CAE 464/517 HVAC Systems Design

Spring 2023

April 11, 2023

Hydronic systems: system characteristics and project questions

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ANNOUNCEMENTS

Announcements

- Assignment 5 is posted (optional)
- A new measurement activity will be posted (optional)
- Anyone opposed to change the exam time?

RECAP

Recap

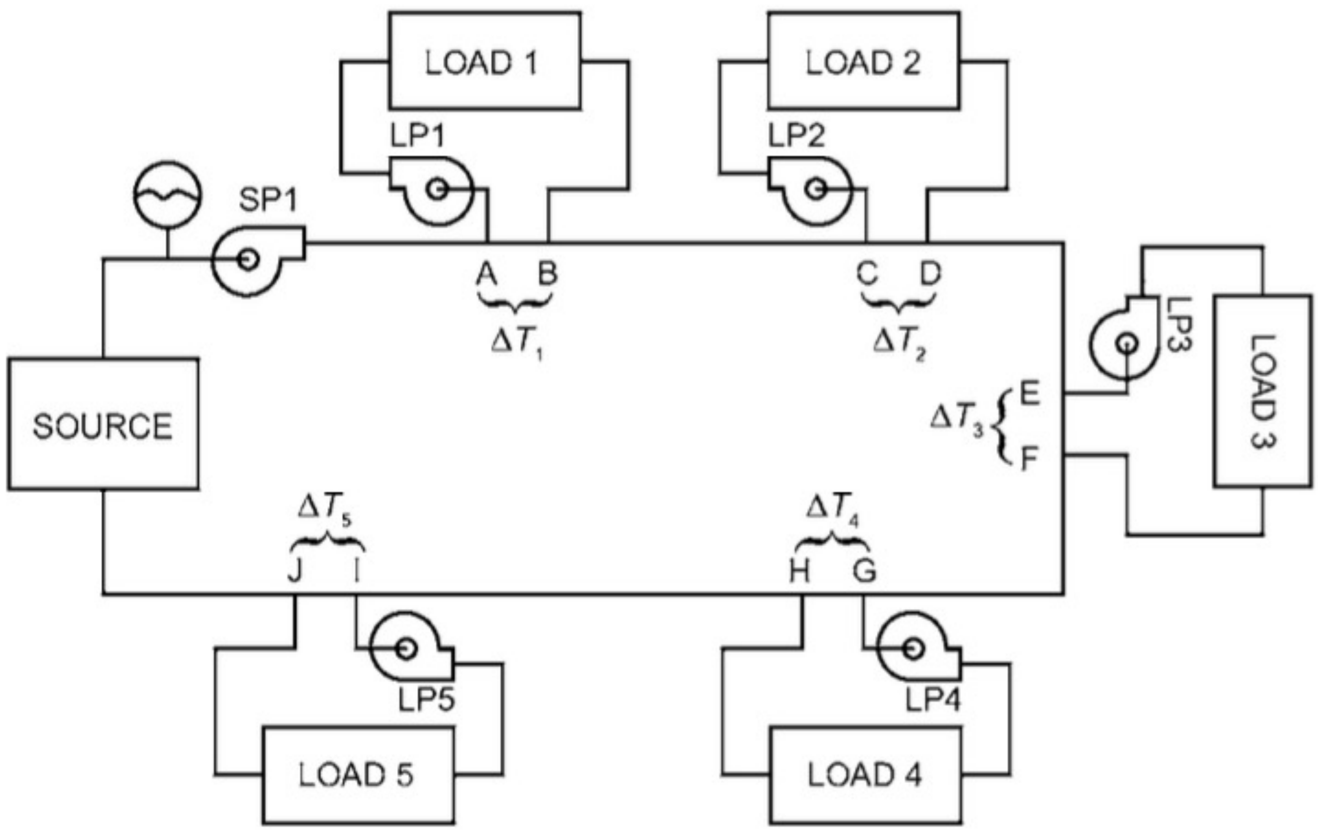
- What are the supply piping layouts (zone level)

Recap

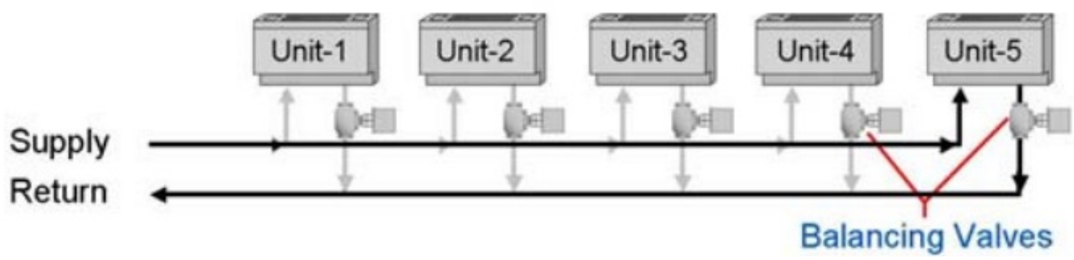
- What are the supply piping layouts (central)

Recap

- Another approach is the series circuit with distributed load pumps:



Recap



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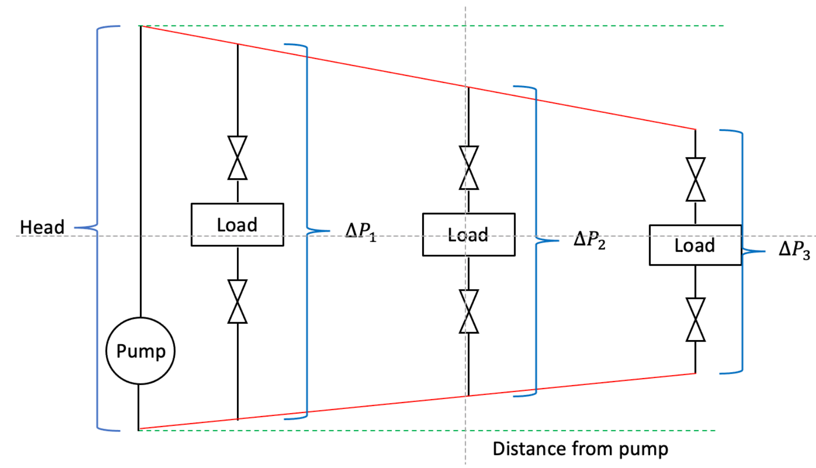
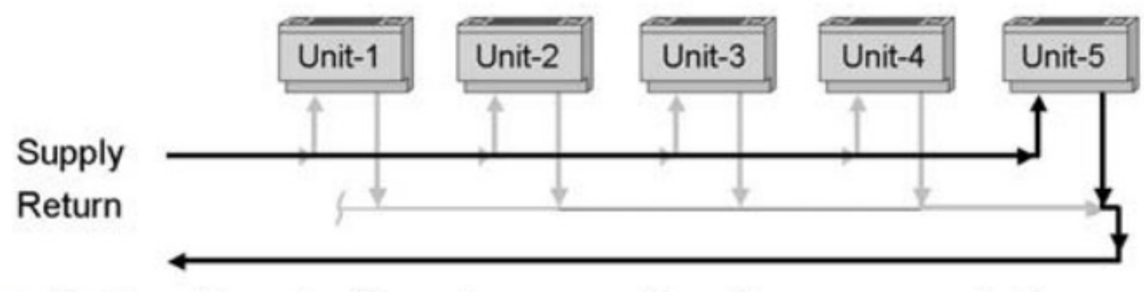
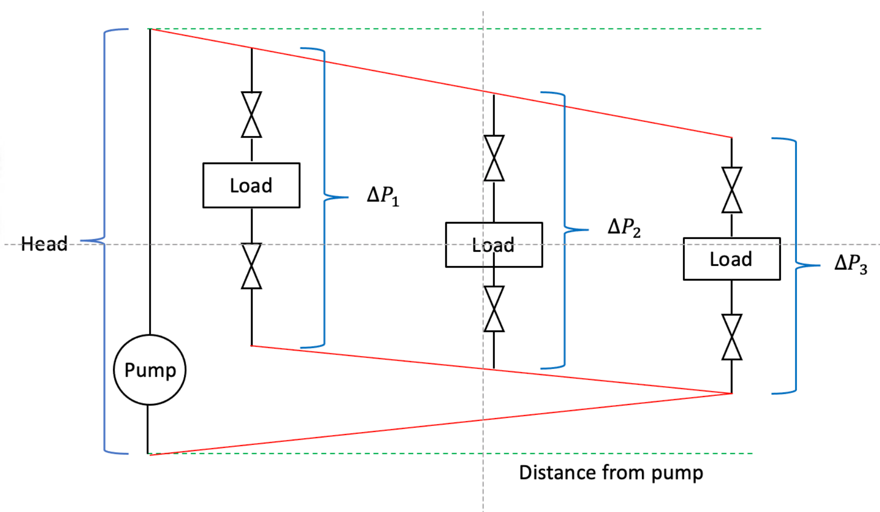




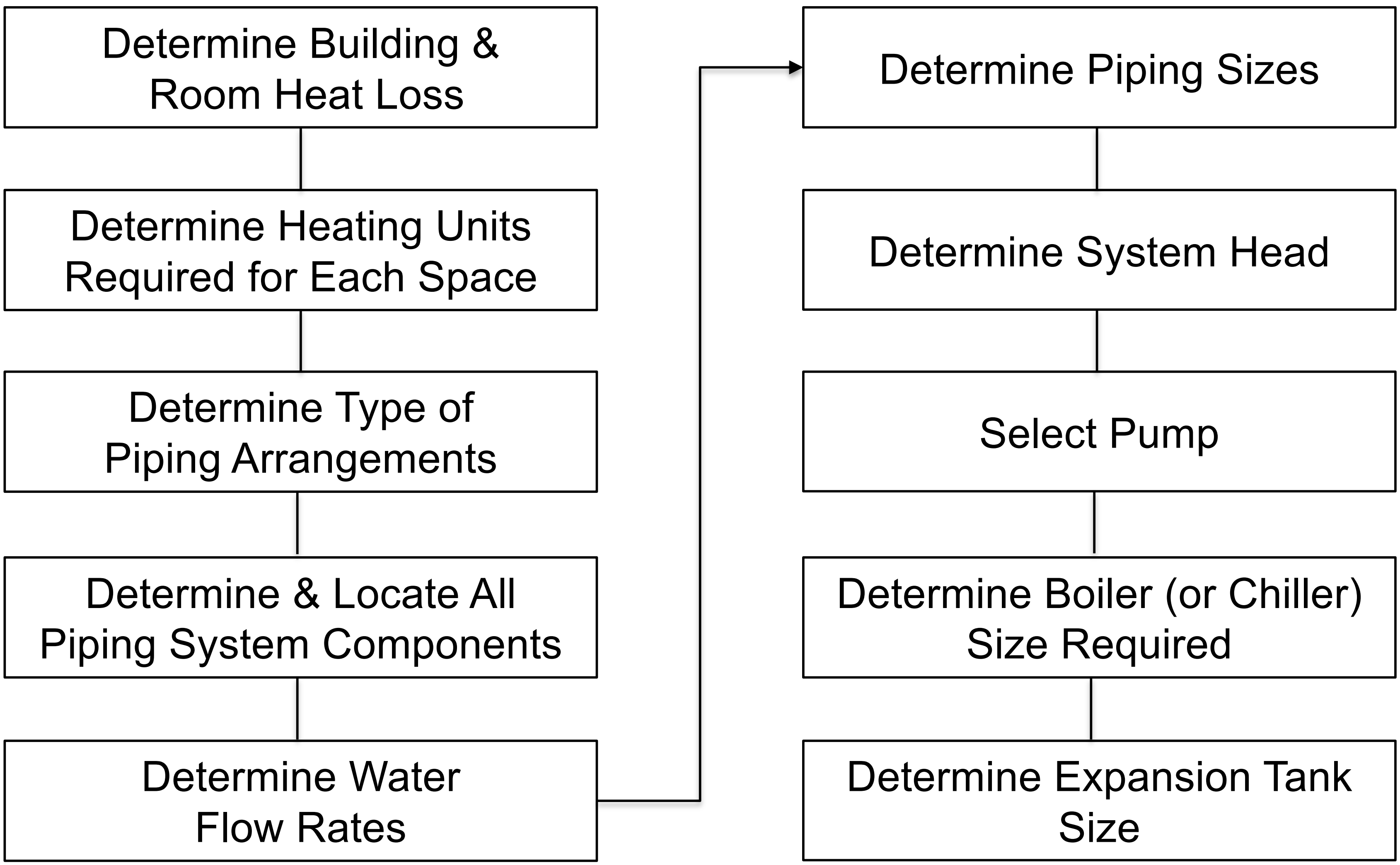
Reverse



http://siglercommercial.com/wp-content/uploads/2017/10/02-Chilled-Water-Piping-Pumps.pdf

DESIGN PROCEDURE

Design Procedure



Design Procedure

FRICTION LOSS IN WATER FITTINGS

Friction Loss in Water Fittings

- Friction loss in a water pipe fitting is equal to:

$$H_{lf} = K\left(\frac{V^2}{2g}\right)$$

Table 3 *K* Factors: Threaded Steel Pipe Fittings

Nominal Pipe Dia., in.	90° Standard Elbow	90° Long-Radius Elbow	45° Elbow	Return Bend	Tee-Line	Tee-Branch	Globe Valve	Gate Valve	Angle Valve	Swing Check Valve	Bell Mouth Inlet	Square Inlet	Projected Inlet
3/8	2.5	—	0.38	2.5	0.90	2.7	20	0.40	—	8.0	0.05	0.5	1.0
1/2	2.1	—	0.37	2.1	0.90	2.4	14	0.33	—	5.5	0.05	0.5	1.0
3/4	1.7	0.92	0.35	1.7	0.90	2.1	10	0.28	6.1	3.7	0.05	0.5	1.0
1	1.5	0.78	0.34	1.5	0.90	1.8	9	0.24	4.6	3.0	0.05	0.5	1.0
1 1/4	1.3	0.65	0.33	1.3	0.90	1.7	8.5	0.22	3.6	2.7	0.05	0.5	1.0
1 1/2	1.2	0.54	0.32	1.2	0.90	1.6	8	0.19	2.9	2.5	0.05	0.5	1.0
2	1.0	0.42	0.31	1.0	0.90	1.4	7	0.17	2.1	2.3	0.05	0.5	1.0
2 1/2	0.85	0.35	0.30	0.85	0.90	1.3	6.5	0.16	1.6	2.2	0.05	0.5	1.0
3	0.80	0.31	0.29	0.80	0.90	1.2	6	0.14	1.3	2.1	0.05	0.5	1.0
4	0.70	0.24	0.28	0.70	0.90	1.1	5.7	0.12	1.0	2.0	0.05	0.5	1.0

Source: *Engineering Data Book* (Hydraulic Institute 1990).

Is there a difference between open or close valve?

Friction Loss in Water Fittings

- Friction loss in a water pipe fitting is equal to:

Table 4 *K* Factors: Flanged Welded Steel Pipe Fittings

Nominal Pipe Dia., in.	90° Standard Elbow	90° Long-Radius Elbow	45° Long-Radius Elbow	Return Bend Standard	Return Bend Long-Radius	Tee-Line	Tee-Branch	Globe Valve	Gate Valve	Angle Valve	Swing Check Valve
1	0.43	0.41	0.22	0.43	0.43	0.26	1.0	13	—	4.8	2.0
1 1/4	0.41	0.37	0.22	0.41	0.38	0.25	0.95	12	—	3.7	2.0
1 1/2	0.40	0.35	0.21	0.40	0.35	0.23	0.90	10	—	3.0	2.0
2	0.38	0.30	0.20	0.38	0.30	0.20	0.84	9	0.34	2.5	2.0
2 1/2	0.35	0.28	0.19	0.35	0.27	0.18	0.79	8	0.27	2.3	2.0
3	0.34	0.25	0.18	0.34	0.25	0.17	0.76	7	0.22	2.2	2.0
4	0.31	0.22	0.18	0.31	0.22	0.15	0.70	6.5	0.16	2.1	2.0
6	0.29	0.18	0.17	0.29	0.18	0.12	0.62	6	0.10	2.1	2.0
8	0.27	0.16	0.17	0.27	0.15	0.10	0.58	5.7	0.08	2.1	2.0
10	0.25	0.14	0.16	0.25	0.14	0.09	0.53	5.7	0.06	2.1	2.0
12	0.24	0.13	0.16	0.24	0.13	0.08	0.50	5.7	0.05	2.1	2.0

Source: *Engineering Data Book* (Hydraulic Institute 1990).

Friction Loss in Water Fittings

- Friction loss in a water pipe fitting is equal to:

Table 6 Summary of *K* Values for Steel Ells, Reducers, and Expansions

		ASHRAE Research[b,c]		
	Past[a]	4 fps	8 fps	12 fps
2 in. S.R.[e] ell (*R/D* = 1) thread	0.60 to 1.0 (1.0)[d]	0.60	0.68	0.736
4 in. S.R. ell (*R/D* = 1) weld	0.30 to 0.34	0.37	0.34	0.33
1 in. L.R. ell (*R/D* = 1.5) weld	to 1.0	—	—	—
2 in. L.R. ell (*R/D* = 1.5) weld	0.50 to 0.7	—	—	—
4 in. L.R. ell (*R/D* = 1.5) weld	0.22 to 0.33 (0.22)[d]	0.26	0.24	0.23
6 in. L.R. ell (*R/D* = 1.5) weld	0.25	0.26	0.24	0.24
8 in. L.R. ell (*R/D* = 1.5) weld	0.20 to 0.26	0.22	0.20	0.19
10 in. L.R. ell (*R/D* = 1.5) weld	0.17	0.21	0.17	0.16
12 in. L.R. ell (*R/D* = 1.5) weld	0.16	0.17	0.17	0.17
16 in. L.R. ell (*R/D* = 1.5) weld	0.12	0.12	0.12	0.11
20 in. L.R. ell (*R/D* = 1.5) weld	0.09	0.12	0.10	0.10
24 in. L.R. ell (*R/D* = 1.5) weld	0.07	0.098	0.089	0.089
Reducer (2 by 1.5 in.) thread	—	0.53	0.28	0.20
(4 by 3 in.) weld	0.22	0.23	0.14	0.10
(6 by 4 in.) weld		0.62	0.54	0.53
(8 by 6 in.) weld		0.31	0.28	0.26
(10 by 8 in.) weld		0.16	0.14	0.14
(12 by 10 in.) weld	—	0.14	0.14	0.14
(16 by 12 in.) weld	—	0.17	0.16	0.17
(20 by 16 in.) weld	—	0.16	0.13	0.13
(24 by 20 in.) weld	—	0.053	0.053	0.055
Expansion (1.5 by 2 in.) thread	—	0.16	0.13	0.02
(3 by 4 in.) weld	—	0.11	0.11	0.11
(4 by 6 in.) weld	—	0.28	0.28	0.29
(6 by 8 in.) weld	—	0.15	0.12	0.11
(8 by 10 in.) weld	—	0.11	0.09	0.08
(10 by 12 in.) weld	—	0.11	0.11	0.11
(12 by 16 in.) weld	—	0.073	0.076	0.073
(16 by 20 in.) weld	—	0.024	0.021	0.022
(20 by 24 in.) weld	—	0.020	0.023	0.020

Source: Rahmeyer (2003a).
[a]Published data by Crane Co. (1988), Freeman (1941), and Hydraulic Institute (1990).
[b]Rahmeyer (1999a, 2002a).
[c]Ding et al. (2005)
[d]( ) Data published in 1993 *ASHRAE Handbook—Fundamentals*.
[e]S.R.—short radius or regular ell; L.R.—long-radius ell.

Friction Loss in Water Fittings

- We also sometimes define equivalent length:

$$Head\ loss\ in\ a\ pipe = f\,\frac{L}{D}\frac{V^2}{2g}$$

$$K = f\,\frac{L}{D}$$

$$Head\ loss\ in\ a\ fitting = K\,\frac{V^2}{2g}$$

- $\frac{L}{D}$ is the equivalent length in pipe diameters of straight pipe that will cause the same pressure drop as the valve or fitting under the same flow conditions

Friction Loss in Water Fittings

- ASHRAE Chapter 22 has some list of equivalent lengths:

Table 27 Equivalent Length in Feet of Pipe for 90° Elbows

Velocity, fps	Pipe Size														
	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12
1	1.2	1.7	2.2	3.0	3.5	4.5	5.4	6.7	7.7	8.6	10.5	12.2	15.4	18.7	22.2
2	1.4	1.9	2.5	3.3	3.9	5.1	6.0	7.5	8.6	9.5	11.7	13.7	17.3	20.8	24.8
3	1.5	2.0	2.7	3.6	4.2	5.4	6.4	8.0	9.2	10.2	12.5	14.6	18.4	22.3	26.5
4	1.5	2.1	2.8	3.7	4.4	5.6	6.7	8.3	9.6	10.6	13.1	15.2	19.2	23.2	27.6
5	1.6	2.2	2.9	3.9	4.5	5.9	7.0	8.7	10.0	11.1	13.6	15.8	19.8	24.2	28.8
6	1.7	2.3	3.0	4.0	4.7	6.0	7.2	8.9	10.3	11.4	14.0	16.3	20.5	24.9	29.6
7	1.7	2.3	3.0	4.1	4.8	6.2	7.4	9.1	10.5	11.7	14.3	16.7	21.0	25.5	30.3
8	1.7	2.4	3.1	4.2	4.9	6.3	7.5	9.3	10.8	11.9	14.6	17.1	21.5	26.1	31.0
9	1.8	2.4	3.2	4.3	5.0	6.4	7.7	9.5	11.0	12.2	14.9	17.4	21.9	26.6	31.6
10	1.8	2.5	3.2	4.3	5.1	6.5	7.8	9.7	11.2	12.4	15.2	17.7	22.2	27.0	32.0

Friction Loss in Water Fittings

- ASHRAE Chapter 22 has some list of equivalent lengths:

Table 28 Iron and Copper Elbow Equivalents*

Fitting	Iron Pipe	Copper Tubing
Elbow, 90°	1.0	1.0
45°	0.7	0.7
90° long-radius	0.5	0.5
90° welded	0.5	0.5
Reduced coupling	0.4	0.4
Open return bend	1.0	1.0
Angle radiator valve	2.0	3.0
Radiator or convector	3.0	4.0
Boiler or heater	3.0	4.0
Open gate valve	0.5	0.7
Open globe valve	12.0	17.0

Sources: Giesecke (1926) and Giesecke and Badgett (1931, 1932a).
*See Table 10 for equivalent length of one elbow.

Equivalent Length

- ASHRAE Chapter 22 has some list of equivalent lengths:

Table 8 Test Summary for Loss Coefficients *K* and Equivalent Loss Lengths

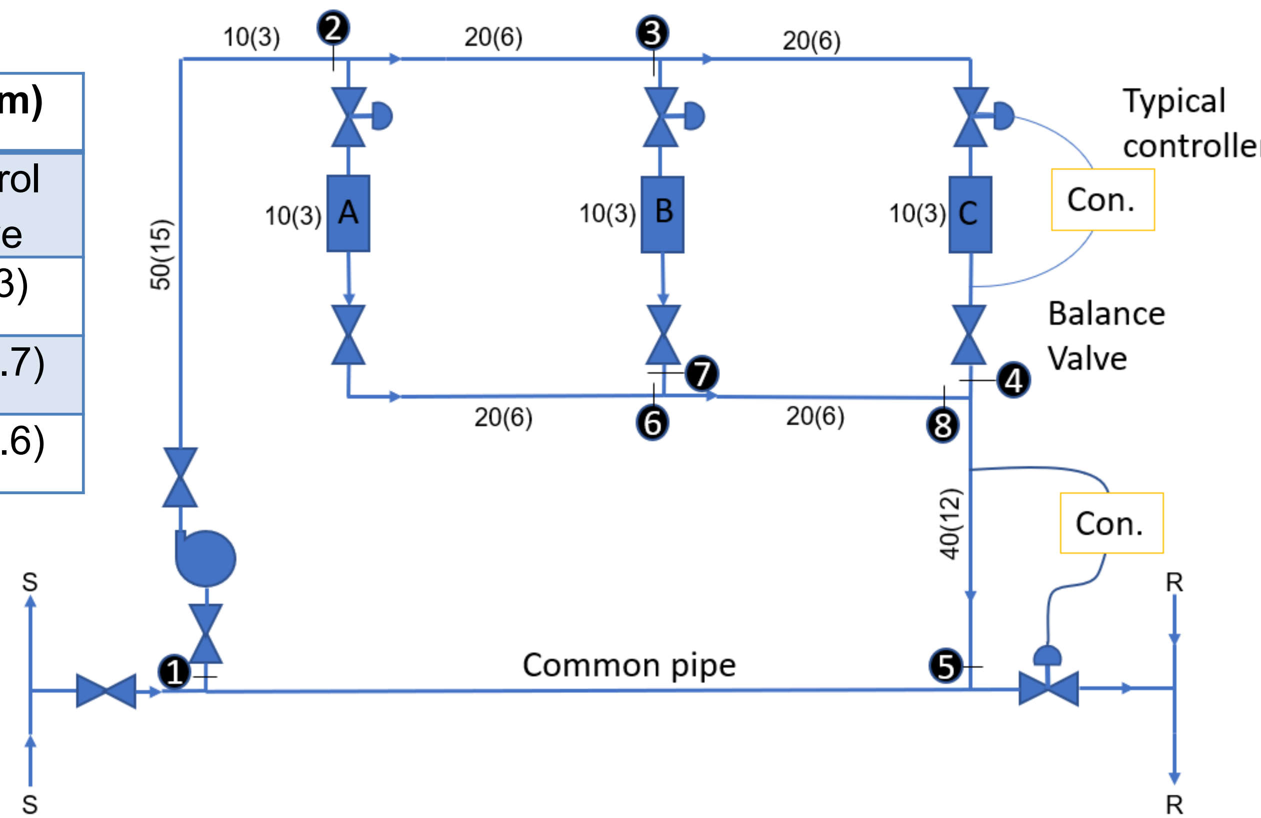
Schedule 80 PVC Fitting		*K*	*L*, ft
Injected molded elbow,	2 in.	0.91 to 1.00	8.4 to 9.2
	4 in.	0.86 to 0.91	18.3 to 19.3
	6 in.	0.76 to 0.91	26.2 to 31.3
	8 in.	0.68 to 0.87	32.9 to 42.1
8 in. fabricated elbow, Type I, components		0.40 to 0.42	19.4 to 20.3
Type II, mitered		0.073 to 0.76	35.3 to 36.8
6 by 4 in. injected molded reducer		0.12 to 0.59	4.1 to 20.3
Bushing type		0.49 to 0.59	16.9 to 20.3
8 by 6 in. injected molded reducer		0.13 to 0.63	6.3 to 30.5
Bushing type		0.48 to 0.68	23.2 to 32.9
Gradual reducer type		0.21	10.2
4 by 6 in. injected molded expansion		0.069 to 1.19	1.5 to 25.3
Bushing type		0.069 to 1.14	1.5 to 24.2
6 by 8 in. injected molded expansion		0.95 to 0.96	32.7 to 33.0
Bushing type		0.94 to 0.95	32.4 to 32.7
Gradual reducer type		0.99	34.1

CLASS ACTIVITY

Class Activity

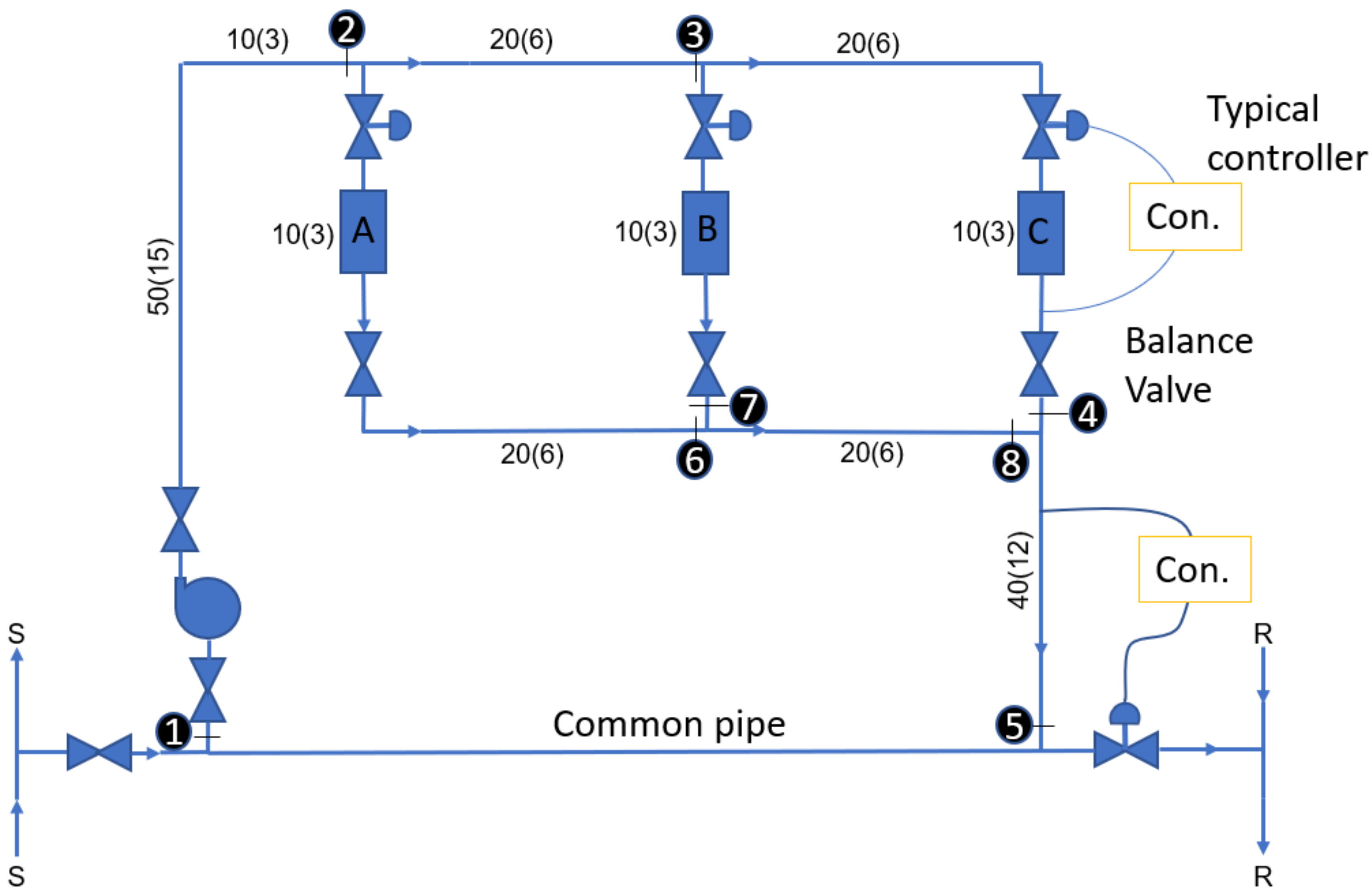
- **Example:** Size the pipe for the water distribution system shown below. The pipe is type L copper. Notice that the lengths given are the total equivalent lengths excluding the coil and control valves.

Coil	Flow rate, gpm (L/s)	Lost head, ft (m)	
		Coil	Control valve
A	40 (2.5)	12 (3.7)	10 (3)
B	40 (2.5)	15 (4.6)	12 (3.7)
C	50 (3.2)	18 (5.5)	15 (4.6)



Class Activity

- **Solution:**
  - ❑ Consider all the routes



Class Activity

- **Solution:**
  - ❑ Calculate the flow rate in each section:

Pipe Section No.	Flow rate(gpm)
1-2	
2-3	
3-4	
4-5	
Common pipe	
2-6	
3-7	
7-8	

Class Activity

- **Solution:**
  - ❑ Calculate the flow rate in each section:

Pipe Section No.	Flow rate(gpm)
1-2	$Q_{total} = Q_A + Q_B + Q_C = 40 + 40 + 50 = 130$
2-3	$Q_{total} - Q_A = 130 - 40 = 90$
3-4	$Q_C = 50$
4-5	$Q_{total} = 130$
Common pipe	0
2-6	$Q_A = 40$
3-7	$Q_B = 40$
7-8	$Q_A + Q_B = 80$

Class Activity

- **Solution:**
  - ❑ Identify the pipe diameter and head loss ft/100-ft of each section (Figure 15 – Chapter 22):

Pipe section No.	Flow rate (gpm)	Nominal size (in)	Lost head per 100 ft $(ft/100ft)$
1-2	130		
2-3	90		
3-4	50		
4-5	130		
Common pipe	0		
2-6	40		
3-7	40		
7-8	80		

Class Activity

- **Solution:**
  - ❑ Identify the pipe diameter and head loss ft/100-ft of each section (Figure 15 – Chapter 22):

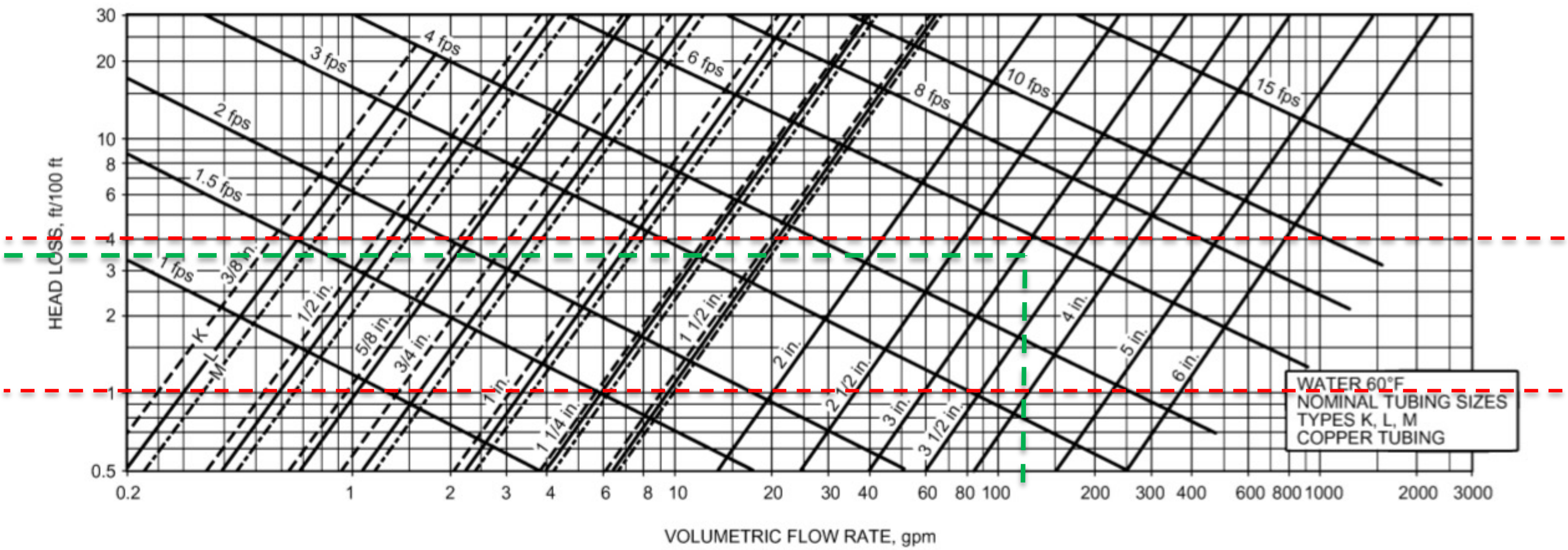


Fig. 15 Friction Loss for Water in Copper Tubing (Types K, L, M)

Class Activity

- **Solution:**
  - Identify the pipe diameter and head loss ft/100-ft of each section (Figure 15 – Chapter 22):

Pipe section No.	Flow rate (gpm)	Nominal size (in)	Lost head per 100 ft $(ft/100ft)$
1-2	130	3	3.7
2-3	90	2 1/2	4.8
3-4	50	2	5.0
4-5	130	3	3.7
Common pipe	0	3	….
2-6	40	2	3.4
3-7	40	2	3.4
7-8	80	2 1/2	3.9

Class Activity

- **Solution:**
  - ❑ Calculate the head loss for each path:

Pipe section No.	Flow rate (gpm)	Nominal size (in)	Lost head per 100 ft $(ft/100ft)$	Pipe equivalent length (L_e (ft))	Lost head of pipe, coil and control valve (ft)	Total loss head (ft)
1-2	130	3	3.7	60	60×3.7/100=2.2	39.2
2-3	90	2 1/2	4.8	20	20×4.8/100=1.0	
3-4	50	2	5.0	30	30×5.0/100=1.5	
Coil C	….	….	….	….	18	
Con. C	….	….	….	….	15	
4-5	130	3	3.7	40	40×3.7/100=1.5	
Common pipe	0	3	….	….	0	
2-6	40	2	3.4	30	30×3.4/100=1.0	23
Coil A	….	….	….	….	12	
Con. A	….	….	….	….	10	
3-7	40	2	3.4	10	10×3.4/100=0.5	28.3
Coil B	….	….	….	….	15	
Con. B	….	….	….	….	12	
7-8	80	2 1/2	3.9	20	20×3.9/100=0.8	

MORE ON FITTINGS

More on Fittings

- Unfortunately, ASHRAE Chapter 22 does not have all the fittings. We can rely on different resources. For example:

  - ❑ Source 1: Engineering Toolbox
  - ❑ Source 2: McQuiston et al. Heating Ventilating and Air Conditioning, 5th Edition
  - ❑ Source 3: Reddy et al., Heating and Cooling of Buildings, 3rd Edition

More on Fittings

- Source 1: Engineering Toolbox

Equivalent Length of Straight Pipe for Valves and Fittings (feet)												
Screwed Fittings		Pipe Size										
		1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
Elbows	Regular 90 deg	2.3	3.1	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0
	Long radius 90 deg	1.5	2.0	2.2	2.3	2.7	3.2	3.4	3.6	3.6	4.0	4.6
	Regular 45 deg	0.3	0.5	0.7	0.9	1.3	1.7	2.1	2.7	3.2	4.0	5.5
Tees	Line flow	0.8	1.2	1.7	2.4	3.2	4.6	5.6	7.7	9.3	12.0	17.0
	Branch flow	2.4	3.5	4.2	5.3	6.6	8.7	9.9	12.0	13.0	17.0	21.0
Return Bends	Regular 180 deg	2.3	3.1	3.6	4.4	5.2	6.6	7.4	8.5	9.3	11.0	13.0
Valves	Globe	21.0	22.0	22.0	24.0	29.0	37.0	42.0	54.0	62.0	79.0	110.0
	Gate	0.3	0.5	0.6	0.7	0.8	1.1	1.2	1.5	1.7	1.9	2.5
	Angle	12.8	15.0	15.0	15.0	17.0	18.0	18.0	18.0	18.0	18.0	18.0
	Swing Check	7.2	7.3	8.0	8.8	11.0	13.0	15.0	19.0	22.0	27.0	38.0
Strainer			4.6	5.0	6.6	7.7	18.0	20.0	27.0	29.0	34.0	42.0

engineeringtoolbox.com

https://www.engineeringtoolbox.com/resistance-equivalent-length-d_192.html

More on Fittings

- Source 1: Engineering Toolbox

Equivalent Length of Straight Pipe for Valves and Fittings (feet)														
Flanged Fittings		Pipe Size												
		1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10
Elbows	Regular 90 deg	0.9	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	7.3	8.9	12	14
	Long radius 90 deg	1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5	5.7	7	8
	Regular 45 deg	0.5	0.6	0.8	1.1	1.3	1.7	2.0	2.6	3.5	4.5	5.6	7.7	9
Tees	Line flow	0.7	0.8	1.0	1.3	1.5	1.8	1.9	2.2	2.8	3.3	3.8	4.7	5.2
	Branch flow	2.0	2.6	3.3	4.4	5.2	6.6	7.5	9.4	12.0	15	18	24	30
Return Bends	Regular 180 deg	0.9	1.2	1.6	2.1	2.4	3.1	3.6	4.4	5.9	7.3	8.9	12	14
	Long radius 180 deg	1.1	1.3	1.6	2.0	2.3	2.7	2.9	3.4	4.2	5	5.7	7	8
Valves	Globe	38.0	40.0	45.0	54.0	59.0	70.0	77.0	94.0	120.0	150	190	260	310
	Gate						2.6	2.7	2.8	2.9	3.1	3.2	3.2	3.2
	Angle	15.0	15.0	17.0	18.0	18.0	21.0	22.0	28.0	38.0	50	63	90	120

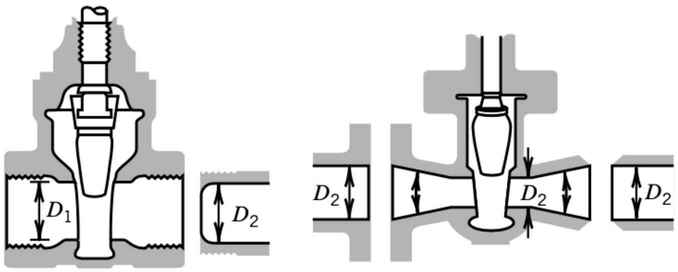
engineeringtoolbox.com

https://www.engineeringtoolbox.com/resistance-equivalent-length-d_192.html

More on Fittings

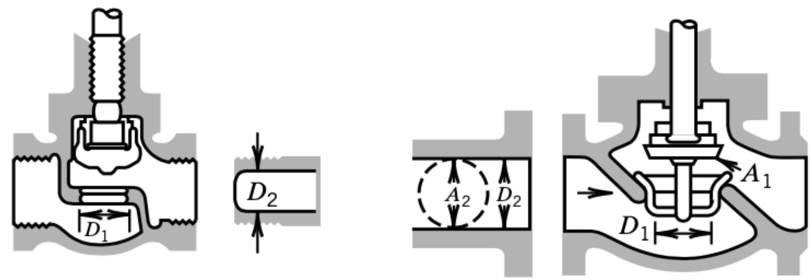
- Source 2: McQuiston et al. Heating Ventilating and Air Conditioning, 5th Edition

Gate valves
wedge disc, double disc or plug type



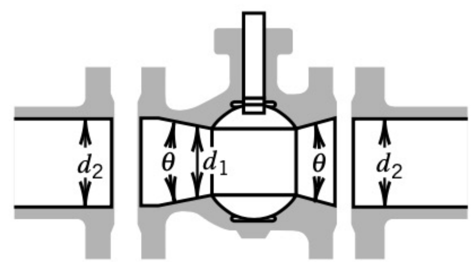
If: $\beta - 1, \theta = o, K_1 = 8\ ft$
$\beta < 1$ and $\theta \lesssim 45°$, K_2 = Formula 1
$\beta < 1$ and $\theta > 45° \lesssim 180°$, K_2 = Formula 2

Globe and angle valves



If: $\beta - 1, K_1 = 340 \times f_t$

Ball valves

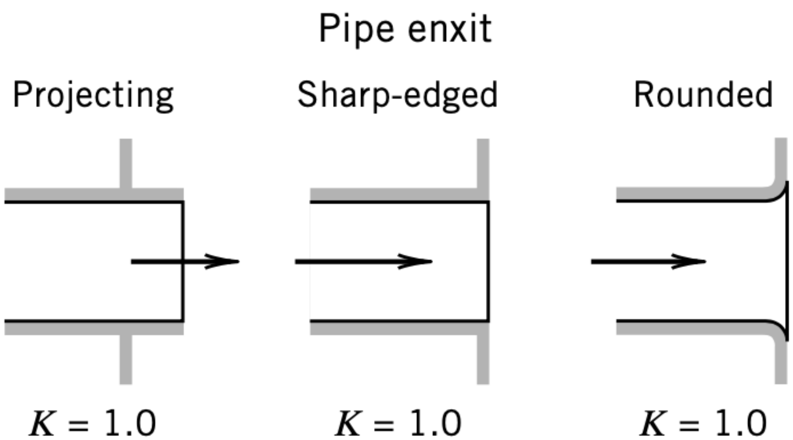


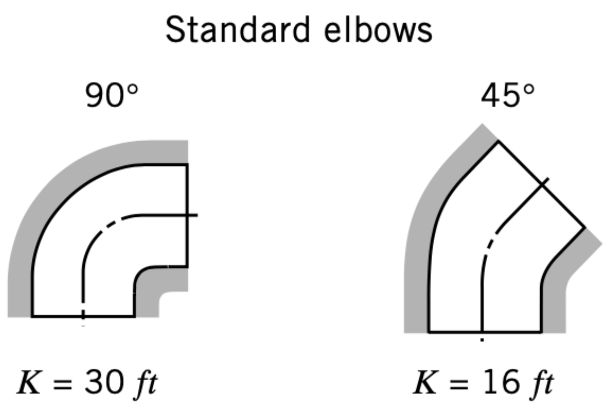
If: $\beta = 1, \theta = o, K_1 = 3 \times f_t$
$\beta < 1$ and $\theta \lesssim 45°$, K_2 = Formula 1
$\beta < 1$ and $\theta > 45° \lesssim 180°$, K_2 = Formula 2

Crane Company, Technical Paper No. 410

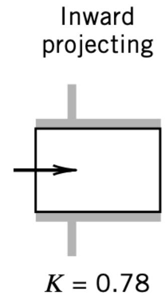
More on Fittings

- Source 2: McQuiston et al. Heating Ventilating and Air Conditioning, 5th Edition



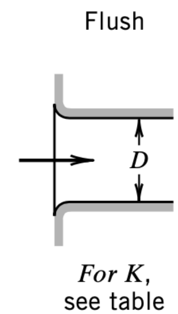


Pipe entrance

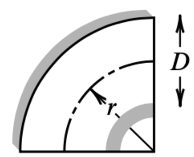


r/D	K
0.00*	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
0.15 & up	0.04

*Sharp-edged



90° Pipe bends and flanged or butt-welding 90° elbows



r/D	K	r/D	K
1	$20\ f_t$	10	$30\ f_t$
2	$12\ f_t$	12	$34\ f_t$
3	$12\ f_t$	14	$38\ f_t$
4	$14\ f_t$	16	$42\ f_t$
6	$17\ f_t$	18	$46\ f_t$
8	$24\ f_t$	20	$50\ f_t$

The resistance coefficient K_B for pipe bends other than 90° may be determined as follows:

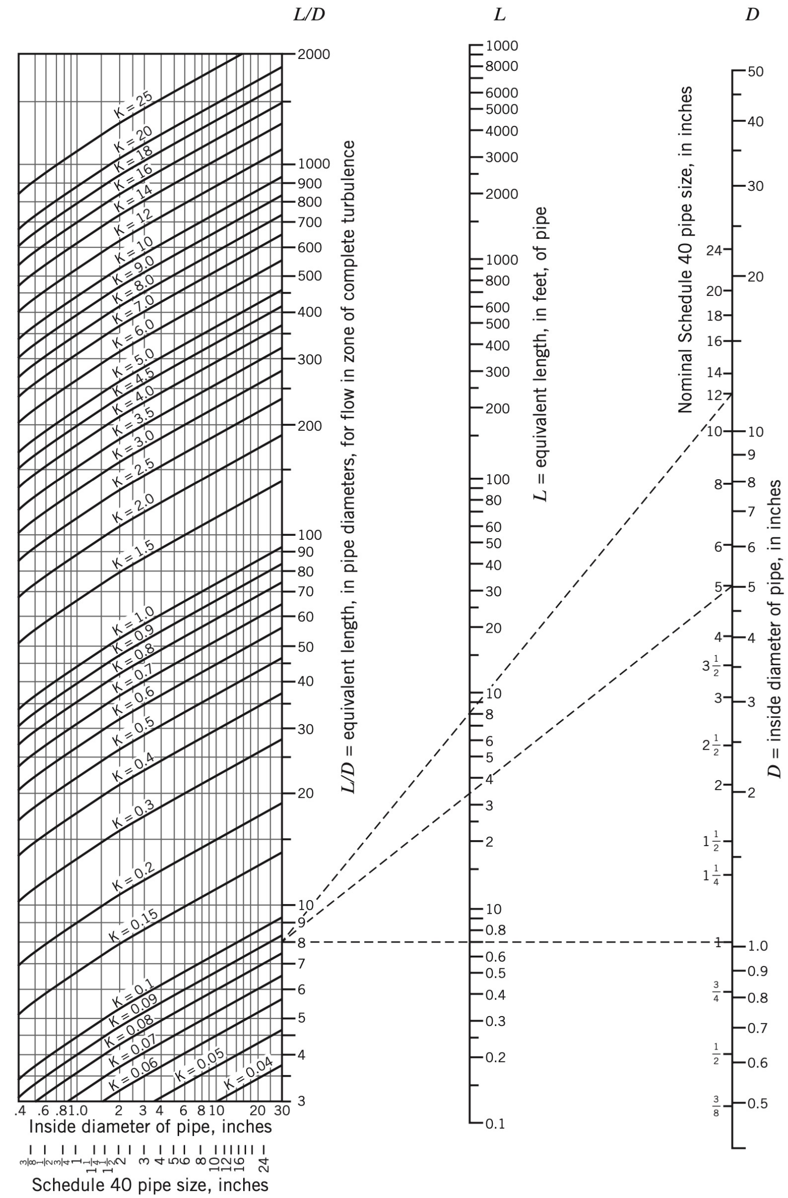
$$K_B = (n - 1)\,(0.25\,\pi\, f_T \tfrac{r}{D} + 0.5\, K) + K$$

n = number of 90° bends
K = resistance coefficient for one 90° bend (per table)

Crane Company, Technical Paper No. 410

More on Fittings

- Source 2: McQuiston et al. Heating Ventilating and Air Conditioning, 5th Edition



Crane Company, Technical Paper No. 410

More on Fittings

- Source 2: McQuiston et al. Heating Ventilating and Air Conditioning, 5th Edition

Table 10-2 Formulas, Definition of Terms, and Values of ft for Fig. 10-22

Formula 1: $$K_2 = \frac{K_1 + \left(\sin\frac{\theta}{2}\right)0.8(1-\beta^2) + 2.6(1-\beta^2)^2}{\beta^4}$$

Formula 2: $$K_2 = \frac{K_1 + 0.5\left(\sin\frac{\theta}{2}\right)(1-\beta^2) + (1-\beta^2)^2}{\beta^4}$$

$$\beta = \frac{D_1}{D_2}; \qquad \beta^2 = \left(\frac{D_1}{D_2}\right)^2 = \frac{A_1}{A_2};$$

D_1 = smaller diameter
A_1 = smaller area

Nominal Size, in.	Friction Factor f_t	Nominal Size, in.	Friction Factor f_t
$\frac{1}{2}$	0.027	4	0.017
$\frac{3}{4}$	0.025	5	0.016
1	0.023	6	0.015
$1\frac{1}{4}$	0.022	8–10	0.014
$1\frac{1}{2}$	0.021	12–16	0.013
2	0.019	18–24	0.012
$2\frac{1}{2}$, 3	0.018		

Crane Company, Technical Paper No. 410

More on Fittings

- Source 3: Reddy et al. Heating and Cooling of Buildings, 3rd Edition

	Nominal Pipe Size (in)										
	½	**¾**	**1**	**1 ¼**	**1 ½**	**2**	**2 ½**	**3**	**4**	**5**	**6**
45 elbow	0.8	0.9	1.3	1.7	2.2	2.8	3.3	4.0	5.5	6.6	8.0
90 elbow (Standard)	1.6	2.0	2.6	3.3	4.3	5.5	6.5	8.0	11.0	13.0	16.0
90 elbow (long)	1.0	1.4	1.7	2.3	2.7	3.5	4.2	5.2	7.0	8.4	10.4
Gate valve open	0.7	0.9	1.0	1.5	1.8	2.3	2.8	3.2	4.5	6.0	7.0
Globe valve open	17	22	27	36	43	55	67	82	110	134	164
Angle valve	7	9	12	15	18	24	-	-	-	-	-
Tee-side flow	3	4	5	7	9	12	14	17	22	28	34
Swing check valve	6	8	10	14	16	20	25	30	40	50	60
Tee-straight throughflow	1.6	2.0	2.6	3.3	4.3	5.5	6.5	8.0	11.0	13.0	16.0
Radiator angle valve	3	6	8	10	13	-	-	-	-	-	-
Diverting tee	-	20	14	11	12	14	14	14	-	-	-
Flow check valve	-	27	42	60	63	83	104	125	126		

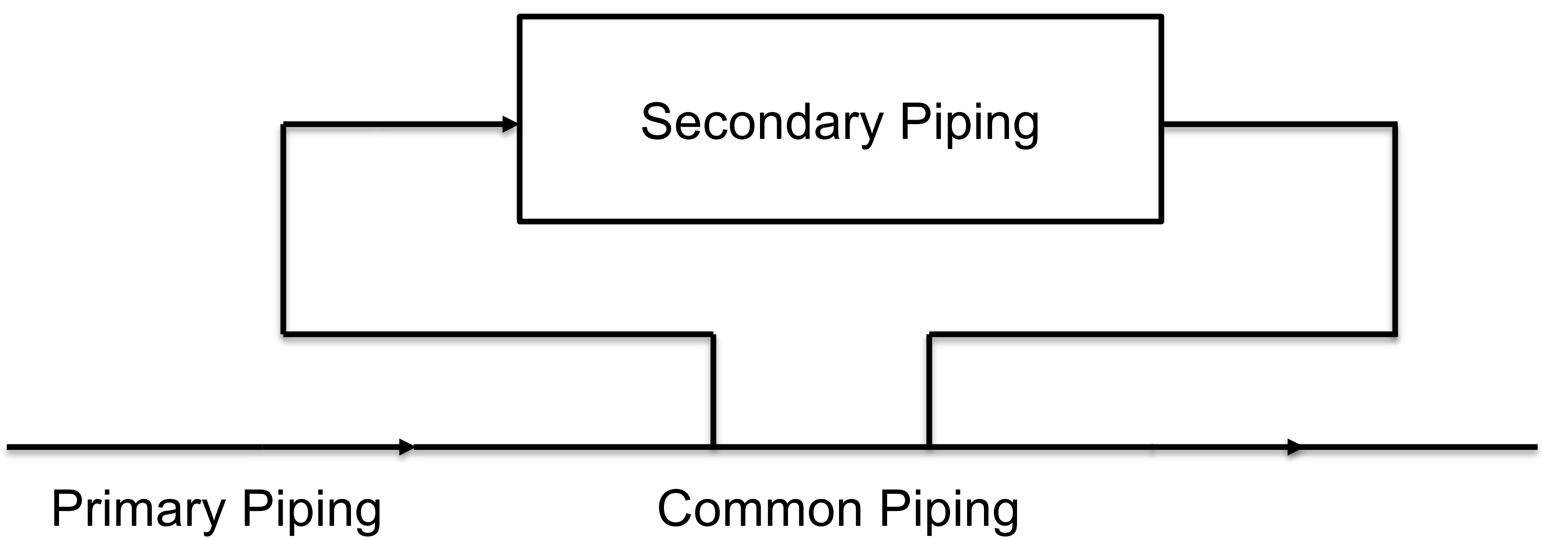
PRIMARY – SECONDARY PUMPING

Primary Secondary Pumping

- Was developed by Bell & Gossett in 1954 as a method to increase system temperature drops, decrease total pump power requirements and increase system controllability
- Systems utilizing low or medium temperatures were allowed due to Primary – Secondary pumping
- Most modern systems utilize some variation of Primary - Secondary pumps

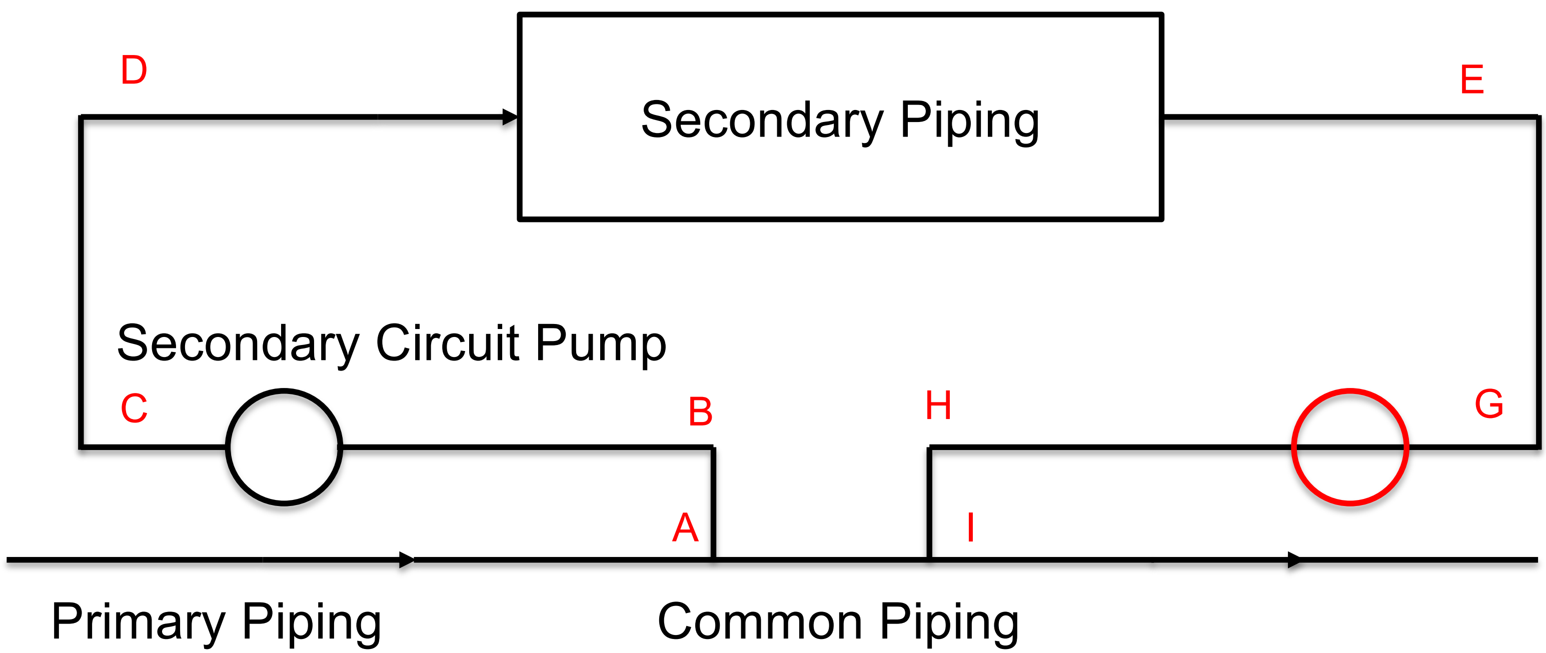
Primary Secondary Pumping

- Common Piping:
  - Interconnects the primary to the secondary circuit
  - Should have minimal to no pressure drop
- Hydraulically disconnects the two piping loops
- Flow in one loop will not cause flow in the other loop



Primary Secondary Pumping

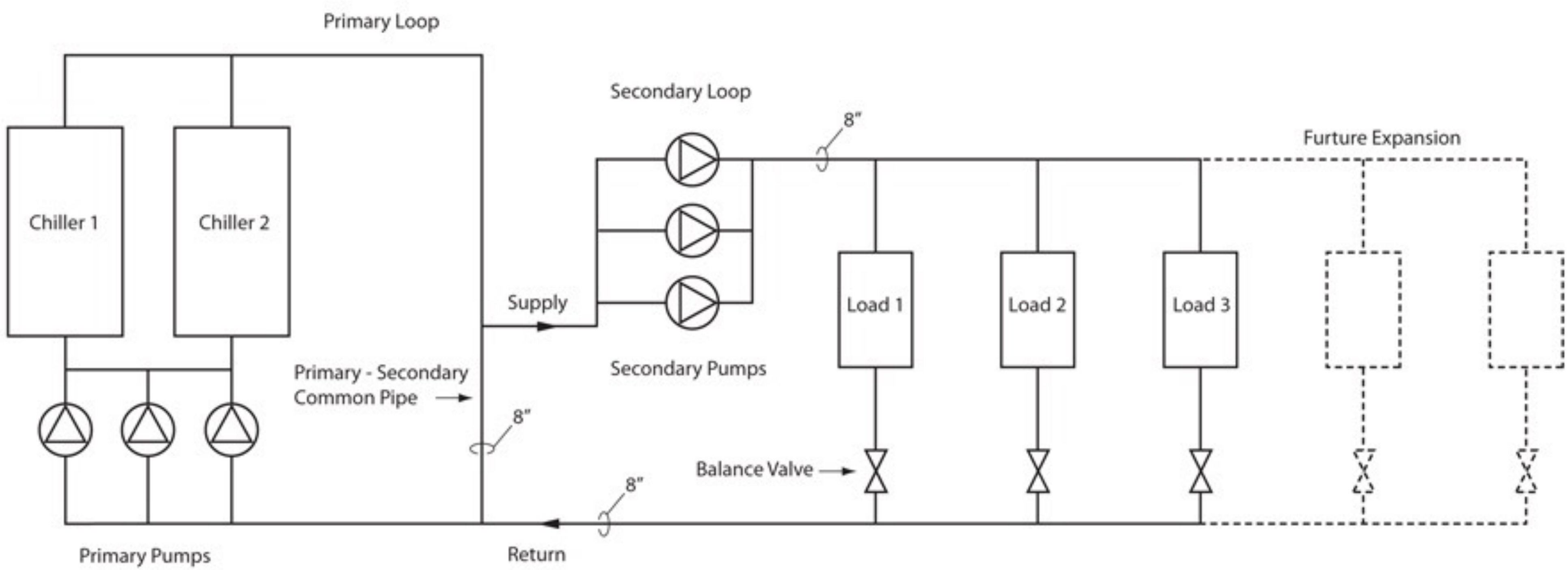
- Secondary pipe pump sized for pressure drops A-B, B-C, C-D, D-E, E-G, G-H, H-I
- I-A should have no pressure drop



Why do not we put the secondary pump at the end of the secondary circuit?

Primary Secondary Pumping

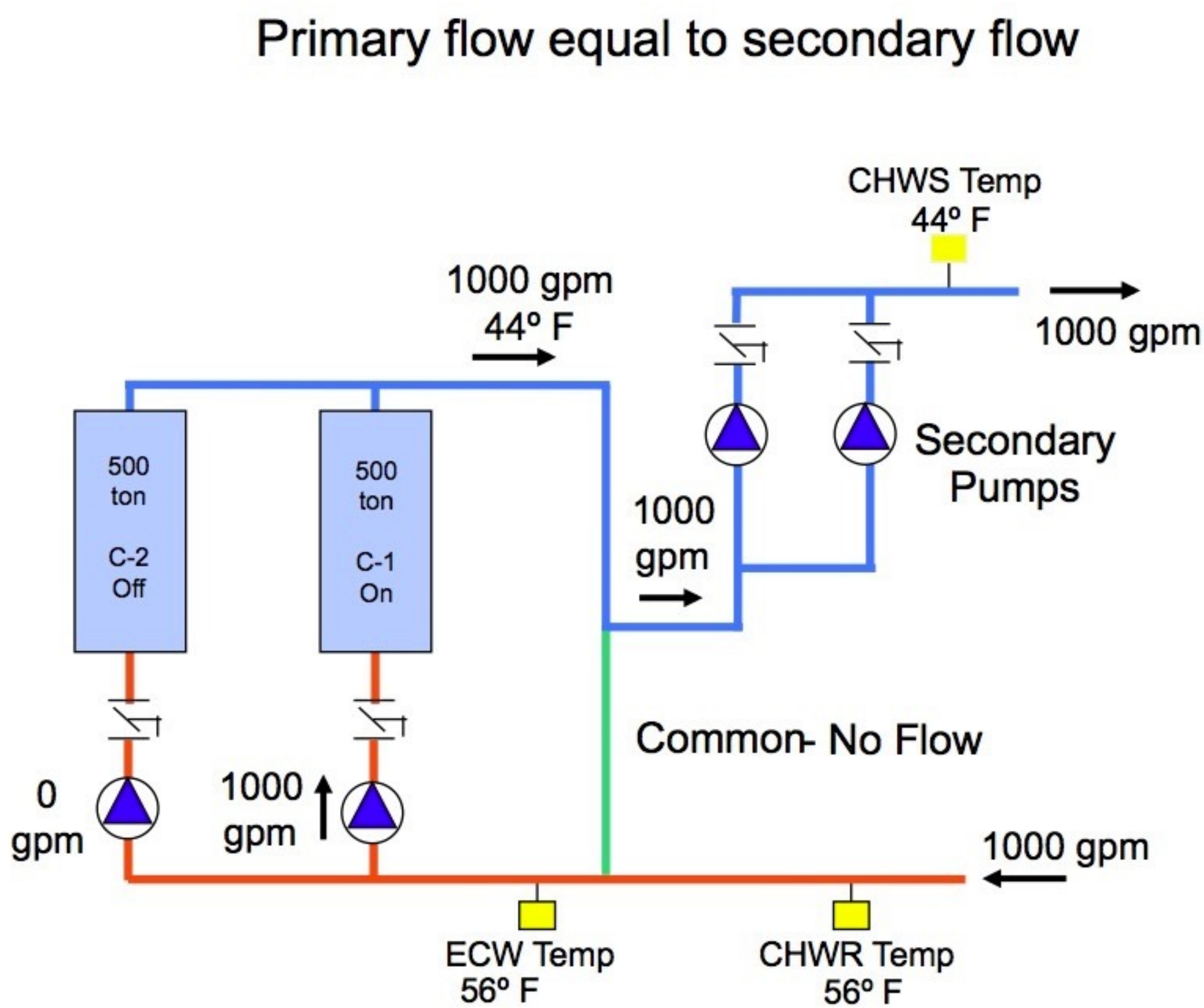
- In hydronic systems, we use this strategy:



https://www.advantageengineering.com/fyi/286/advantageFYI286.php

Primary Secondary Pumping

- In hydronic systems, we use this strategy:

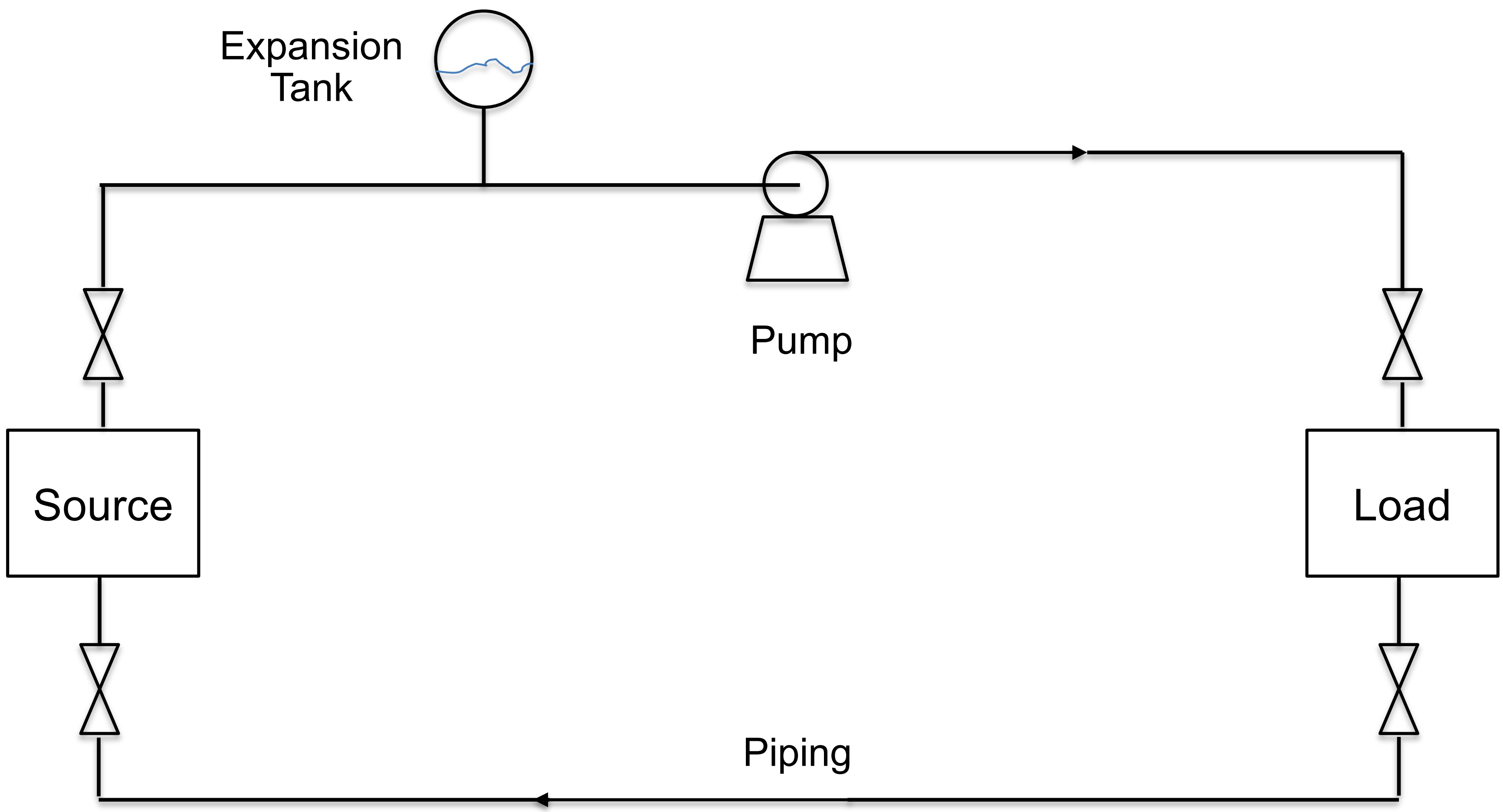


http://jmpcoblog.com/hvac-blog/understanding-primary-secondary-pumping-part-4-what-happens-when

PUMPS

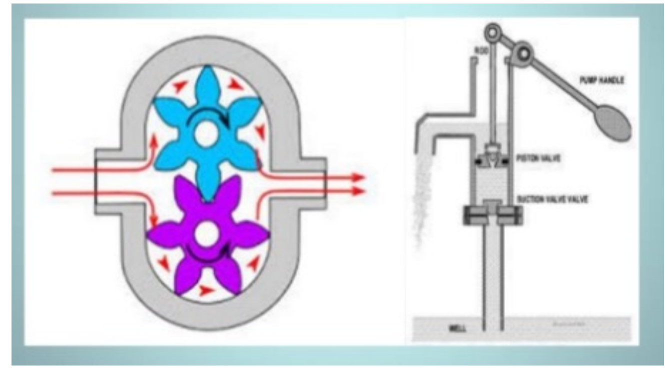
Intro to Pumps

- Pumps provide differential pressure by converting electrical energy to move water



Intro to Pumps

- Positive displacement pumps
  - ❑ Rotary-type pumps
  - ❑ Reciprocating-type pump



- Rotodynamic pumps
  - ❑ Centrifugal pump
    - Radial flow pump
    - Axial flow pump
    - Mixed flow pump

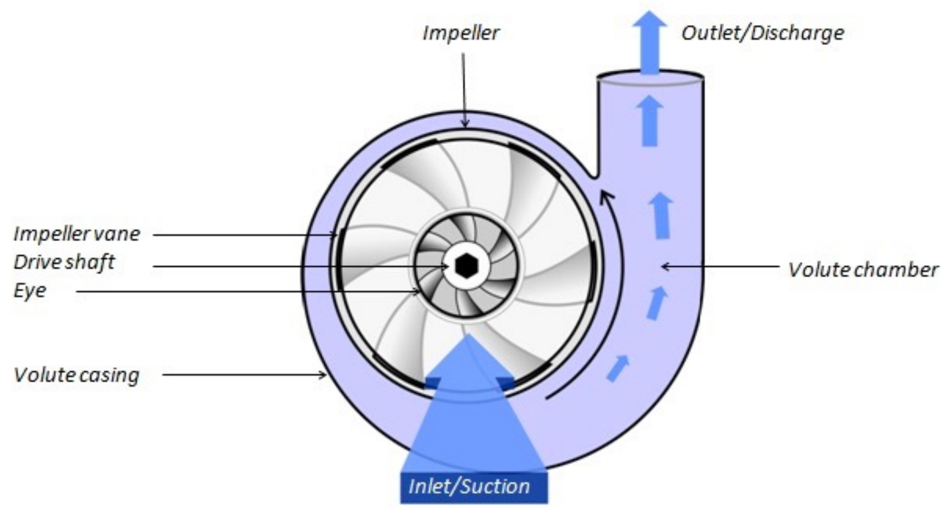
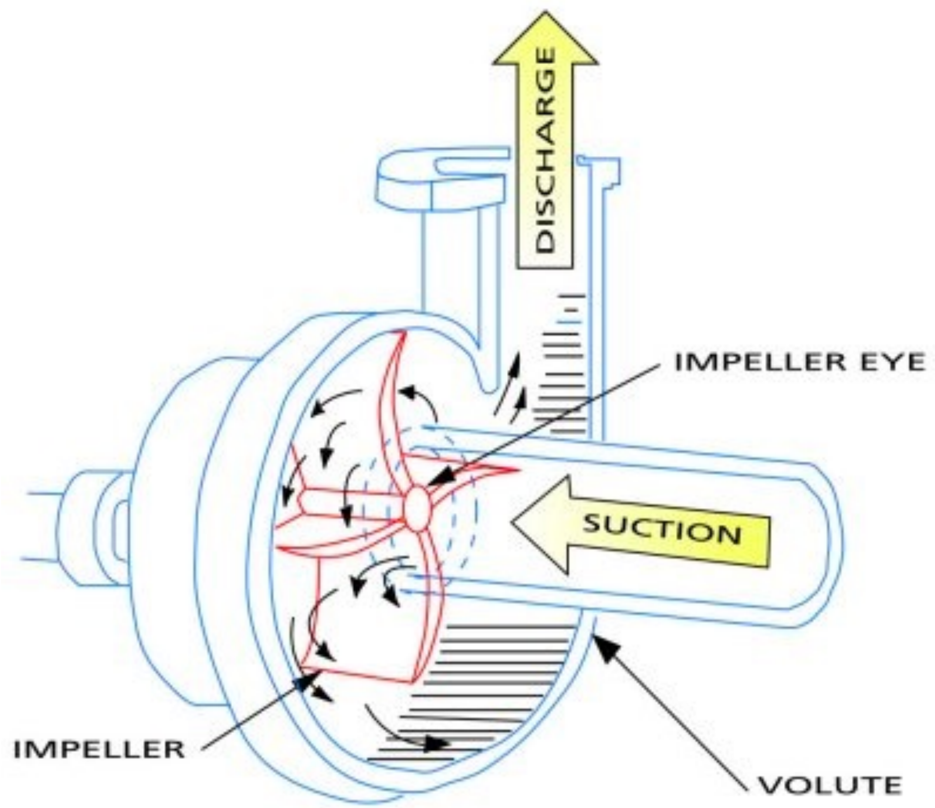
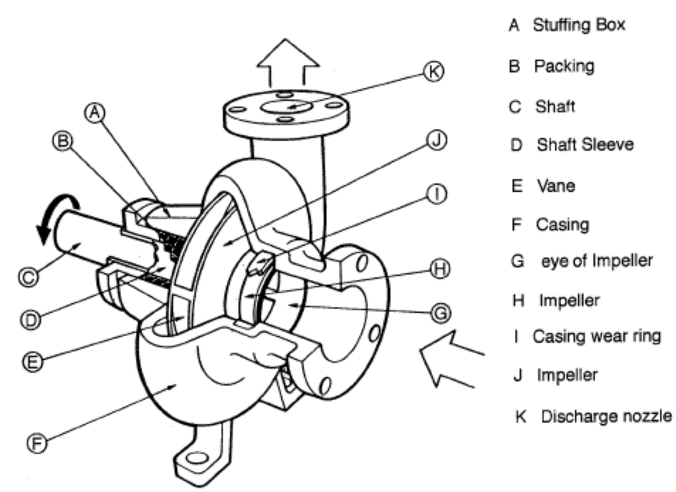


Figure 2. Volute case design

https://www.slideshare.net/MohammudHanifDewan/positive-displacement-pumps-46499848 & https://www.michael-smith-engineers.co.uk/resources/useful-info/centrifugal-pumps

Centrifugal Pumps





https://www.pumpfundamentals.com/tutorial2.htm

Centrifugal Pumps

- Most common use in HVAC industry
  - ❑ Chilled water
  - ❑ Cooling tower

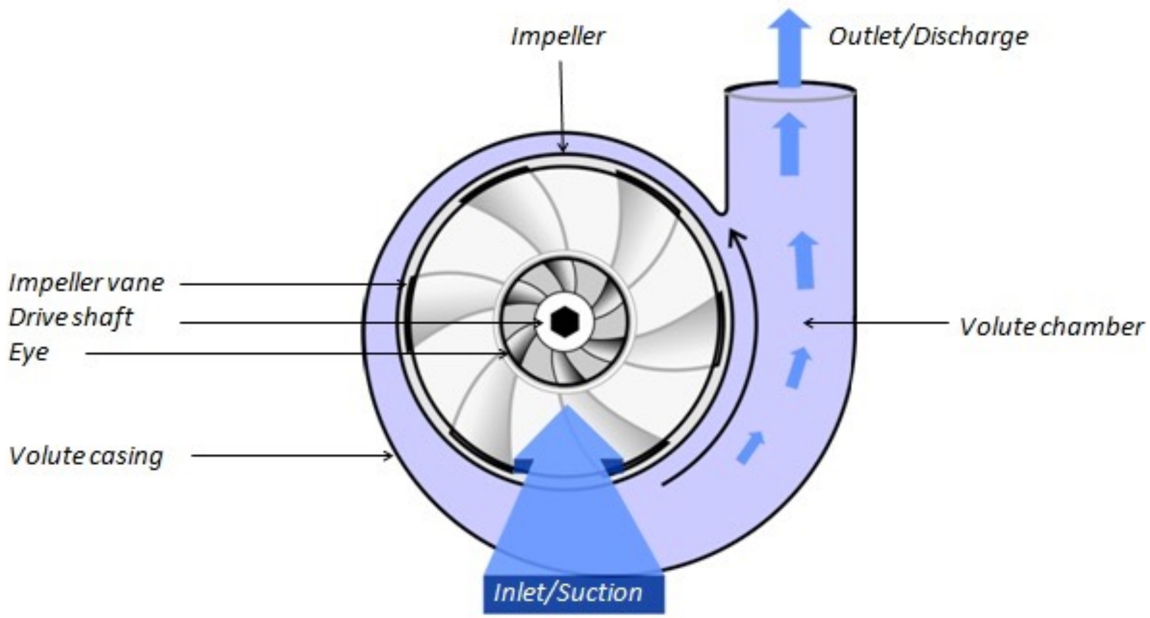


Figure 2. Volute case design

- Basic Principle
  - ❑ Water enters impeller at low velocity & pressure
  - ❑ Water thrown outward by centrifugal force
  - ❑ Water leaves at high velocity & pressure

https://www.michael-smith-engineers.co.uk/resources/useful-info/centrifugal-pumps

Centrifugal Pumps

- Impeller types

Figure 1. Impeller Types (l to r): Open, Semi-Enclosed (or Semi-Open), Enclosed.

https://www.michael-smith-engineers.co.uk/resources/useful-info/centrifugal-pumps

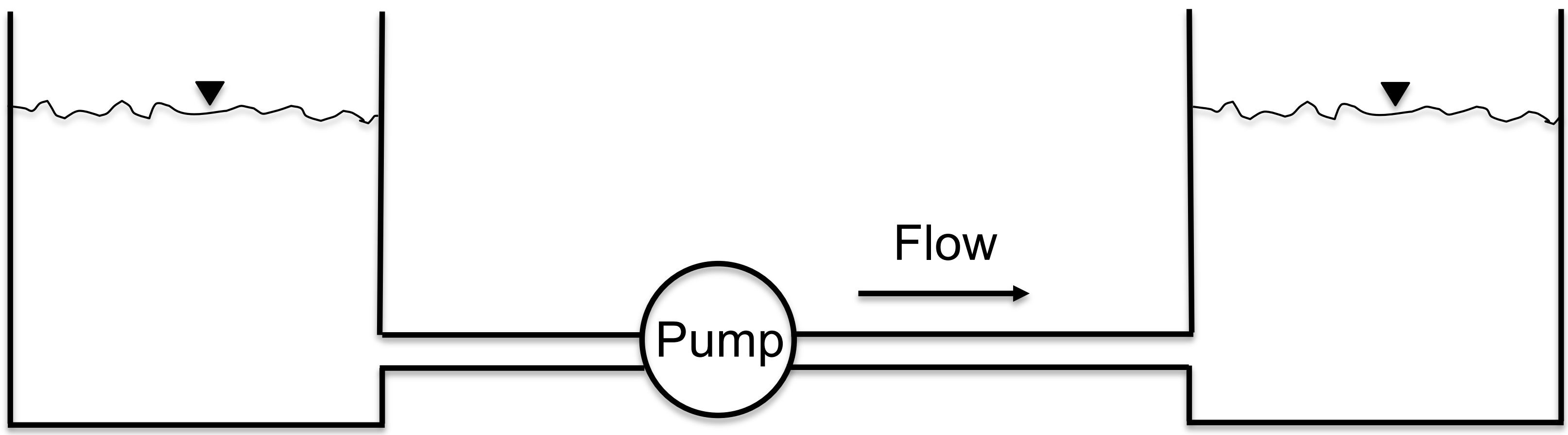
Centrifugal Pumps

- It needs to be base mounted:

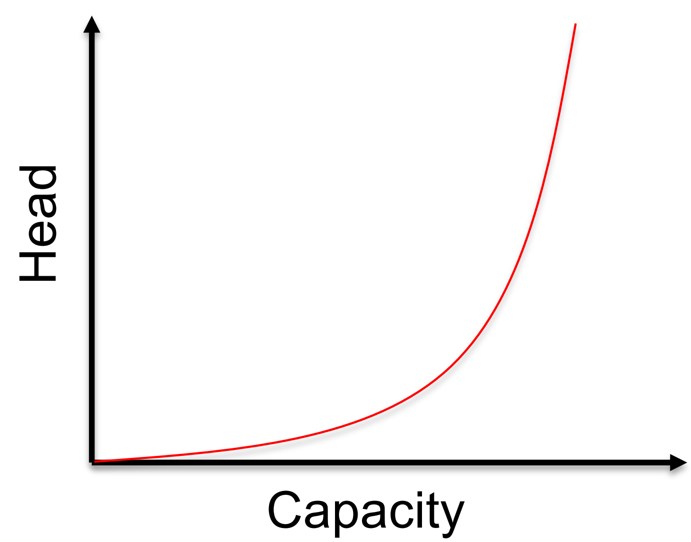
SYSTEM CURVE

System Curve

- Assume there is only friction and no change in elevation (no static lift)

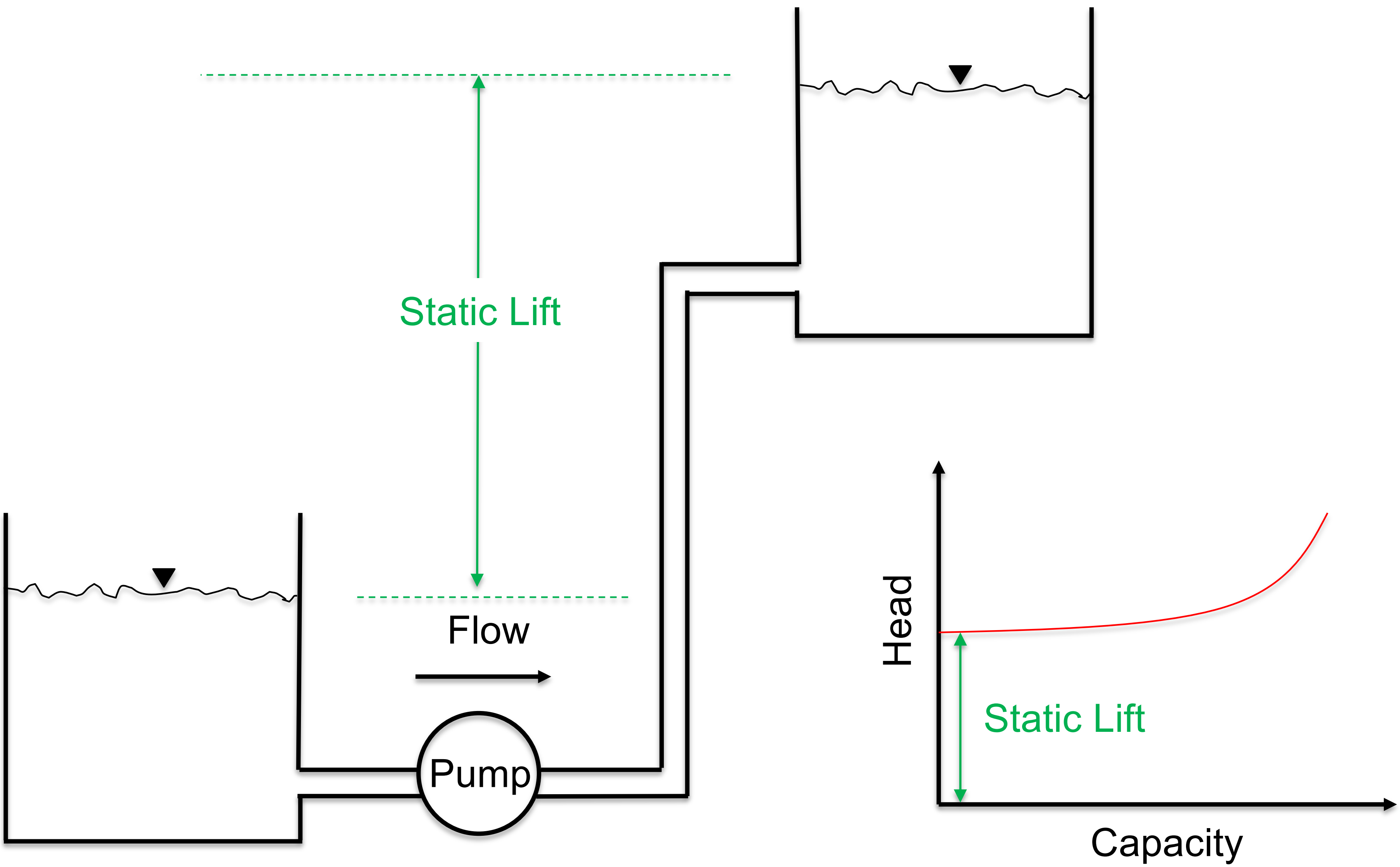


- How is the system curve?



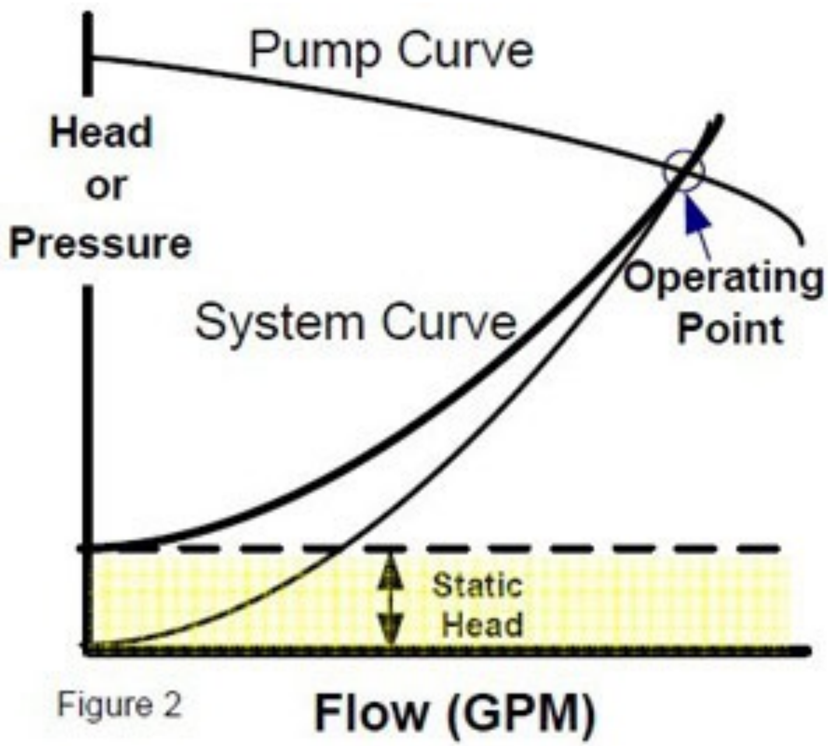
System Curve

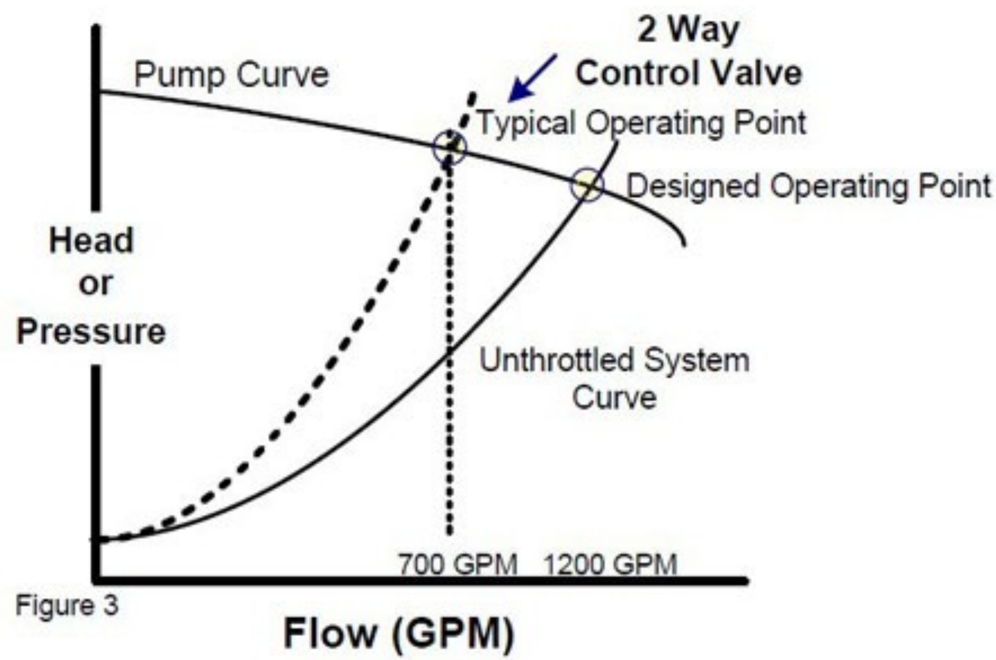
- How is the system curve for this one?



System Curve

- System curve can change over time





http://www.frequencyinverters.org/frequency-converter-for-pumps-278604.html

System Curve

- System curve can change over time

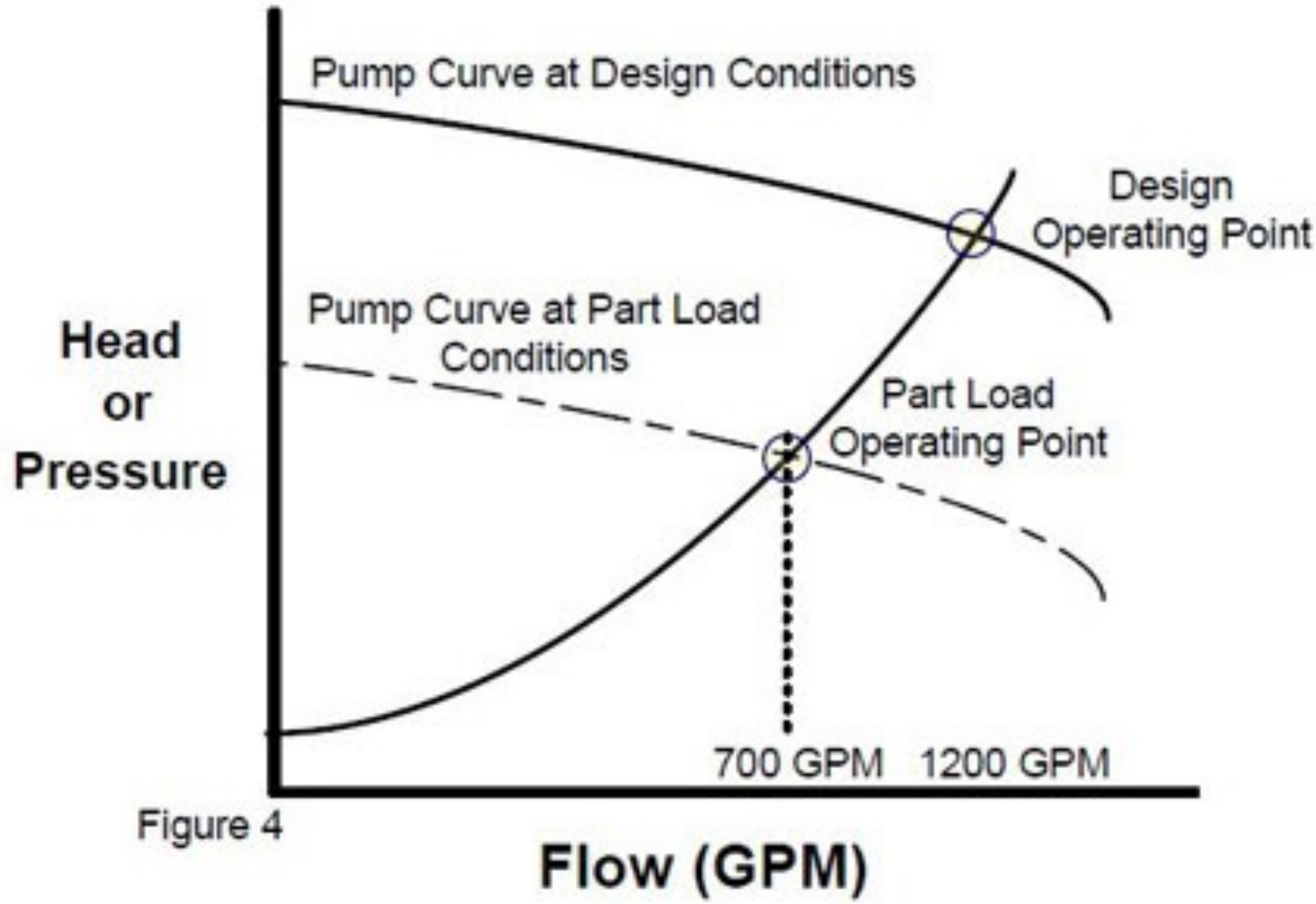


Figure 4

http://www.frequencyinverters.org/frequency-converter-for-pumps-278604.html

PROJECT

Project