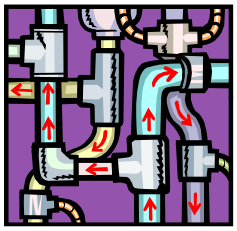
Chapter 11

Pipes in Series



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What are Pipes In Series?

- Multiple pipe sizes connected to each other
- No branches off the pipes

Continuity Eq. For Pipes in Series

- Volumetric flow (Incompressible fluids) must be same in all pipes
- Velocity changes from pipe to pipe via Volumetric rate / Cross sectional area

Frictional Losses Through Round Pipes in Series

- Eq (1) Losses are additive:

$$h_{total} = \sum \left[\left(f_i \frac{L_i}{D_i} + K_i \right) \left(\frac{8 \dot{V}^2}{g \pi^2 D_i^4} \right) \right]$$

- Note for special case of laminar, the pipe's losses (not minor losses) are $\propto \frac{L_i \dot{V}}{D_i^4}$

Friction factors for Pipes in Series

- $f_{i's}$ are not identical, but similar
- For example, max $D_1/D_2 = 4$, so velocity ratio is $4^{2,}$ & f might change from 0.021 to 0.013
  - While Re goes from 40,000 to 640,000

How to Keep Frictional Losses Down

- Use big enough pipe, because its losses are proportional to 1/ D^4 for laminar and 1 / D^5 for turbulent
- Regulate flow rates with ball valve (K = 0.05) or globe valve (K = 10)
- If you only need only off/on, use gate (K = 0.2)

How Big Is Appropriate

- An economic balance between capital cost of pipe and pumping costs over life of usage
- Design for 10 to 30 ft/s is typical
- Many companies design for even lower velocities (like 5 to 15 ft/ s), particularly to allow for future expansion, etc.

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Types of problems for Single Pipes & Pipes in Series

- Class 1 – Known flow rate. We calculate the losses.
  - All our problems to date have been with known flow rates
- Class 2- Known Losses. We calculate the flow rate.
  - A trial and error solution, because of the friction factors

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Doing Loss Calculations for Pipes in Series

- Pipes in series more difficult to calculate than a single pipe
- Why? Because we typically know only the pressure drop, elevation changes, etc for the entire series, not the individual pipes

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Neat trick to Solve Class 1 problems for Pipes in Series.

- We estimate the equiv. length of size 1 pipe whose losses would match that of the size 2 pipe
- $$h_L = \frac{8 f_2 L_2}{D_2^5}\frac{\dot{V}^2}{\pi^2 g} = \frac{8 f_1 L_{equiv}}{D_1^5}\frac{\dot{V}^2}{\pi^2 g}$$

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Trick Continued

- Solving for L_{equiv}

$$L_{equiv} = L_2\left(\frac{D_1}{D_2}\right)^5 \frac{f_2}{f_1}$$

- Where we assume ratio of f's is one

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Sample Problem

- If pipe 1 is 30 ft long, 3 in ID, and pipe 2 is 1 ft long, 1 ½ in ID, L_{equiv} is

$$L_{equiv} = 1\left(\frac{3}{1.5}\right)^5 = 32 ft!$$

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Bernoulli Equation To Determine Known Losses for Class 2 Problem

Eq (2) - If we write Bernoulli from upstream (u) to down steam (d) of all the pipes, and then rearrange to solve for the total losses:

$$h_L = \left(\frac{P_u - P_d}{\lambda}\right) + (z_u - z_d) + \frac{v_{aveu}^2 - v_{aveD}^2}{2g} + h_A - h_R$$

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Hand Trial & Error Solution for Class 2 Problem

1. Use Eq (2) to calculate your target losses
2. Also express your losses in terms of Eq(1), and do as much of the math as possible, so estimated losses are in terms of friction factors and v_1 (use continuity to get the other velocities)
3. Guess a v_1, calculate the Reynolds, get friction factors, and put into Eq(1) to get the estimated losses with your guess

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More on Trial & Error Solution

4. If don't match known losses, guess another v, basing your next guess on the equation :

$$\frac{\text{Estimated Losses with v}}{\text{Known Losses}} = \left(\frac{\text{guessed v}}{\text{next guess for v}}\right)^2$$

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Sample Trial & Error Problem(single Pipe)

1. Operator accidentally leaves open globe valve, letting 60 F water drain out side of a tank (h = 30 ft) through 340 ft of 6 in ID cast iron pipe. (roughness = 8.5×10^{-4} ft) . Neglect all the minor losses.
2. What's initial gpm flow rate?

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Excel Spreadsheet for Finding Flow Rate for Known Losses

- Still trial and error, but we use Goal Seek under Tools menu to do it!
- Have spreadsheet on web site that focuses on the pipe losses, but can also include the minor losses
- This same spreadsheet does single & two pipe in series, class 1 and class 2 problems.

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Demo of Spreadsheet

- Repeat with spreadsheet the previous example we did by hand trial and error
- Demo spread sheet for single garden hose (like problem on midterm)
- Demo spreadsheet for two different size hoses in series.
- Point how to include the minor losses.

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Homework for next Time

- See next slide

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Homework Continued

- We have a 135 ft run of Schedule 40 steel pipe. All the pipe is 2 inch, except for two sections, one 2 ft long and the other 4 ft long, that are 1 inch .
- For frictional losses, what is the ft equivalent length of this run as all 2 inch pipe?

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