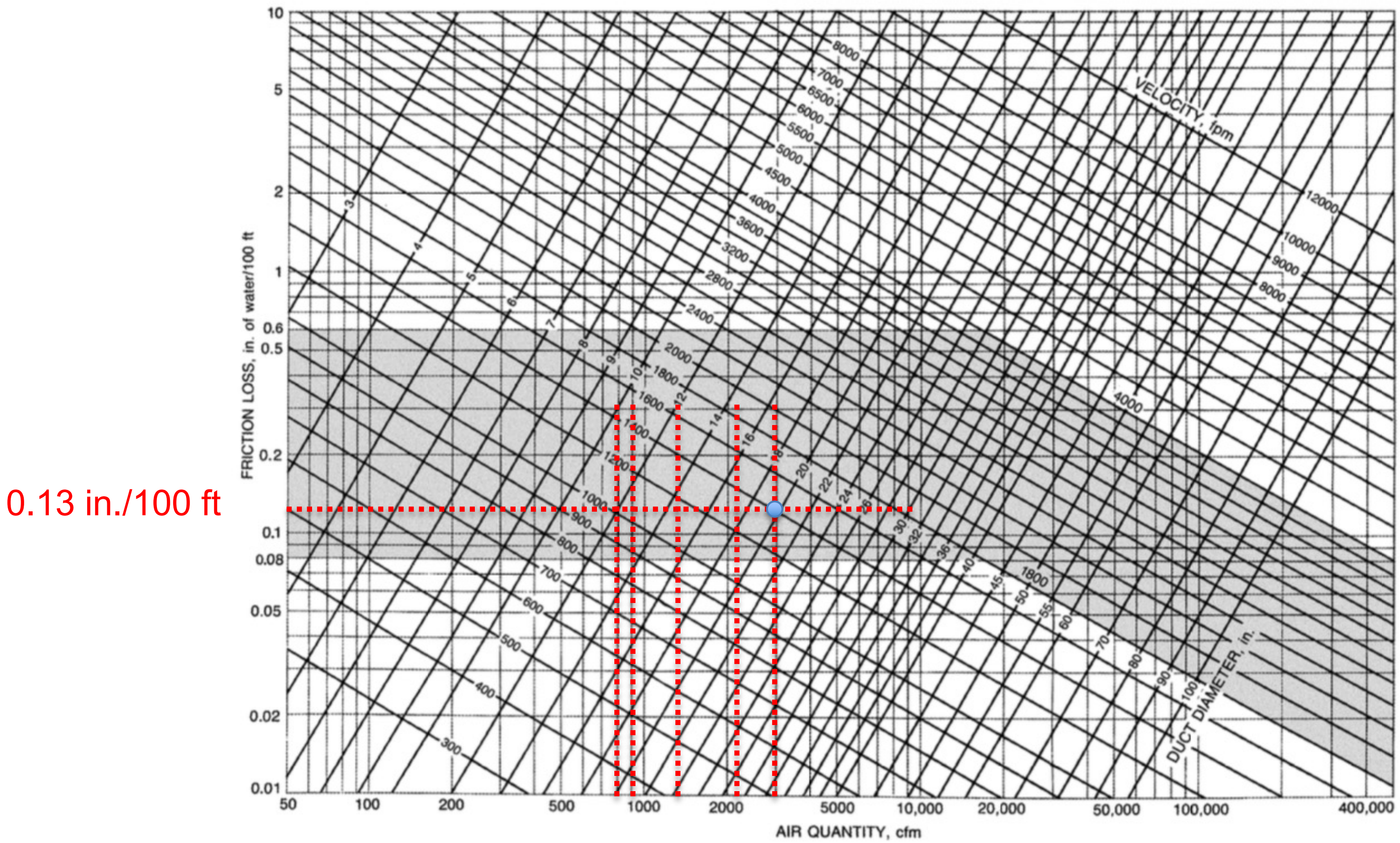
- **Solution:**
  - ❑ Add labels for different branches and fittings



Class Activity

- **Solution:**
  - ❑ Estimate the equal friction method

$$Q_{main} = 900\ cfm + 800\ cfm + 1300\ cfm = 3000\ cfm \qquad V_{max} = 1400\ fpm$$



Class Activity

- **Solution:**
  - ❑ Find the friction losses at 0.13 in/100 ft

Section	Air Flow Rate (cfm)	D_e (in)	Length (ft)	Section Loss (in. w.c.)
A-B	3,000	20	50	$0.13\times\left(\frac{50}{100}\right) = 0.065$
B-C	2,100	18	8	$0.13\times\left(\frac{8}{100}\right) = 0.010$
C-D	1,300	14	160	$0.13\times\left(\frac{160}{100}\right) = 0.208$
B-E	900	13	10	$0.13\times\left(\frac{10}{100}\right) = 0.013$
C-F	800	12	20	$0.13\times\left(\frac{20}{100}\right) = 0.026$

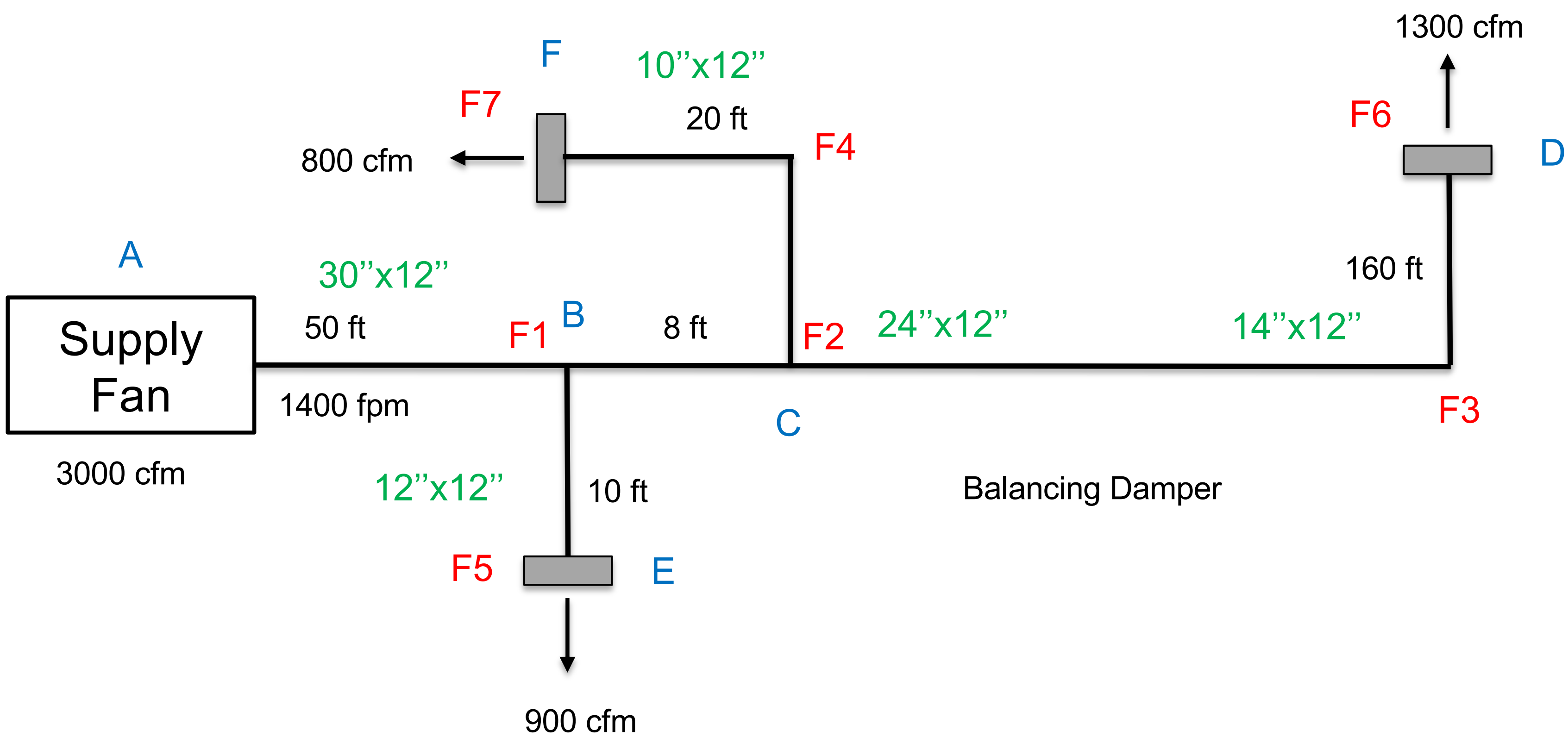
Class Activity

- **Solution:**
  - ❑ Find square duct sizes

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														C-F
12.5		32	24	20	17	15	13														
13		35	27	22	18	16	14	12													B-E
13.5		38	29	24	20	17	15	13													
14			32	26	22	19	17	14													C-D
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											B-C
19				54	44	38	33	26	22	19	18										
20					50	43	37	29	24	21	19										A-B
21					57	48	41	33	27	23	20										

Class Activity

- **Solution:**
  - ❑ Add the duct sizes to the schematic



Class Activity

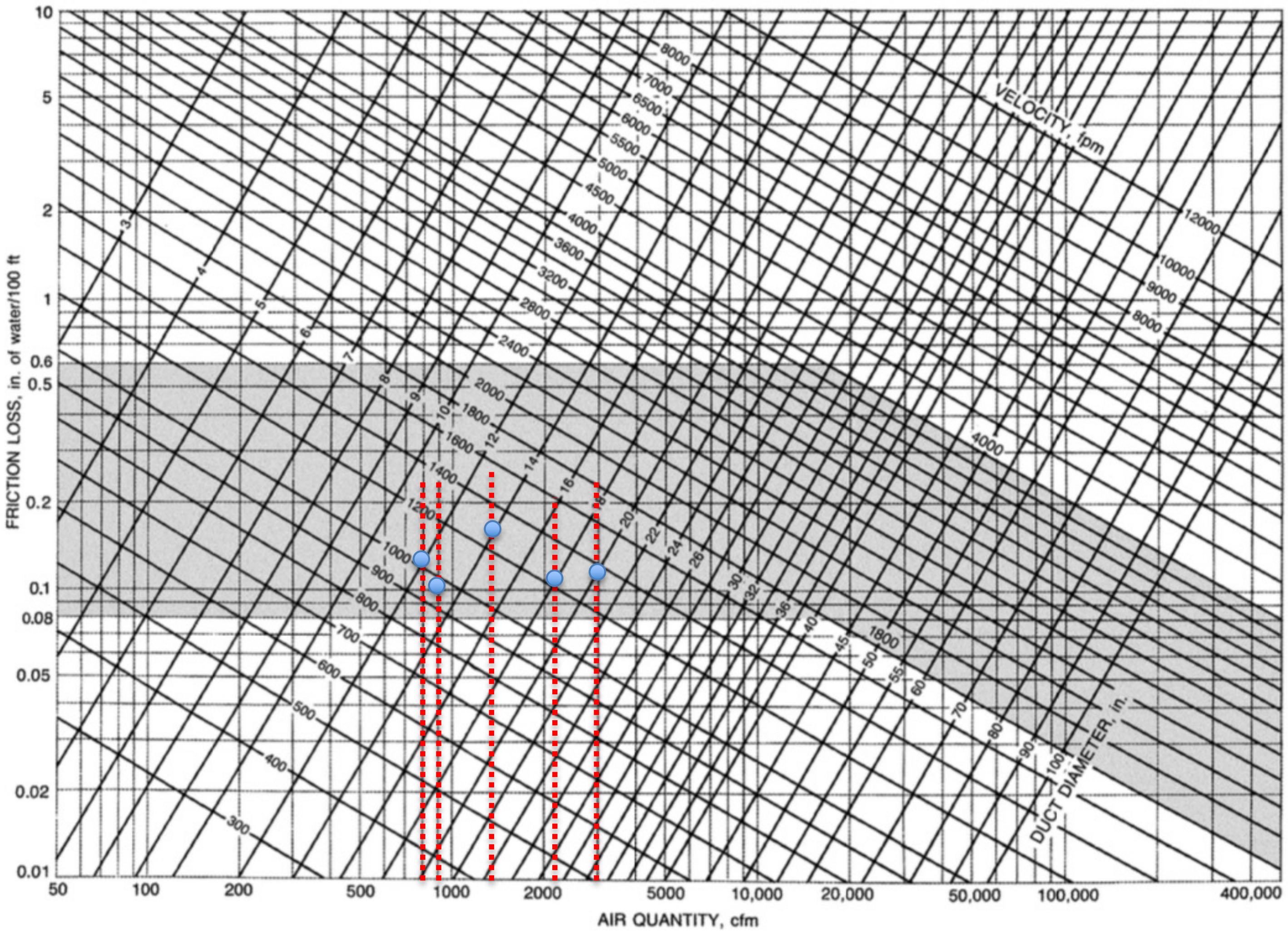
- **Solution:**
  - ❑ Add the rectangular values to the table

Section	Air Flow Rate (cfm)	Duct Size (in)	Duct (in Rectangular)	Area (ft^2)	Velocity (fpm)
A-B	3,000	20	30 / 12	2.50	
B-C	2,100	18	24 /12	2.00	
C-D	1,300	14	14 / 12	1.17	
B-E	900	13	12 / 12	1.00	
C-F	800	12	10 / 12	0.83	

Question: How do we calculate the velocity?

Class Activity

- **Solution:**
  - ❑ Method 1: Friction losses (in/100 ft) for round ducts



Class Activity

- **Solution:**
  - ❑ Method 1: Velocity using the chart for the round ducts

Section	Air Flow Rate (cfm)	Duct Size (in)	Duct (in Rectangular)	Area (ft^2)	Velocity (fpm)
A-B	3,000	20	30 / 12	2.50	1,300
B-C	2,100	18	24 /12	2.00	1,230
C-D	1,300	14	14 / 12	1.17	1,250
B-E	900	13	12 / 12	1.00	950
C-F	800	12	10 / 12	0.83	1,000

Class Activity

- **Solution:**
  - Method 2: Velocity using the cfm and area for the rectangular ducts

Section	Air Flow Rate (cfm)	Duct Size (in)	Duct (in Rectangular)	Area (ft^2)	Velocity (fpm)
A-B	3,000	20	30 / 12	2.50	(3,000)/(2.5)=1,200
B-C	2,100	18	24 /12	2.00	(2,100)/(2.0)=1,050
C-D	1,300	14	14 / 12	1.17	(1,300)/(1.17)=1,114
B-E	900	13	12 / 12	1.00	(900)/(1.0)=900
C-F	800	12	10 / 12	0.83	(800)/(0.83)=960

If I use the rectangular, can I use the chart?

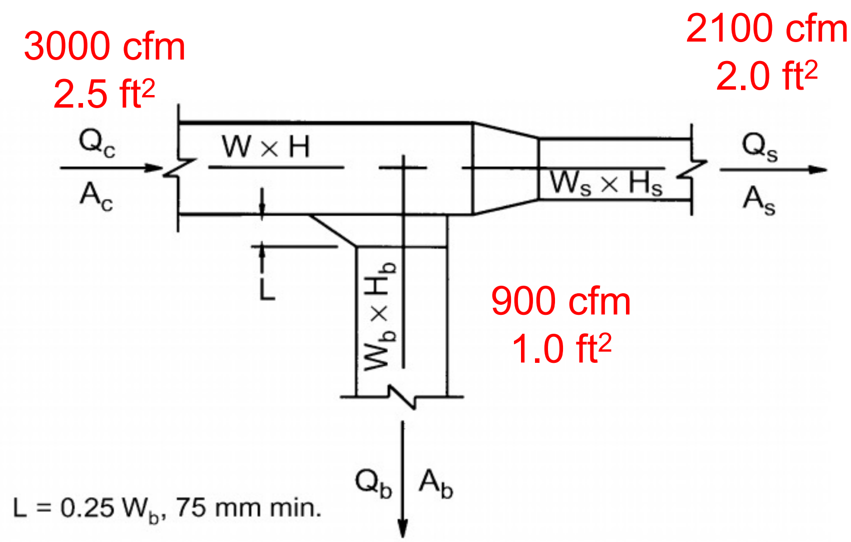
Class Activity

- **Solution:**
  - ❑ Find the fitting losses (F1)

SR5-13 Tee, 45 Degree Entry Branch, 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	0.73	0.34	0.32	0.34	0.35	0.37	0.38	0.39	0.40
0.2	3.10	0.73	0.41	0.34	0.32	0.32	0.33	0.34	0.35
0.3	7.59	1.65	0.73	0.47	0.37	0.34	0.32	0.32	0.32
0.4	14.20	3.10	1.28	0.73	0.51	0.41	0.36	0.34	0.32
0.5	22.92	5.08	2.07	1.12	0.73	0.54	0.44	0.38	0.35
0.6	33.76	7.59	3.10	1.65	1.03	0.73	0.56	0.47	0.41
0.7	46.71	10.63	4.36	2.31	1.42	0.98	0.73	0.58	0.49
0.8	61.79	14.20	5.86	3.10	1.90	1.28	0.94	0.73	0.60
0.9	78.98	18.29	7.59	4.02	2.46	1.65	1.19	0.91	0.73

	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	0.04								
0.2	0.98	0.04							
0.3	3.48	0.31	0.04						
0.4	7.55	0.98	0.18	0.04					
0.5	13.18	2.03	0.49	0.13	0.04				
0.6	20.38	3.48	0.98	0.31	0.10	0.04			
0.7	29.15	5.32	1.64	0.60	0.23	0.09	0.04		
0.8	39.48	7.55	2.47	0.98	0.42	0.18	0.08	0.04	
0.9	51.37	10.17	3.48	1.46	0.67	0.31	0.15	0.07	0.04



Branch

$$\frac{Q_b}{Q_c} = \left(\frac{900\ cfm}{3{,}000\ cfm}\right) = 0.3 \qquad \frac{A_b}{A_c} = \frac{1.0\ ft^2}{2.5\ ft^2} = 0.40$$

$$C_{b1} = 1.28$$

Straight

$$\frac{Q_s}{Q_c} = \left(\frac{2{,}100\ cfm}{3{,}000\ cfm}\right) = 0.7 \qquad \frac{A_b}{A_c} = \frac{2.0\ ft^2}{2.5\ ft^2} = 0.80$$

$$C_{s1} = 0.08$$

Class Activity

- **Solution:**
  - ❑ Find the fitting losses (F2)

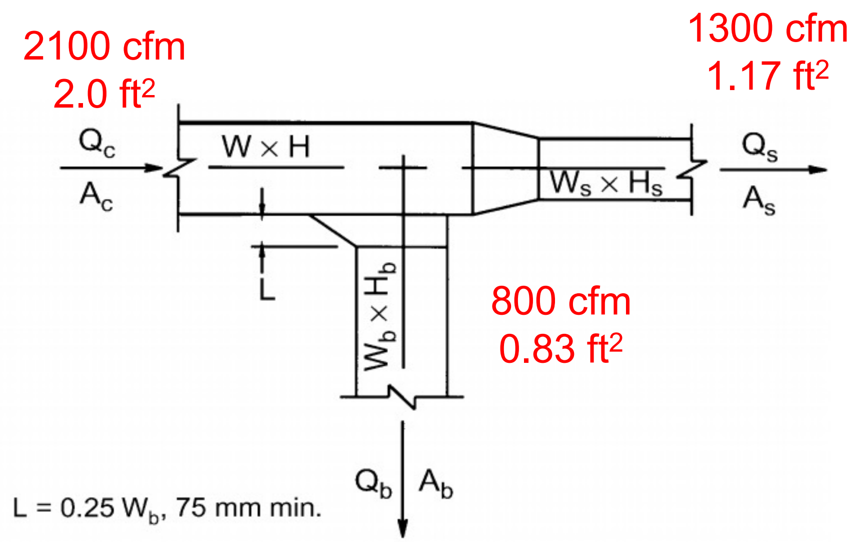
SR5-13 Tee, 45 Degree Entry Branch, Diverging

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	0.73	0.34	0.32	0.34	0.35	0.37	0.38	0.39	0.40
0.2	3.10	0.73	0.41	0.34	0.32	0.32	0.33	0.34	0.35
0.3	7.59	1.65	0.73	0.47	0.37	0.34	0.32	0.32	0.32
0.4	14.20	3.10	1.28	0.73	0.51	0.41	0.36	0.34	0.32
0.5	22.92	5.08	2.07	1.12	0.73	0.54	0.44	0.38	0.35
0.6	33.76	7.59	3.10	1.65	1.03	0.73	0.56	0.47	0.41
0.7	46.71	10.63	4.36	2.31	1.42	0.98	0.73	0.58	0.49
0.8	61.79	14.20	5.86	3.10	1.90	1.28	0.94	0.73	0.60
0.9	78.98	18.29	7.59	4.02	2.46	1.65	1.19	0.91	0.73

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	0.04								
0.2	0.98	0.04							
0.3	3.48	0.31	0.04						
0.4	7.55	0.98	0.18	0.04					
0.5	13.18	2.03	0.49	0.13	0.04				
0.6	20.38	3.48	0.98	0.31	0.10	0.04			
0.7	29.15	5.32	1.64	0.60	0.23	0.09	0.04		
0.8	39.48	7.55	2.47	0.98	0.42	0.18	0.08	0.04	
0.9	51.37	10.17	3.48	1.46	0.67	0.31	0.15	0.07	0.04



Branch

$$\begin{cases} \dfrac{Q_b}{Q_c} = \left(\dfrac{800\ cfm}{2{,}100\ cfm}\right) = 0.38 \\ \dfrac{A_b}{A_c} = \dfrac{0.83\ ft^2}{2.0\ ft^2} = 0.42 \end{cases} \quad C_{b1} = 0.94$$

Straight

$$\begin{cases} \dfrac{Q_s}{Q_c} = \left(\dfrac{1{,}300\ cfm}{2{,}100\ cfm}\right) = 0.62 \\ \dfrac{A_b}{A_c} = \dfrac{1.17\ ft^2}{2.0\ ft^2} = 0.59 \end{cases} \quad C_{s1} = 0.034$$

Class Activity

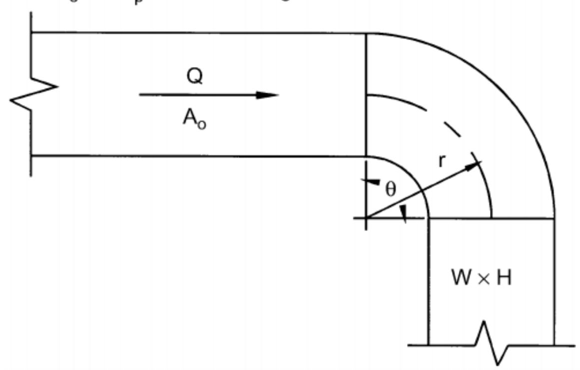
- **Solution:**
  - ❑ Find the fitting losses (F3 and F4)

CR3-1 Elbow, Smooth Radius, Without Vanes

C_p Values											
	H/W										
r/W	**0.25**	**0.50**	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**8.00**
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	0.00	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

$C_o = KC_p$ where K = angle factor



F3

$$\frac{H}{W} = \frac{12}{14} = 0.86$$

$$C_{03} = KC_{p3} = (1)(0.18) = 0.18$$

F4

$$\frac{H}{W} = \frac{12}{10} = 1.2$$

$$C_{04} = KC_{p3} = (1)(0.16) = 0.16$$

Class Activity

- **Solution:** Compute fittings

Section	Fitting No	Fitting Type	ASHRAE Fitting No.	Airflow rate (Q_c)	Airflow rate (Q_b)	Duct Size	Duct Area	Loss Coefficient	Velocity (fpm)	P_v	P_t
From – To	Number	Type	ASHRAE	cfm	cfm	$W \times H$	ft^2	C_0	fpm	in. w.c.	in. w.c.
A-B	F1	Tee Branch	SR5-13	3,000	2,100	24×12	2.00	0.08	1,050	0.069	0.0055
	F1	Tee Branch	SR5-13	3,000	900	12×12	1.00	1.28	900	0.050	0.646
B-C	F2	Tee Branch	SR5-13	2,100	1,300	14×12	1.17	0.034	1,111	0.077	0.0026
	F2	Tee Branch	SR5-13	2,100	800	10×12	0.83	0.94	960	0.058	0.0541
C-D	F3	Elbow	CR3-1	1,300	1,300	14×12	1.17	0.18	1,111	0.077	0.0139
C-F	F4	Elbow	CR3-1	800	800	10×12	0.83	0.16	964	0.058	0.0093

Class Activity

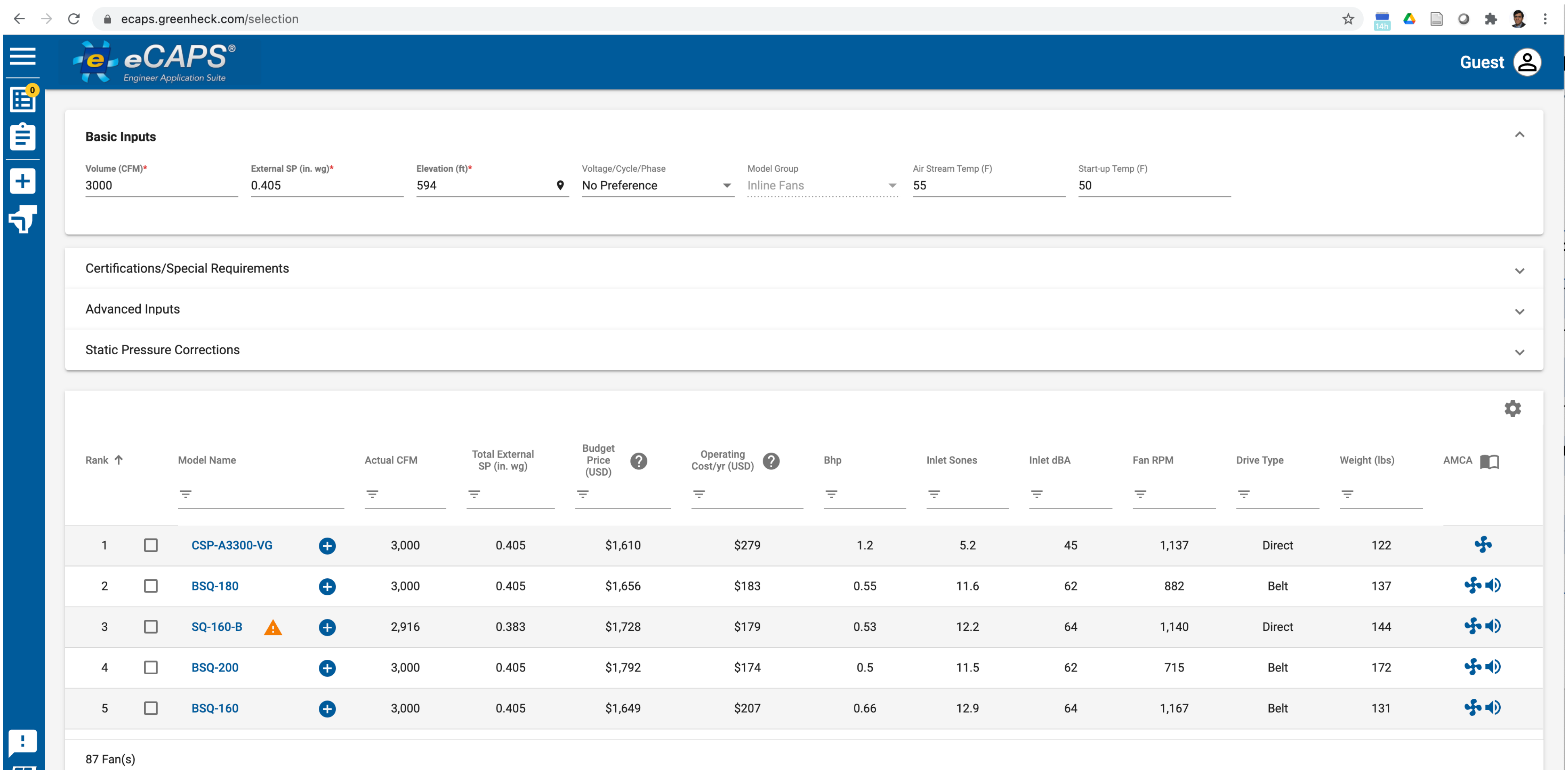
- **Solution:** Pressure loss summary

ΔP (in. w.c.)

Path	Note	Duct	Fitting	Duct	Fitting	Duct	Fitting	Device	Total	Differential Path ΔP
ABCD	Path/Fitting Duct	AB	F1	BC	F2	CD	F3	Outlet	in w.c.	in w.c.
Critical Path		0.0650	0.0055	0.0104	0.0026	0.208	0.0139	0.1	0.405	0.000
ABCF	Path/Fitting Duct	AB	F1	BC	F2	CF	F4	Outlet	in w.c.	Path ΔP
		0.0650	0.0055	0.0105	0.0541	0.026	0.0093	0.1	0.370	-0.135
ABE	Path/Fitting Duct	AB	F1	BE	---	--	--	Outlet	in w.c.	Path ΔP
		0.0650	0.0646	0.013	---			0.1	0.243	-0.163

Class Activity

- **Solution:** Select the fan



Rank	Model Name	Actual CFM	Total External SP (in. wg)	Budget Price (USD)	Operating Cost/yr (USD)	Bhp	Inlet Sones	Inlet dBA	Fan RPM	Drive Type	Weight (lbs)	AMCA
1	CSP-A3300-VG	3,000	0.405	$1,610	$279	1.2	5.2	45	1,137	Direct	122	
2	BSQ-180	3,000	0.405	$1,656	$183	0.55	11.6	62	882	Belt	137	
3	SQ-160-B	2,916	0.383	$1,728	$179	0.53	12.2	64	1,140	Direct	144	
4	BSQ-200	3,000	0.405	$1,792	$174	0.5	11.5	62	715	Belt	172	
5	BSQ-160	3,000	0.405	$1,649	$207	0.66	12.9	64	1,167	Belt	131	

87 Fan(s)

Class Activity

- **Solution:**
  - ❑ Select one of the fans from the list. For example:

BSQ-200 Product Information

Information | Customize

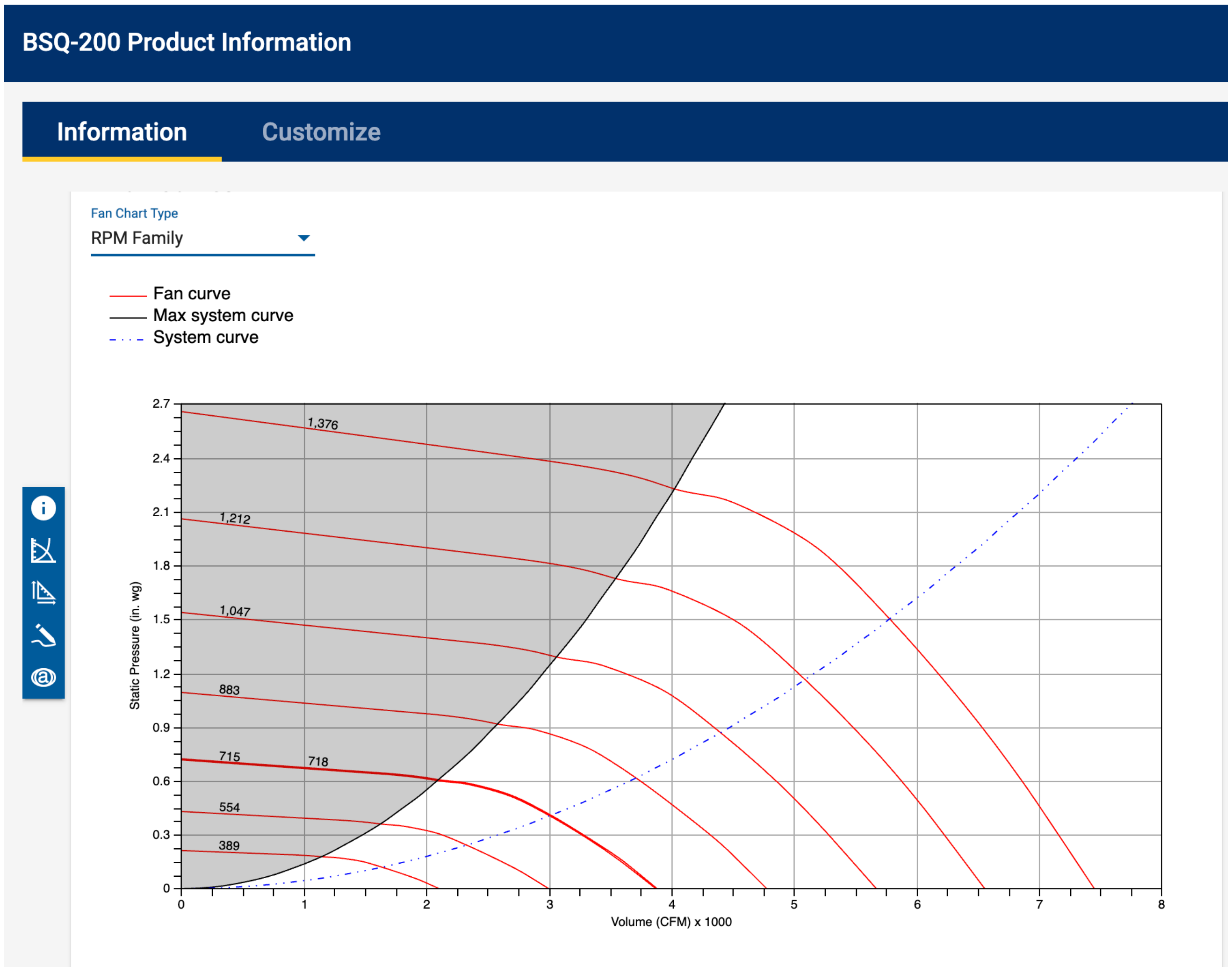
Model BSQ centrifugal inline belt drive fans are the ideal selection for clean air applications (intake, exhaust, return, or make-up air systems) where space is a prime consideration. Fan wheels shall be backward inclined and constructed of aluminum. Performance capabilities range from 62 CFM to 26,600 CFM and up to 4 in. wg of static pressure. Maximum operating temperature is 180 F.

Class Activity

- **Solution:**
  - ❑ Look at the fan curve

Class Activity

- **Solution:**
  - ❑ Look at the family of fans



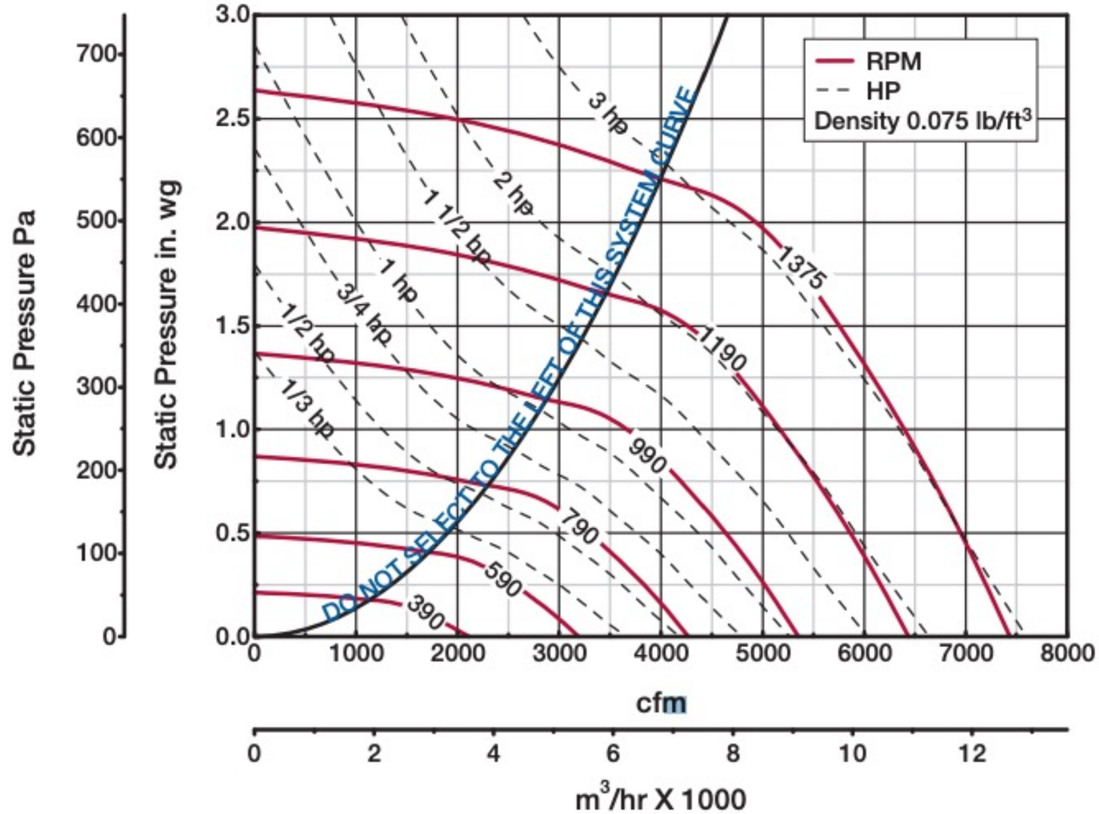
Class Activity

- **Solution:**
  - ❑ If you want to use the manufacture datasheets without the software?

https://content.greenheck.com/public/DAMProd/Original/10003/SQBSQ_catalog.pdf

Class Activity

- **Solution:**
  - Select the fan that meets your pressure drop and the volume flow rate:



What was the cfm and pressure drop for this example?

Class Activity

- **Solution:**
  - Select the fan that meets your pressure drop and the volume flow rate:

Model Number	Motor HP	Fan RPM		CFM / Static Pressure in Inches wg									
				0.125	0.250	0.500	0.750	0.875	1.000	1.250	1.500	1.750	2.000
200													
200-3	1/3	600	CFM	2960	2616								
			BHP	0.25	0.26								
			Sones	11.1	10.6								
		660	CFM	3315	3018	2042							
			BHP	0.33	0.34	0.33							
			Sones	11.7	11.2	10.5							
200-5	1/2	756	CFM	3867	3624	3036							
			BHP	0.49	0.50	0.52							
			Sones	12.7	12.0	11.7							
200-7	3/4	811	CFM	4179	3959	3442	2563						
			BHP	0.60	0.62	0.64	0.62						
			Sones	13.4	12.8	12.3	13.0						
		865	CFM	4484	4285	3812	3239	2516					
			BHP	0.73	0.75	0.77	0.79	0.72					
			Sones	14.1	13.7	13.1	13.0	13.9					
200-10	1	952	CFM	4972	4796	4391	3916	3646	3203				
			BHP	0.96	0.99	1.01	1.04	1.05	1.03				
			Sones	15.7	15.5	15.1	14.9	14.5	14.4				
200-15	1½	1090	CFM	5741	5587	5253	4874	4672	4452	3878			
			BHP	1.43	1.47	1.51	1.53	1.55	1.56	1.56			
			Sones	19.1	18.9	18.7	18.5	18.6	18.7	17.3			
200-20	2	1145	CFM	6046	5899	5588	5240	5047	4855	4413	3580		
			BHP	1.66	1.69	1.74	1.77	1.79	1.81	1.82	1.73		
			Sones	21	20	20	20	20	20	19.2	18.6		
		1200	CFM	6350	6210	5920	5597	5416	5233	4836	4316		
			BHP	1.90	1.94	2.00	2.02	2.04	2.06	2.09	2.08		
			Sones	22	22	21	21	21	21	21	19.8		
200-30	3	1287	CFM	6830	6699	6439	6138	5988	5818	5475	5088	4557	
			BHP	2.34	2.38	2.46	2.49	2.50	2.52	2.56	2.58	2.56	
			Sones	25	24	24	24	23	23	23	23	22	
		1375	CFM	7314	7192	6948	6677	6537	6396	6076	5753	5379	4862
			BHP	2.85	2.89	2.98	3.02	3.03	3.05	3.09	3.14	3.15	3.13
			Sones	27	27	26	26	26	26	25	25	25	24

MAX Bhp AT A GIVEN RPM = $(rpm/937)^3$
MAXIMUM RPM = 1375
TIP SPEED (ft/min) = rpm x 5.595
MAX NEMA MOTOR FRAME SIZE = 184T
OUTLET VELOCITY (ft/min) = 0.1870 x cfm

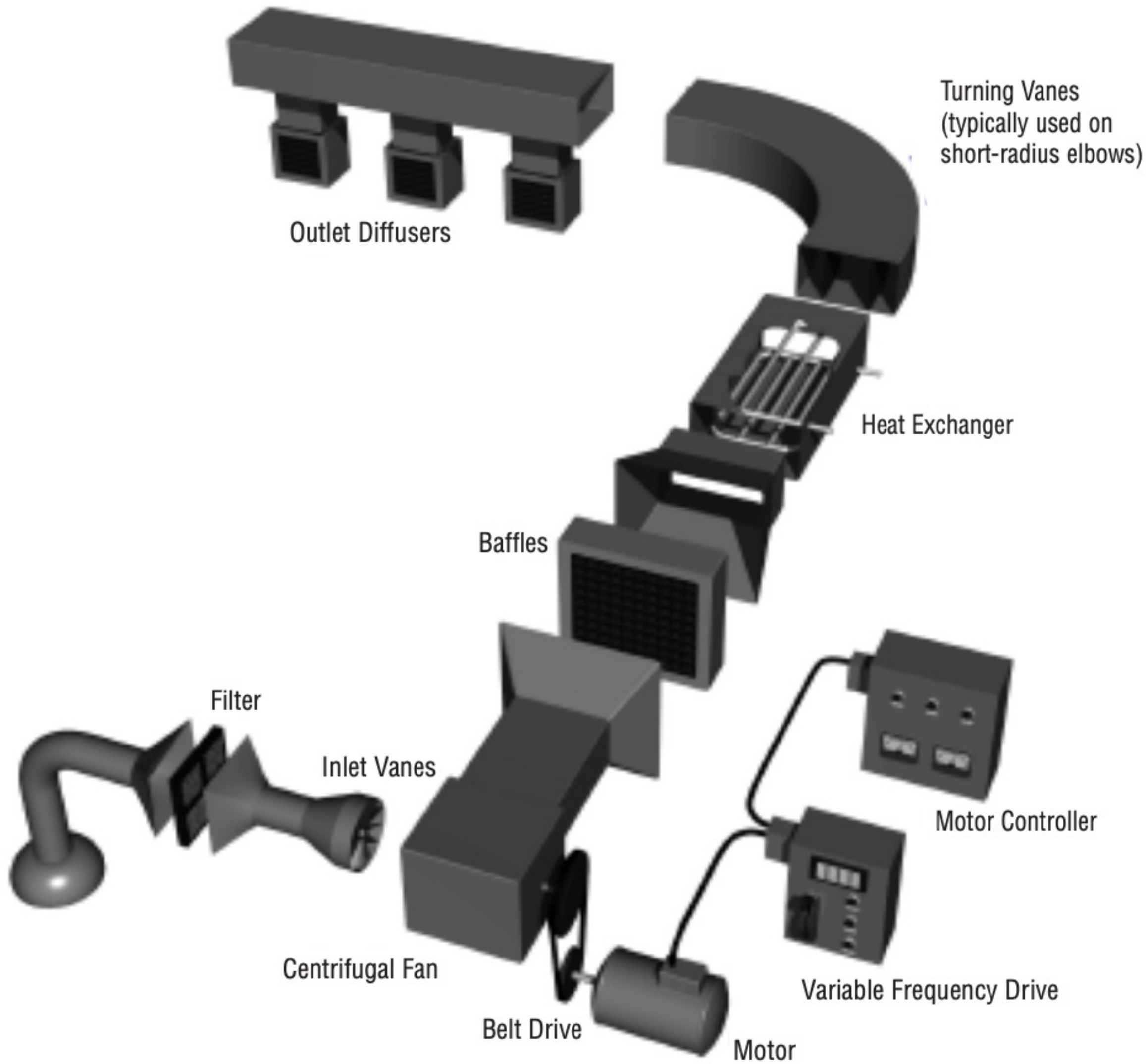
Class Activity

- See Chapter 21 for another duct design example (Examples 8 and 9)

WHAT ELSE SHOULD WE CONSIDER?

Ductwork in Practice

- The air distribution includes various components:



https://www.nrel.gov/docs/fy03osti/29166.pdf

Filtration

- What was one major recommendation to reopen buildings?

Mechanical Air Filters

- Filters consist of media with porous structures of fibers or stretched membrane material to remove particles from airstreams.
- The fraction of particles removed from air passing through a filter is termed "filter efficiency" and is provided by the Minimum Efficiency Reporting Value (MERV) under standard conditions.
  - MERV ranges from 1 to 16; higher MERV = higher efficiency
  - MERV ≥13 (or ISO ePM_1) are efficient at capturing airborne viruses
  - MERV 14 (or ISO equivalent) filters are preferred
  - High efficiency particulate air (HEPA) filters are more efficient than MERV 16 filters.

https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-filtration_disinfection-c19-guidance.pdf

Filtration

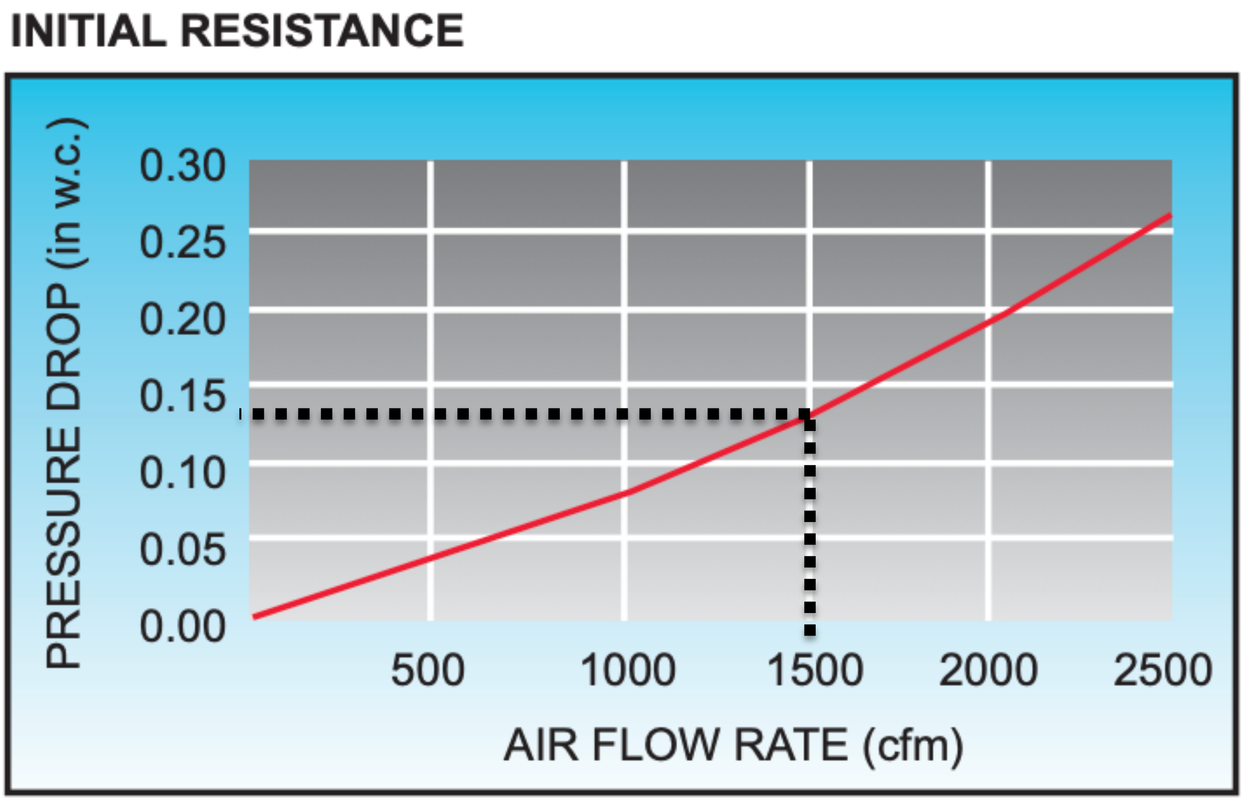
- Let's look at some manufacture data

Model	Nominal Size (L x W x D)	Capacity (CFM) Medium	High	Case Quantity	Price (Case)
DF13-10x20x1	10x20x1	525	700	6	$84.00
DF13-12x12x1	12x12x1	375	500	6	214.00
DF13-12x20x1	12x20x1	625	825	6	93.00
DF13-12x24x1	12x24x1	750	1000	6	108.00
DF13-14x20x1	14x20x1	725	975	6	97.00
DF13-14x25x1	14x25x1	900	1200	6	119.00
DF13-15x20x1	15x20x1	775	1050	6	100.00
DF13-16x16x1	16x16x1	650	875	6	228.00
DF13-16x20x1	16x20x1	825	1100	6	99.00
DF13-16x24x1	16x24x1	1000	1325	6	122.00
DF13-16x25x1	16x25x1	1050	1400	6	125.00
DF13-18x20x1	18x20x1	925	1250	6	109.00
DF13-18x24x1	18x24x1	1125	1500	6	129.00
DF13-18x25x1	18x25x1	1175	1550	6	137.00
DF13-20x20x1	20x20x1	1050	1400	6	112.00
DF13-20x24x1	20x24x1	1250	1650	6	140.00
DF13-20x25x1	20x25x1	1300	1750	6	142.00
DF13-20x30x1	20x30x1	1550	2100	6	148.00
DF13-24x24x1	24x24x1	1500	2000	6	152.00
DF13-25x25x1	25x25x1	1625	2150	6	170.00

https://www.dwyer-inst.com/PDF_files/Priced/DF13_cat.pdf

Filtration

- Let's look at some manufacture data (MERV 8)

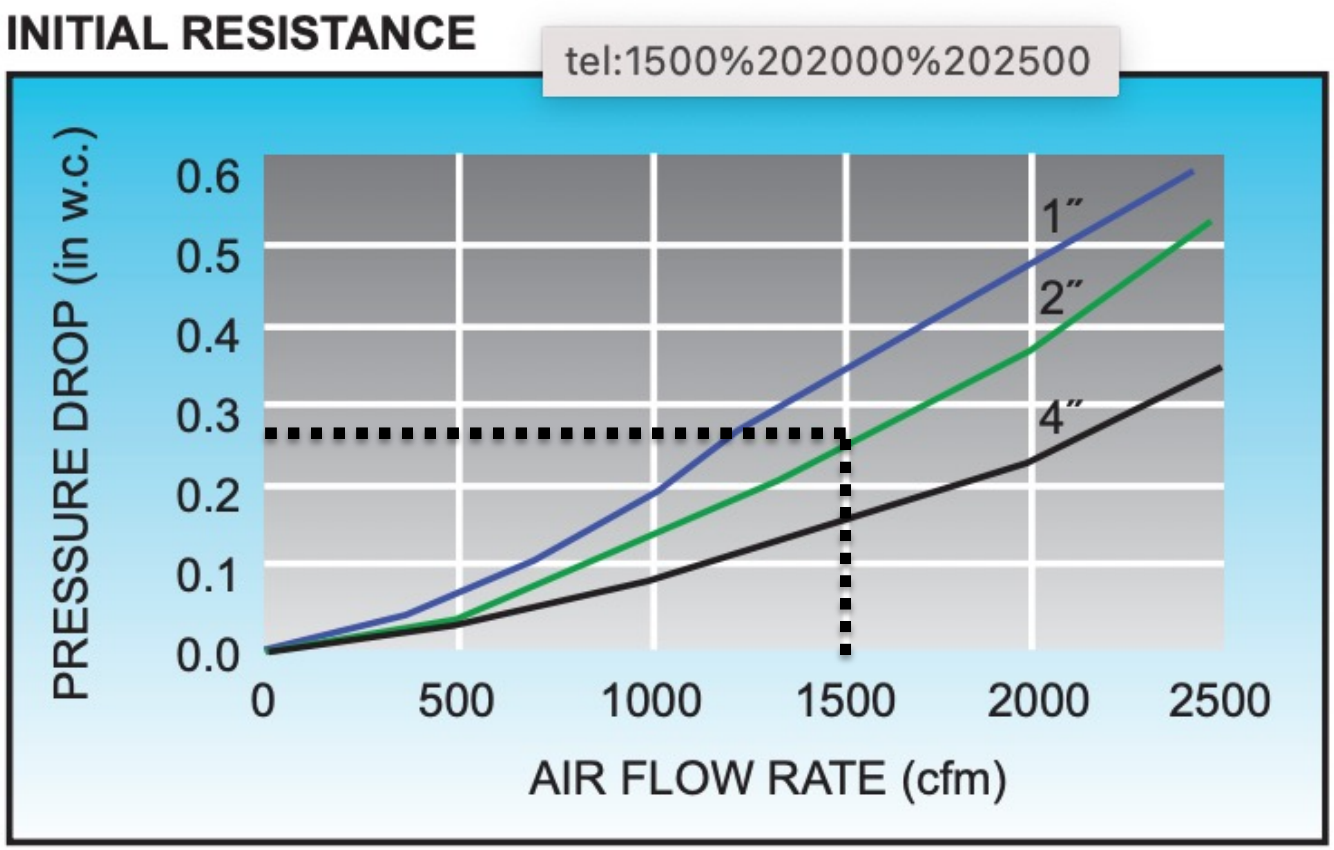


Why does it say initial resistance?

https://www.dwyer-inst.com/PDF_files/Priced/DF8_cat.pdf

Filtration

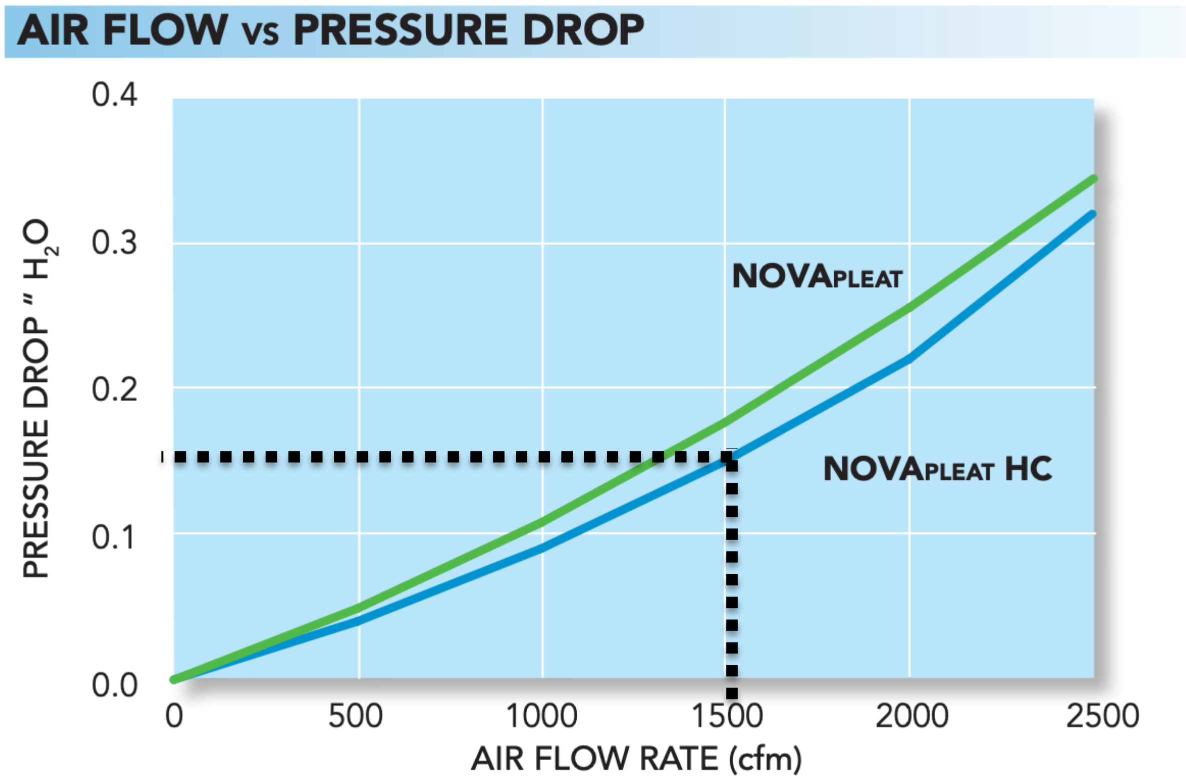
- Let’s look at some manufacture data (MERV 13)



https://www.dwyer-inst.com/PDF_files/Priced/DF13_cat.pdf

Filtration

- Let's look at some manufacture data (MERV 8)



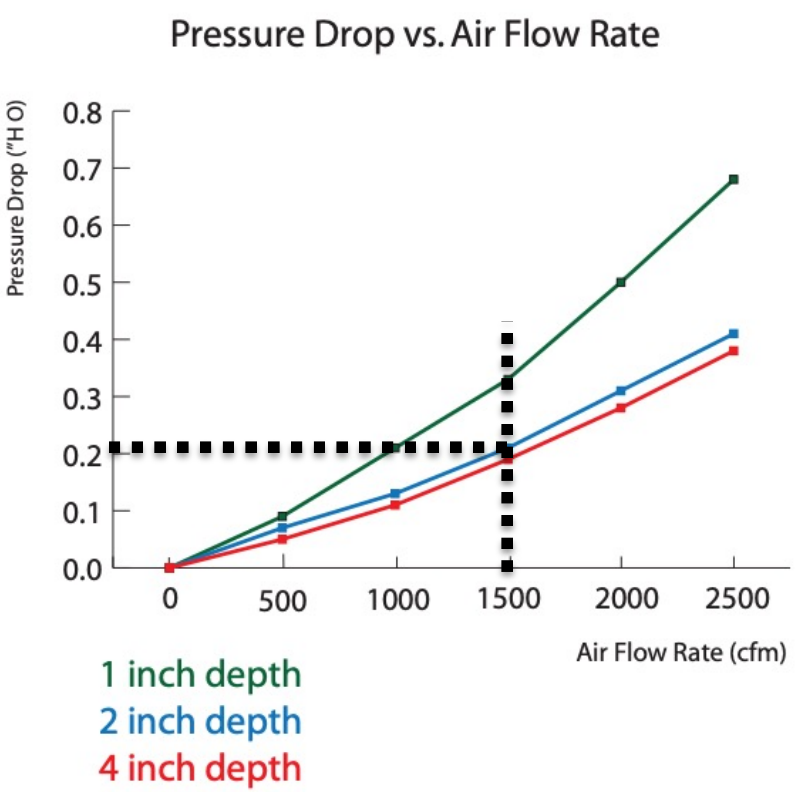
24 x 24 x 2 INITIAL RESISTANCE

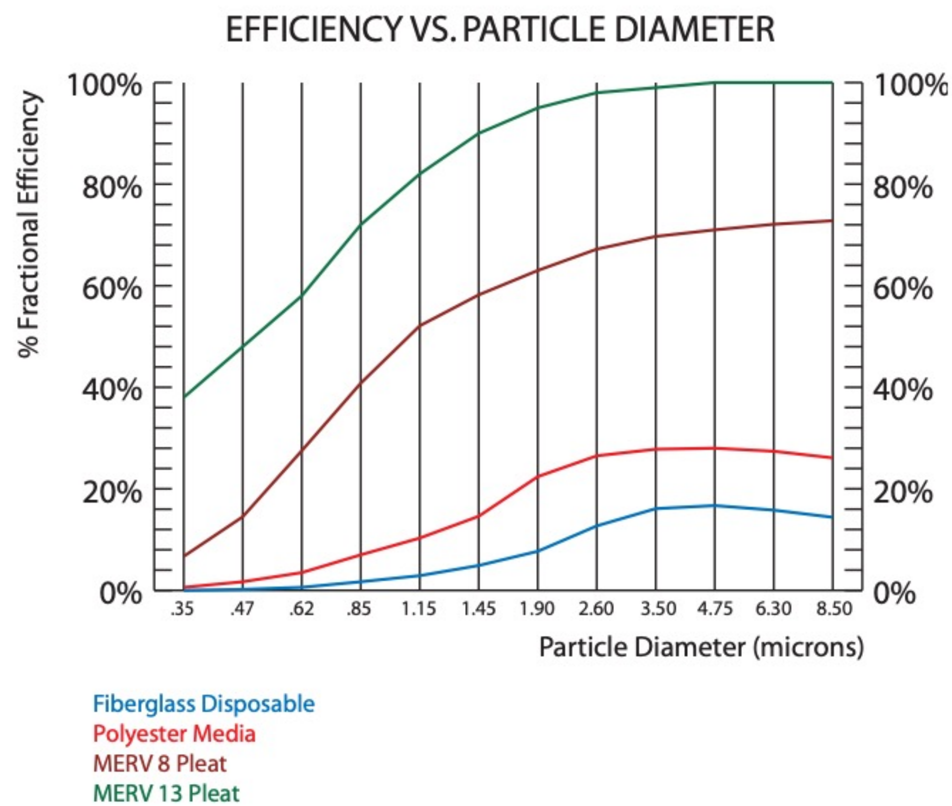
PRODUCT	300 FPM	500 FPM	MERV
NOVAPLEAT	0.14" w.g.	0.26" w.g.	8
NOVAPLEAT HC	0.11" w.g.	0.23" w.g.	8

https://www.filtersales.com/pdf/novapleat_2inch_lit.pdf

Filtration

- Let's look at some manufacture data (MERV 13)





https://leeduser.buildinggreen.com/sites/default/files/credit_documentation/EQc5_MERV13%20filter.pdf

Filtration

- Are there other resources to calculate the pressure drop due to the installation of the filter?
  - ❑ Fan manufacture – pay attention to the MERV

Model	Fan Size	Filter Box Weight	Filter Size	Filter Quantity	Filter Factor (F)			
					1 inch *(25)*		2 inch *(51)*	
					Aluminum	Paper Filters (MERV 7)	Aluminum	Paper Filters (MERV 8)
Model SQ	60 - 75	40 *(18)*	10 x 12 *(254 x 305)*	1	186	318.06	251.1	303.18
Model SQ	80 - 95	74 *(34)*	14 x 25 *(356 x 635)*	1	21.8	37.28	29.43	35.53
Model SQ	100	88 *(40)*	16 x 20 *(406 x 508)*	2	8.72	14.91	11.77	14.21
Model SQ	120	114 *(52)*	16 x 25 *(406 x 635)*	2	5.58	9.54	7.53	9.10
Model SQ	130	120 *(54)*	20 x 20 *(508 x 508)*	2	5.58	9.54	7.53	9.10
Model SQ	140	174 *(79)*	20 x 25 *(508 x 635)*	2	3.57	6.11	4.82	5.82
Model SQ	160	246 *(112)*	20 x 20 *(508 x 508)*	4	2.09	3.57	2.82	3.41
Model BSQ	70 - 80 - 90	117 *(53)*	14 x 25 *(356 x 635)*	1	21.8	37.28	29.43	35.53
Model BSQ	100	120 *(54)*	16 x 20 *(406 x 508)*	2	8.72	14.91	11.77	14.21
Model BSQ	120	144 *(79)*	16 x 25 *(406 x 635)*	2	5.58	9.54	7.53	9.10
Model BSQ	130 - 130HP	140 *(64)*	20 x 20 *(508 x 508)*	2	5.58	9.54	7.53	9.10
Model BSQ	140 - 140HP	181 *(82)*	20 x 25 *(508 x 635)*	2	3.57	6.11	4.82	5.82
Model BSQ	160 - 160HP	294 *(133)*	20 x 20 *(508 x 508)*	4	2.09	3.57	2.82	3.41
Model BSQ	180 - 180HP	344 *(156)*	20 x 25 *(508 x 635)*	4	1.34	2.29	1.81	2.18
Model BSQ	200 - 200HP	441 *(200)*	12 x 25 *(305 x 635)* 16 x 25 *(406 x 635)*	3 3	0.77	1.32	1.04	1.26
Model BSQ	240 - 240HP	573 *(260)*	20 x 25 *(508 x 635)* 16 x 25 *(406 x 635)*	4 4	0.41	0.70	0.55	0.67
Model BSQ	300 - 300HP	759 *(344)*	20 x 25 *(508 x 635)*	8	0.33	0.56	0.45	0.54
Model BSQ	360 - 360HP	957 *(434)*	16 x 25 *(406 x 635)* 20 x 25 *(508 x 635)*	10 5	0.15	0.26	0.20	0.25
Model BSQ	420	1185 *(538)*	16 x 25 *(406 x 635)* 20 x 25 *(508 x 635)*	5 10	0.13	0.22	0.18	0.21

Note: 24-inch side clearance is recommended for accessing and removing filters.
All dimensions in inches *(millimeters)* and weight in pounds *(kilograms)*.

$$P_t = F \times \left(\frac{cfm}{10{,}000}\right)^2$$

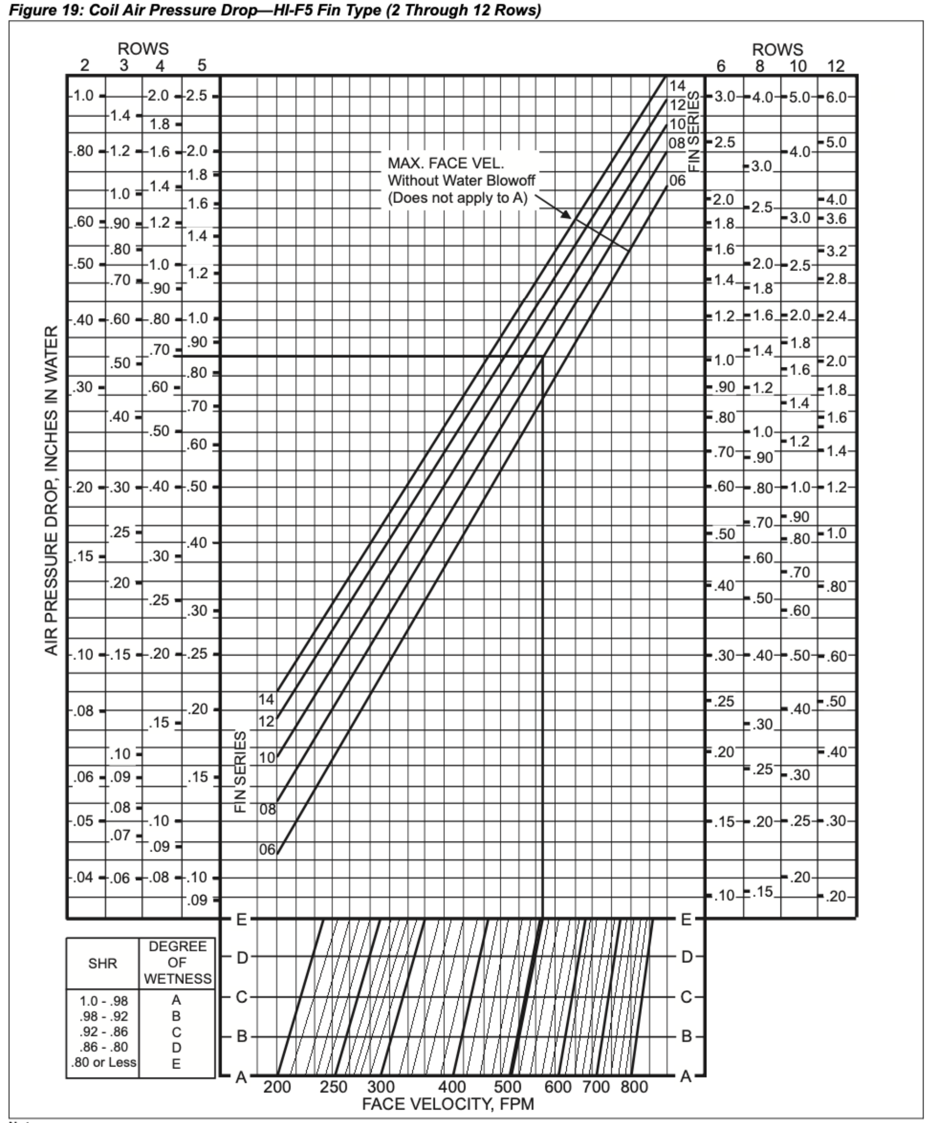
https://content.greenheck.com/public/DAMProd/Original/10003/SQBSQ_catalog.pdf

WHAT ELSE SHOULD WE CONSIDER?

Heating and Cooling Coils

- Heating and cooling coils:

Figure 19: Coil Air Pressure Drop—HI-F5 Fin Type (2 Through 12 Rows)



Notes:

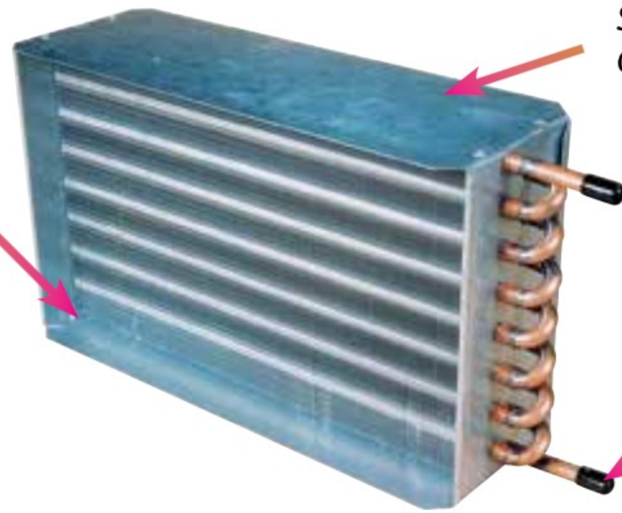
- The letters A,B,C,D or E following the face velocity indicate the degree of wetness at which the coil is operating.
- Dry coils are shown by the letter A, wet coils by the letter E. Intermediate conditions are shown by the letters B, C, and D.
- Air pressure drop for odd fin spacings can be found by interpolation.

https://oslo.daikinapplied.com/api/daikindocument/DownloadDocumentByName/Doc100/Vision%20Indoor%20Air%20Handler%20Catalog%20Daikin%20CAT%20550.pdf/

AIR HANDLING UNIT SELECTION

Air Handling Unit Selection

- Heating and cooling coils:



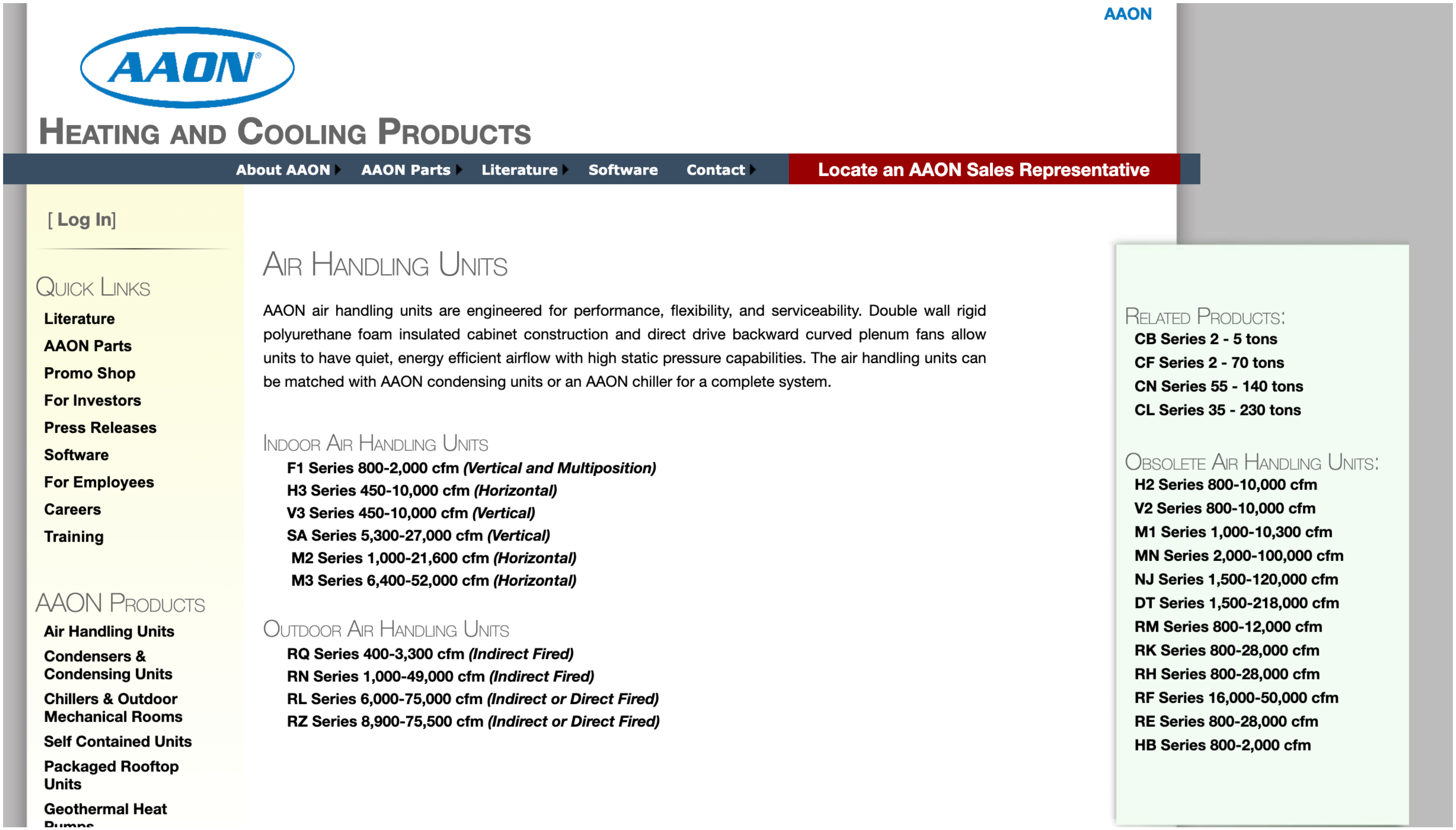
Booster Coils										
Type	Tube Material	Fin Material	Casing Material	Casing Type	Rows	FPI	Circuitry	Tube Diameter (OD)	Connection Type	Optional Corrosion Protection
Hot Water or Steam	Copper	Aluminum or Copper	G90 Galvanized, Aluminum, or 304 Stainless Steel	U-Flange, Slip and Drive or None	Up to 12	Up to 16	Quarter to Double Serpentine, or Steam Distributing	1/2″ or 5/8″	Sweat, MPT, or FPT*	Polymer E-Coating

** MPT (Male Pipe Thread) and FPT (Female Pipe Thread)*

https://www.aaon.com/Coils

Air Handling Unit Selection

- Let's look at some manufacture: Aaon



https://www.aaon.com/AirHandlers

Air Handling Unit Selection

- Let’s look at some manufacture: Daikin

Catalog 550-14

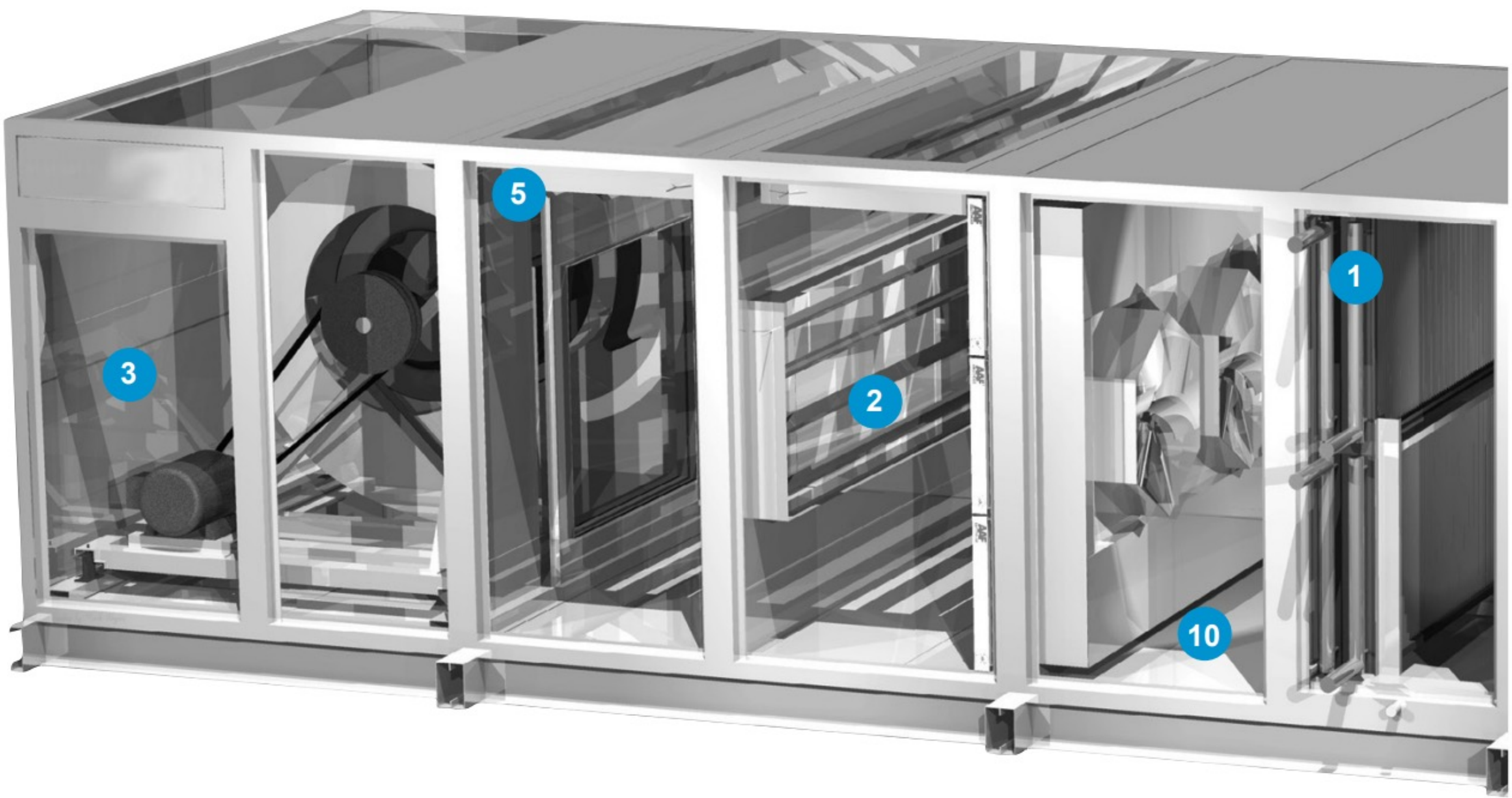
Vision® Air Handler

Sizes 003—090

https://oslo.daikinapplied.com/api/daikindocument/DownloadDocumentByName/Doc100/Vision%20Indoor%20Air%20Handler%20Catalog%20Daikin%20CAT%20550.pdf/

Air Handling Unit Selection

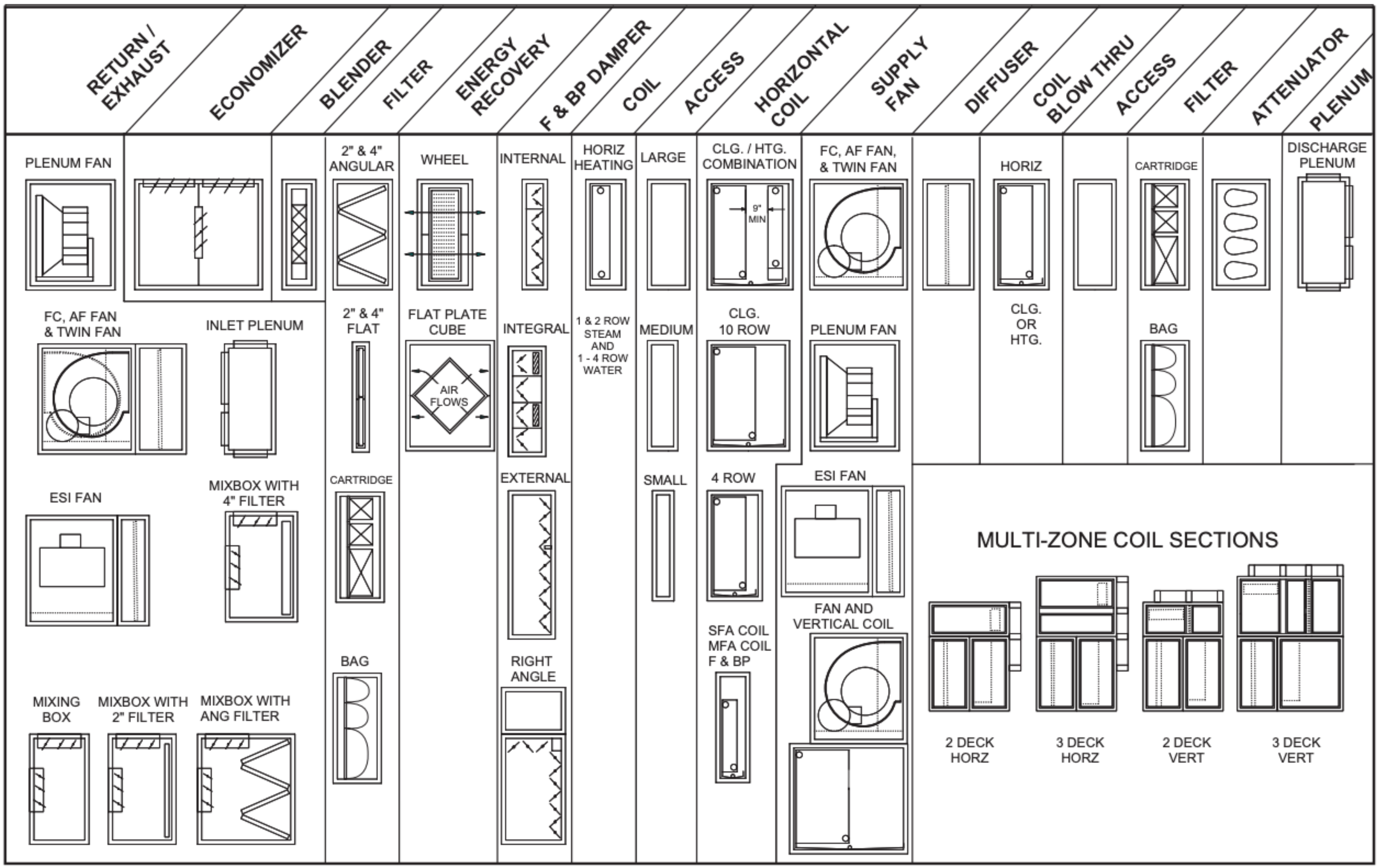
- Let's look at some manufacture: Daikin



https://oslo.daikinapplied.com/api/daikindocument/DownloadDocumentByName/Doc100/Vision%20Indoor%20Air%20Handler%20Catalog%20Daikin%20CAT%20550.pdf/

Air Handling Unit Selection

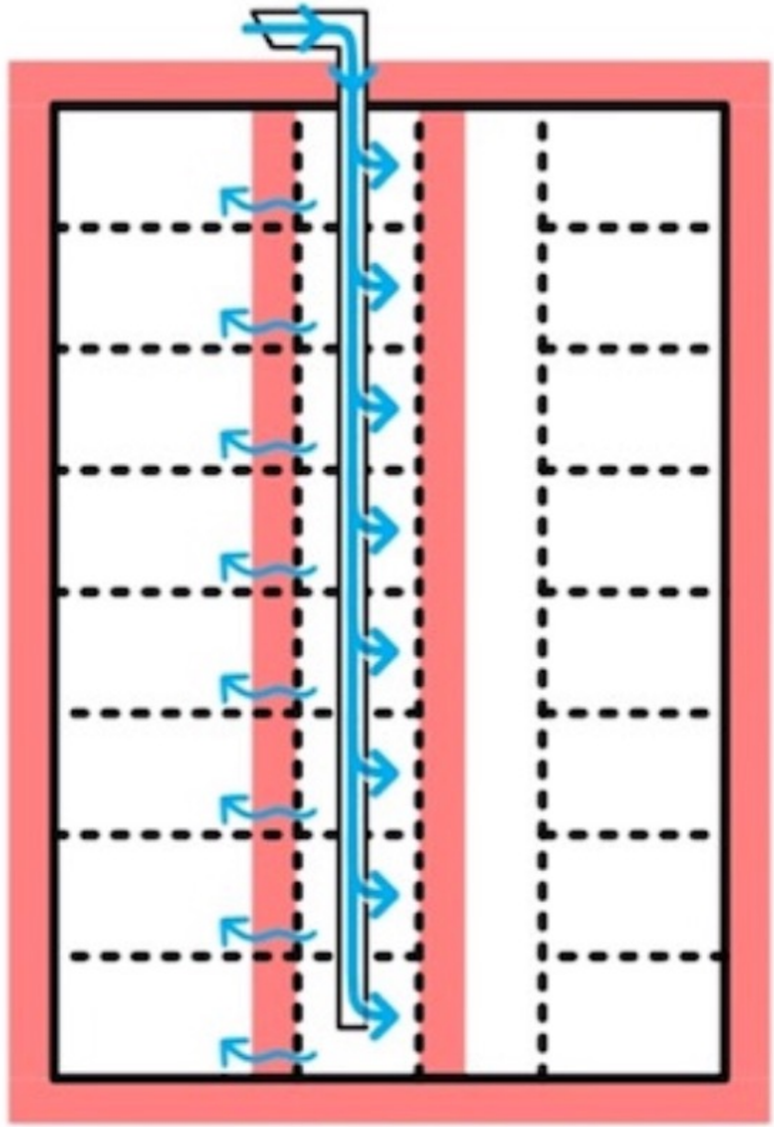
- Let's look at some manufacture: Daikin



https://oslo.daikinapplied.com/api/daikindocument/DownloadDocumentByName/Doc100/Vision%20Indoor%20Air%20Handler%20Catalog%20Daikin%20CAT%20550.pdf/

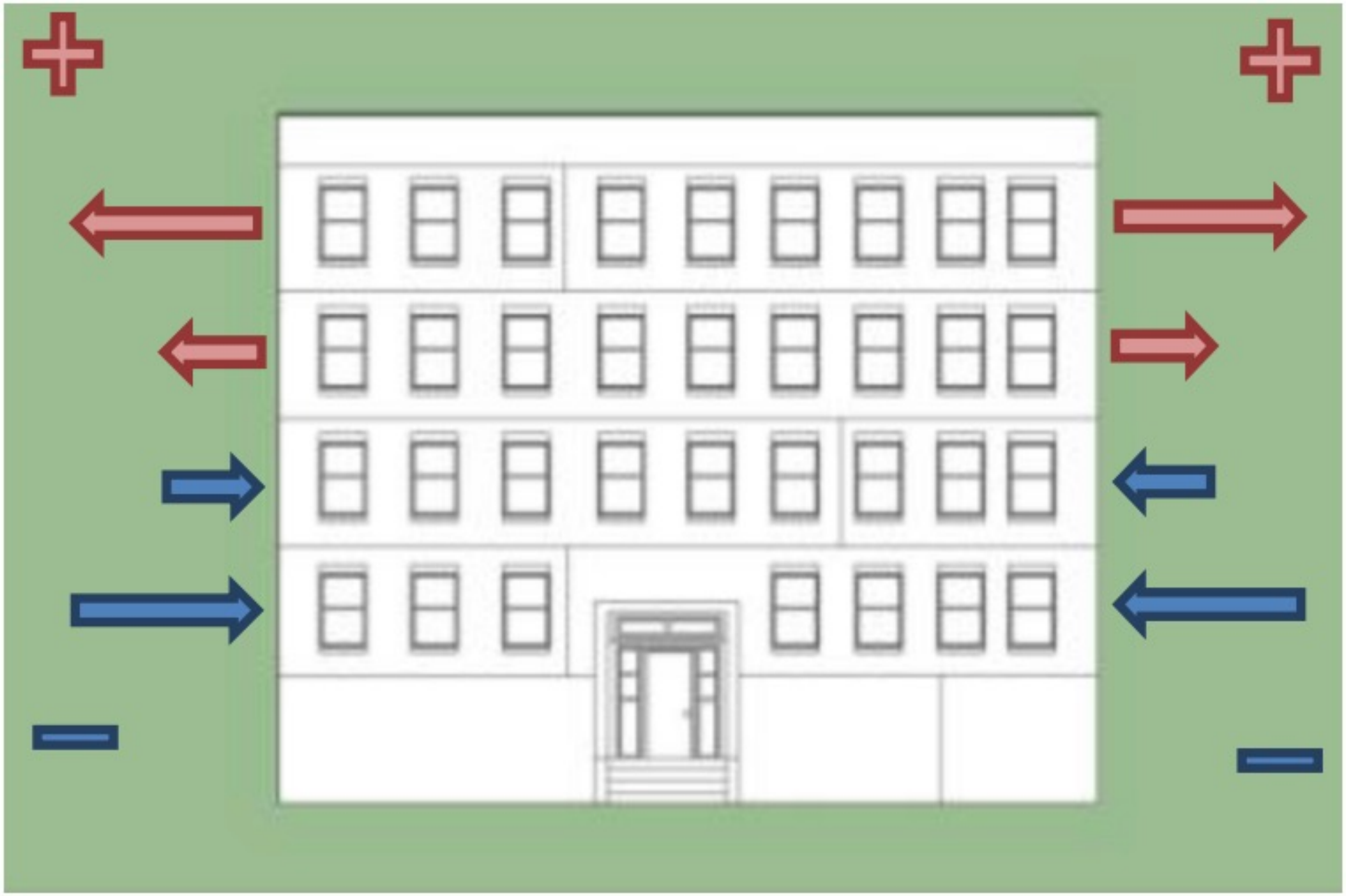
HALLWAY VENTILATION

Hallway Ventilation



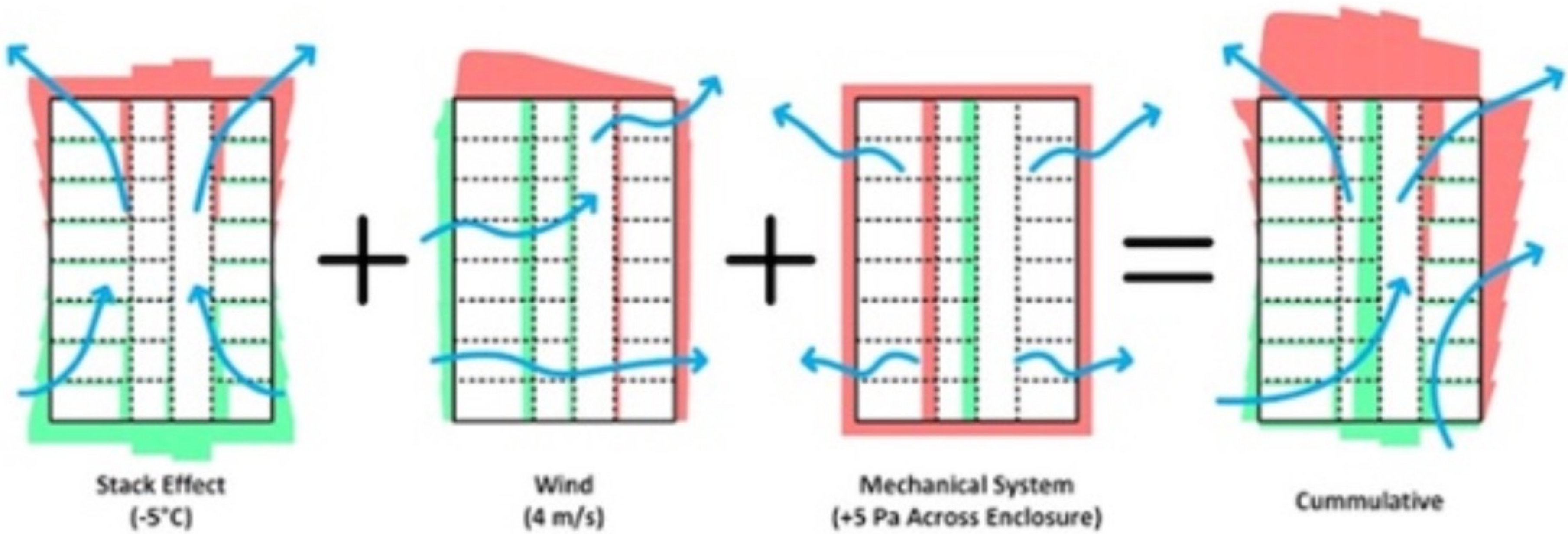
https://www.energyvanguard.com/blog/ventilating-high-rise-multifamily-buildings-a-first-look

Hallway Ventilation



https://www.nrel.gov/docs/fy14osti/62313.pdf

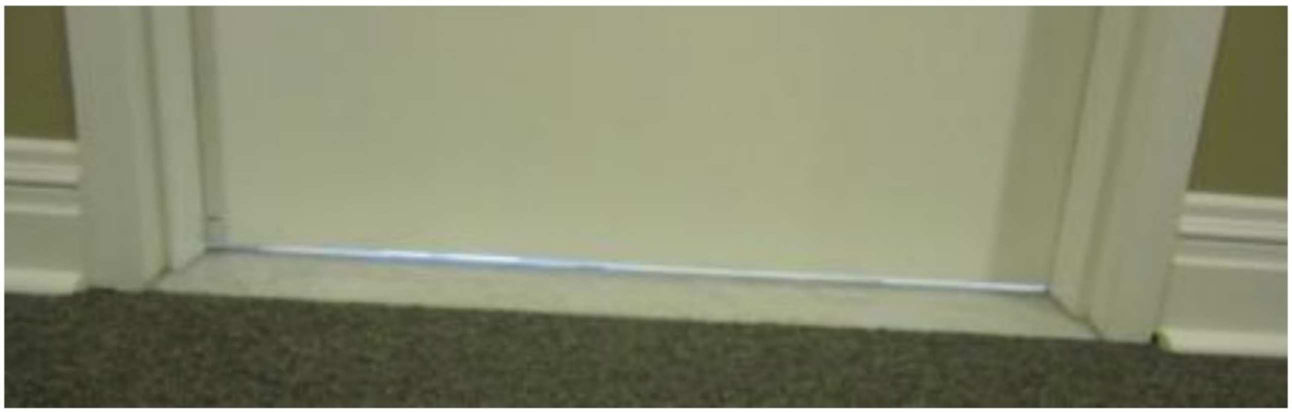
Hallway Ventilation



40% x 20% = 8%

https://www.energyvanguard.com/blog/ventilating-high-rise-multifamily-buildings-a-first-look

Hallway Ventilation



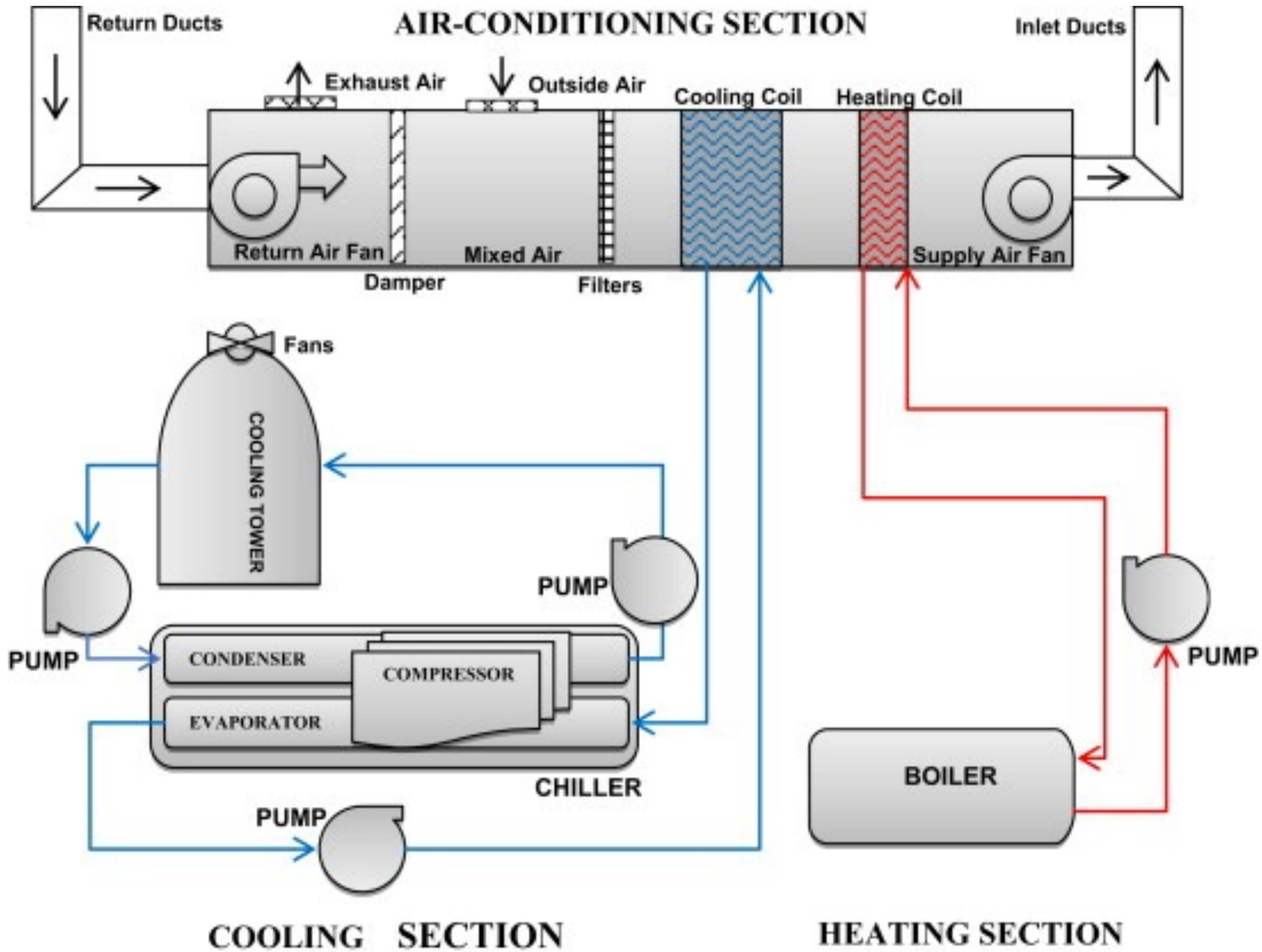
https://www.nrel.gov/docs/fy14osti/62313.pdf

INTRODUCTION TO HYDRONIC SYSTEMS

Hydronic Systems

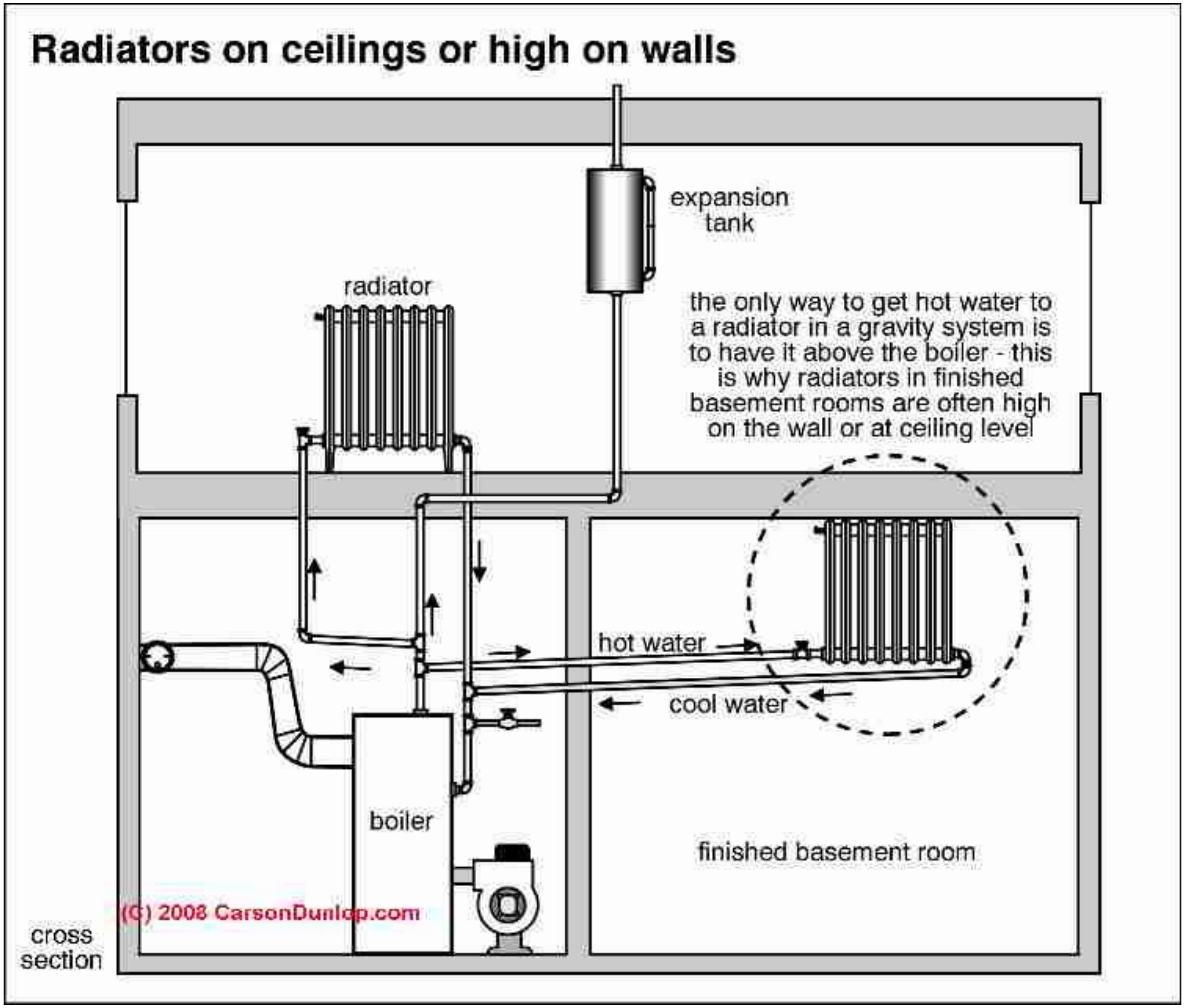
- A system that uses water as the heat transfer medium in heating and cooling applications
- A system in which the heat carrier is neither consumed nor rejected after use but is used repeatedly by recirculation
- Heat carriers are then circulated throughout a series of pipes or tubes to produce a desired room temperature

Hydronic Systems



Hydronic Systems

- Boilers



https://inspectapedia.com/heat/Cold_Radiator_Repair.php

Hydronic Systems

- Hydronic vs electric baseboards considerations:
  - ❑ Initial cost
  - ❑ Energy efficiency
  - ❑ Performance (e.g., warm up, duration)

https://homeverity.com/hydronic-baseboard-heaters-vs-electric/
https://www.primebuyersreport.org/industry/atlantic-county-nj/atlantic-county/air-conditioning-heating-ventilation-contractors/

Hydronic Systems

- Hot Water Storage Tanks

Residential
- Vertical (40 gallons)
- 34,000 – 40,000 Btu

Commercial
- Vertical (150 gallons to 4,000 gallons)
- Horizontal (250 gallons to 4,000 gallons)

https://www.homedepot.com/p/Rheem-Performance-40-Gal-Short-6-Year-38-000-BTU-Natural-Gas-Tank-Water-Heater-XG40S06HE38U0/204321639?cm_mmc=Shopping%7CG%7CVF%7CD26P%7C26-10_WATER_HEATERS%7CRheem%7CPLA%7c71700000033150354%7c58700003868932471%7c92700031086650195&gclid=Cj0KCQjwjpjkBRDRARIsAKv-0O0b0R1tJLZzrGIcr5jyyvf6j5g6-PsQ7HTNl7RaXcHrLSlFm8MtFRoaApx4EALw_wcB&gclsrc=aw.ds https://www.pvi.com/products/commercial-hot-water-storage-tanks.htm

Hydronic Systems

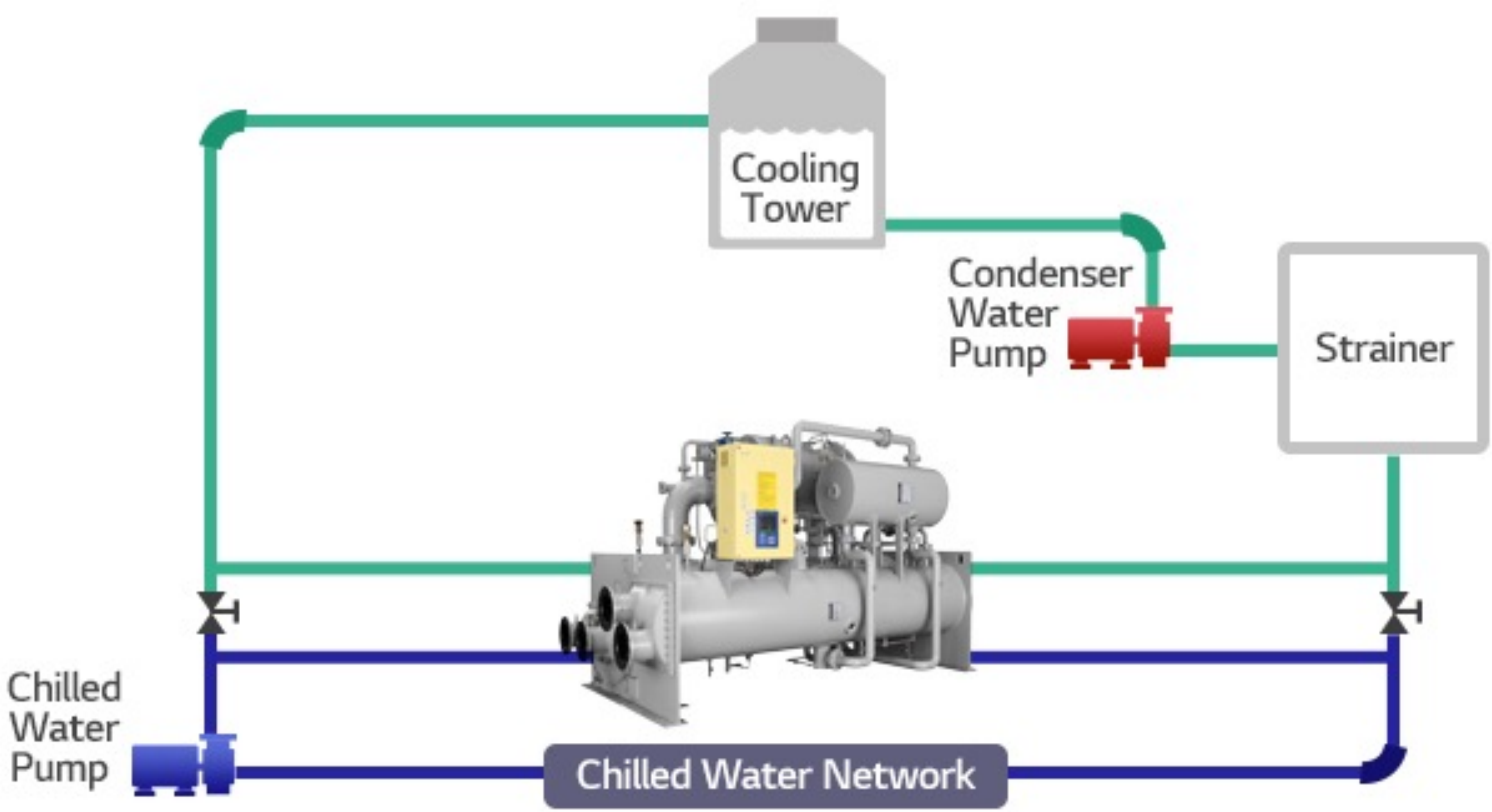
- Tankless water heater

Advantages and setbacks?

https://express.google.com/u/0/product/2600371301634687312_7920860133981164464_7472660?utm_source=google_shopping&utm_medium=tu_prop&utm_content=eid-lsjeuxoeqt&gtim=CNHuioe1w5C3-AEQscvZ7cHH4I8hGKDuz8YCIgNVU0Qo8OjF5AUwIIzIAw&utm_campaign=7472660&gclid=Cj0K

Hydronic Systems

- Chilled water



https://www.lghvacstory.com/chillers/

Hydronic Systems

- We used a few of chapters of ASHRAE Systems Handbook:
  - Chapter 22: Pipe Design
  - Chapter 13: Hydronic Heating and Cooling
  - Chapter 32: Boiler
  - Chapter 36: Radiators

BASIC OF HYDRONIC SYSTEMS

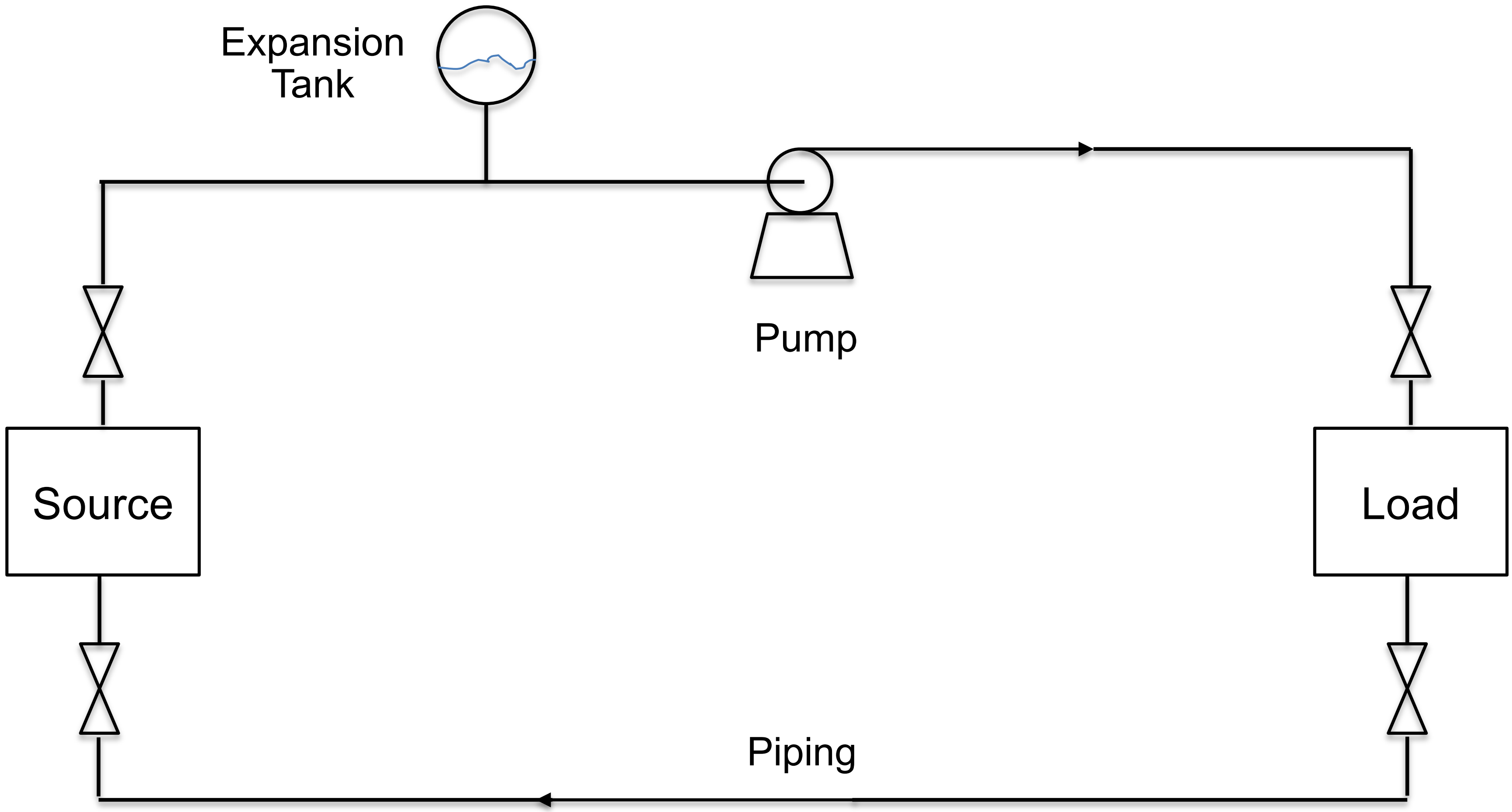
Basic of Hydronic Systems

- There are two main component types:

  - ❑ Thermal components:
    - Heat source(s)
    - Heat load(s)
    - Expansion tank

  - ❑ Hydraulic components
    - Piping
    - Pump
    - Expansion tank

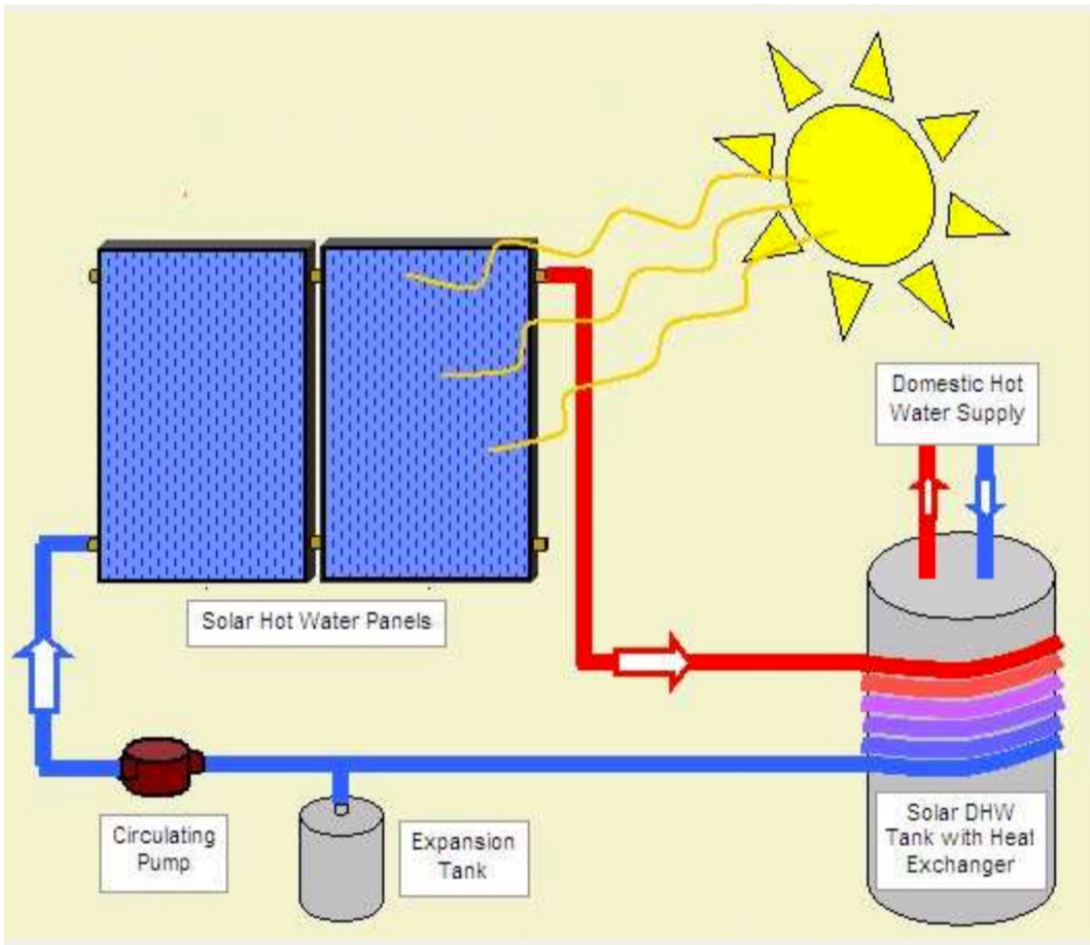
Basic of Hydronic Systems



Is this an open or closed loop system?

Basic of Hydronic Systems

- An example is a closed-loop system is a solar hot water system



Basic of Hydronic Systems

- There are different temperature ranges:

  - ❑ Chilled Water (CHW):
    - Temperature range: 39 ºF to 50 ºF
  - ❑ Condenser Water (CW):
    - Temperature range: 55 ºF to 100 ºF
  - ❑ Hot Water (HW):
    - Temperature range: 100 ºF to 210 ºF
  - ❑ High Temperature Water (HTW):
    - Temperature range: 212 ºF to 455 ºF

Basic of Hydronic Systems

- Another important considerations for selecting hydronic systems are:
  - Amps / voltage / power (kW)
  - Water temperature range
  - Capacity (MBH, Ton, …)
  - Fuel type
  - Application (residential, commercial, …)

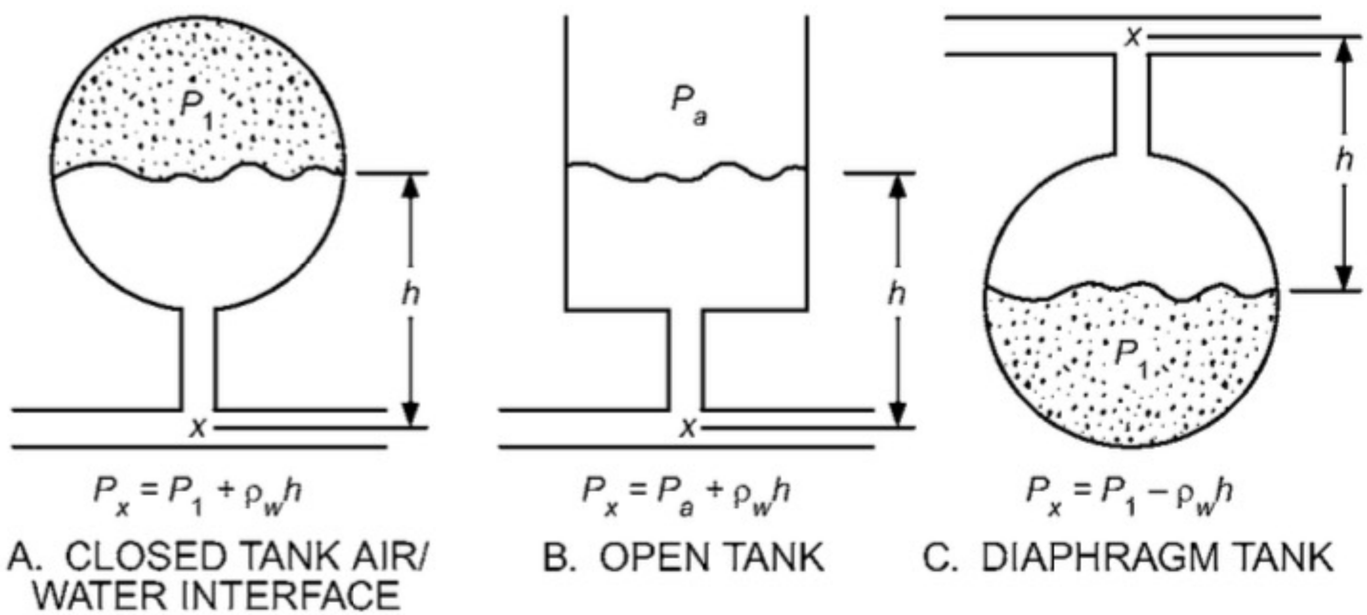
Basic of Hydronic Systems

- Water expand as it is heated, meaning the pressure in the system changes
- In the installation, we use expansion tank or expansion chamber vessel to accommodate the increase in the pressure of the system:
  - ❑ Look similar to a mini tank or boiler
  - ❑ Located typically on top of or next to the water heater
  - ❑ Sized based on the water pressure in the system
  - ❑ Avoid failure or bursting

https://westank.com/expansion-tanks/

Basic of Hydronic Systems

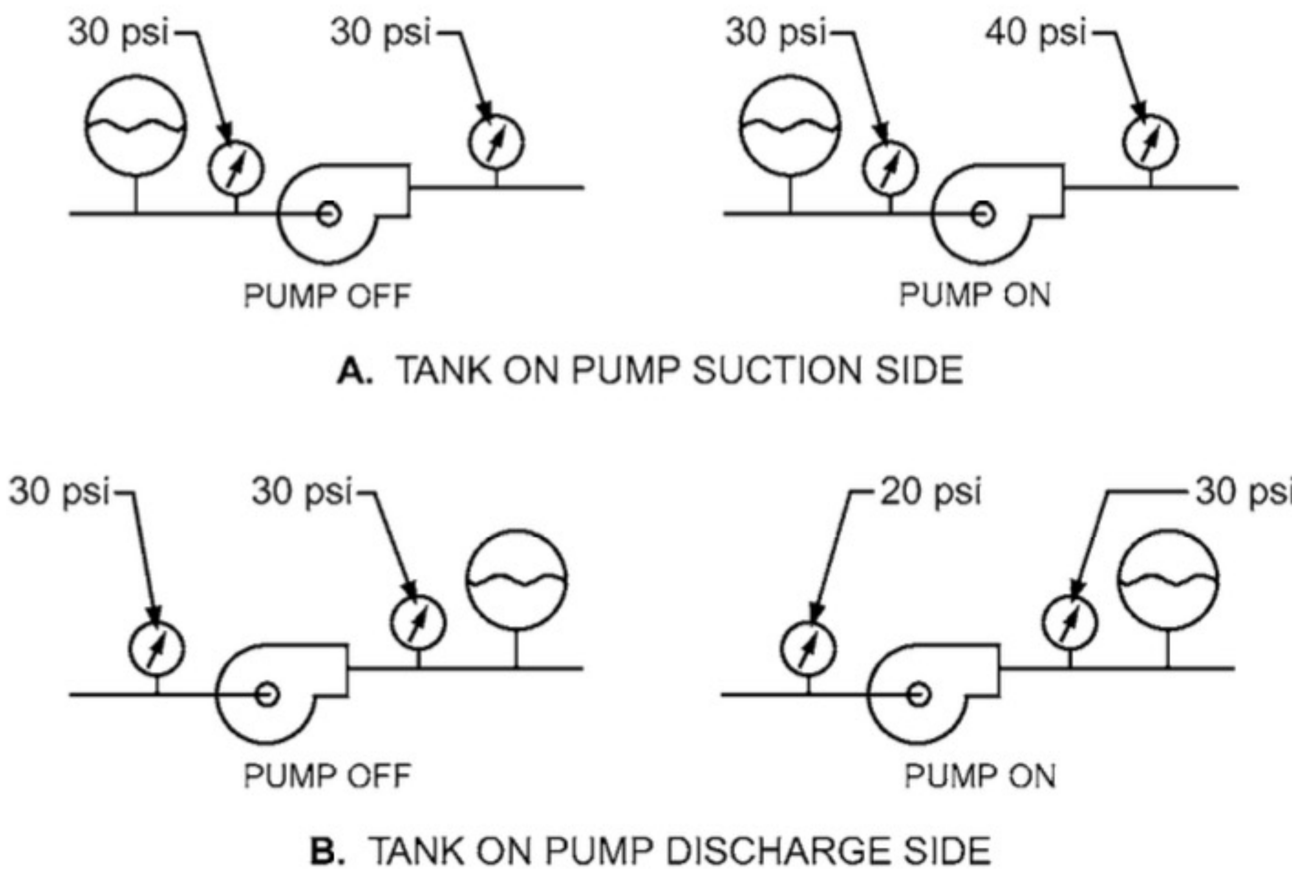
- Three common expansion tank types are:
  - ❑ Closed tank
  - ❑ Open tank
  - ❑ Diaphragm tank



ASHRAE Systems, Chapter 13

Basic of Hydronic Systems

- An example of installing expansion tanks in a hydronic systems:



ASHRAE Systems, Chapter 13