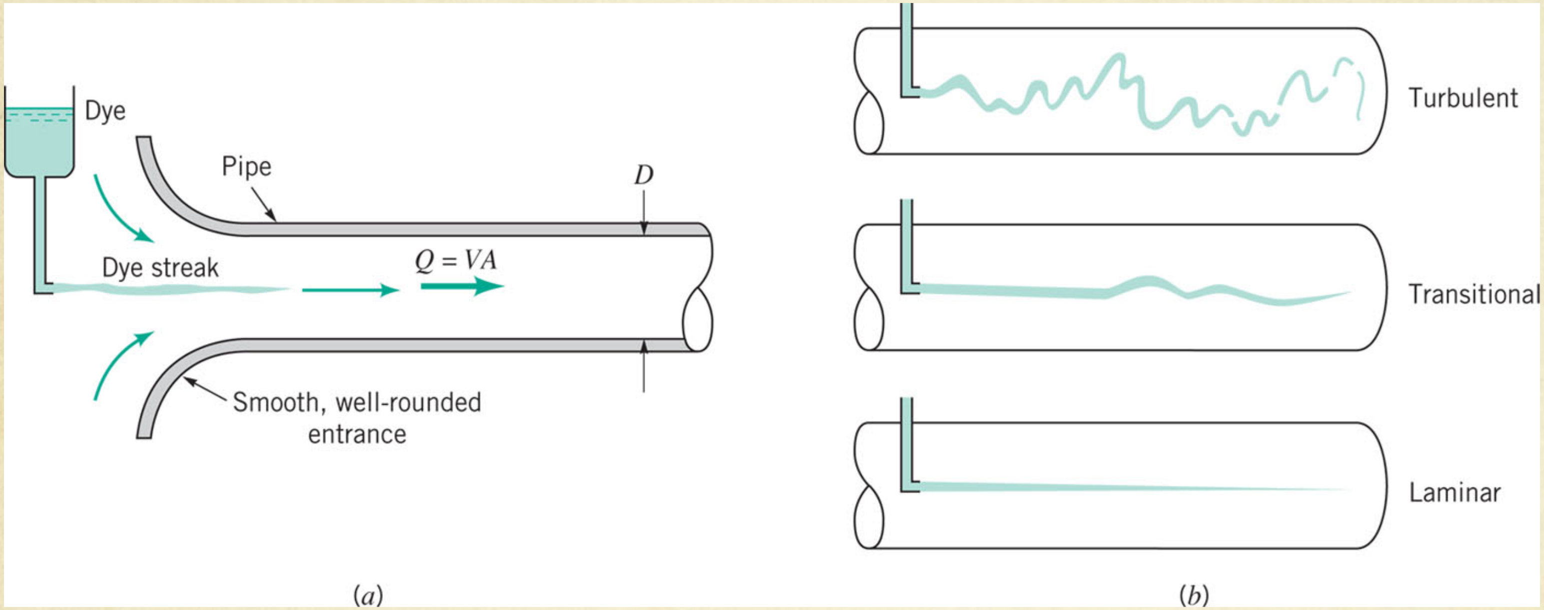
Chapter 8 – Pipe Flow

CE30460 - Fluid Mechanics
Diogo Bolster

Laminar or Turbulent Flow



Re>4000

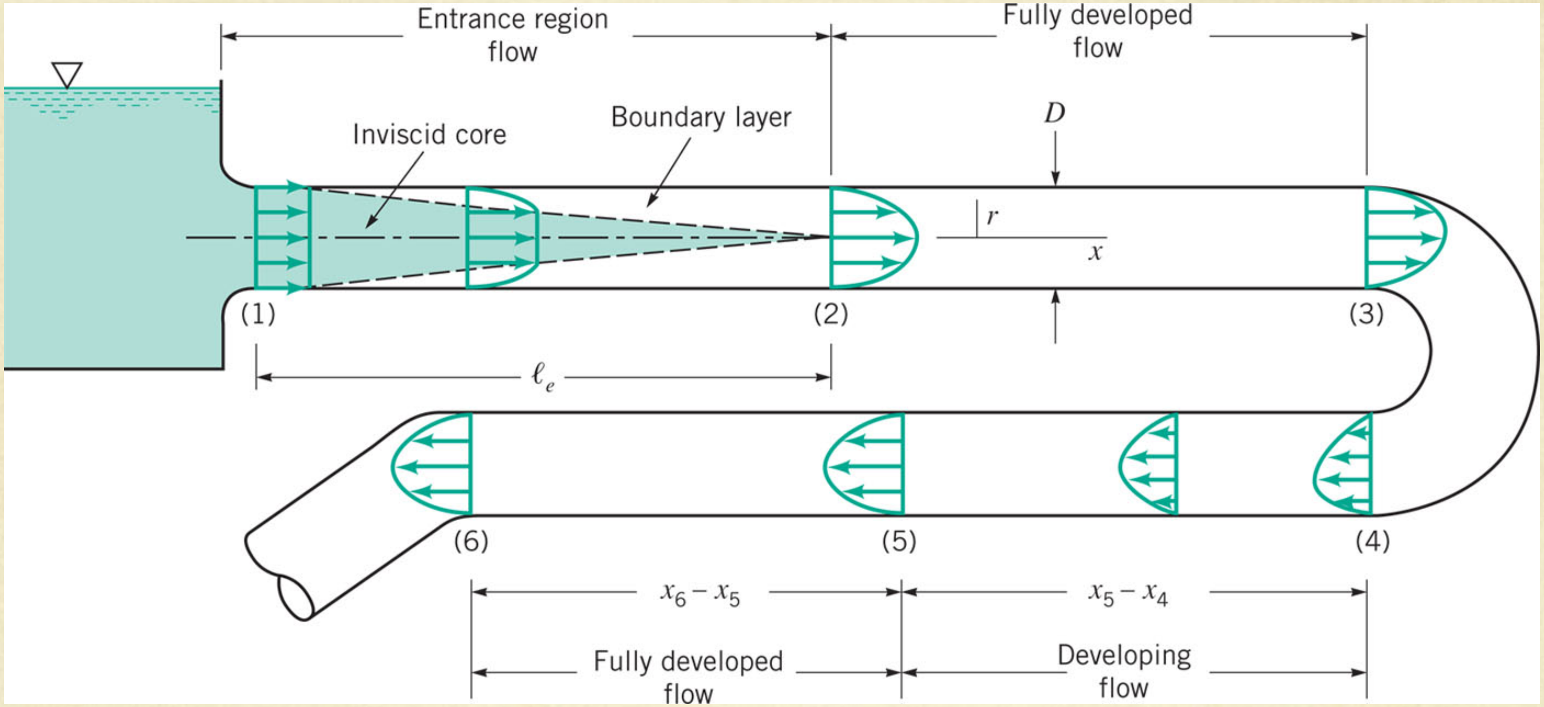
Re<1000

Re=UDρ/μ

Laminar Flow http://www.youtube.com/watch?v=KqqtOb30jWs&NR=1

Turbulent Flow http://www.youtube.com/watch?v=NplrDarMDF8

Fully Developed Flow



Entrance length:

$$\frac{\ell_e}{D} = 0.06 \text{ Re for laminar flow}$$

$$\frac{\ell_e}{D} = 4.4 \,(\text{Re})^{1/6} \text{ for turbulent flow}$$

Fully Developed Laminar Flow

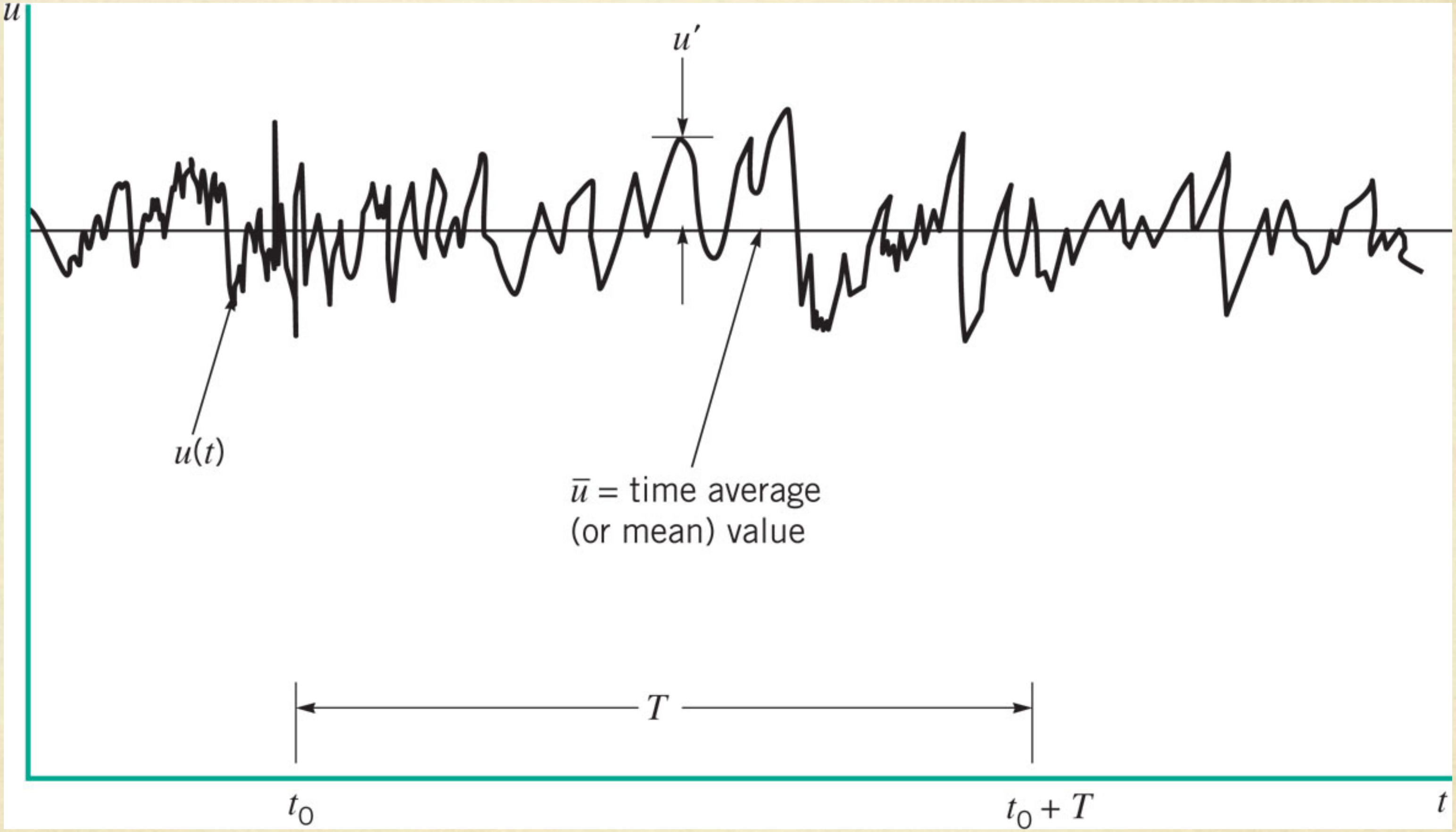
- We've done this one already in chapter 6

$$u(r) = \left(\frac{\Delta p D^2}{16\mu\ell}\right)\left[1 - \left(\frac{2r}{D}\right)^2\right] = V_c\left[1 - \left(\frac{2r}{D}\right)^2\right]$$

$$Q = \frac{\pi D^4 \, \Delta p}{128\mu\ell}$$

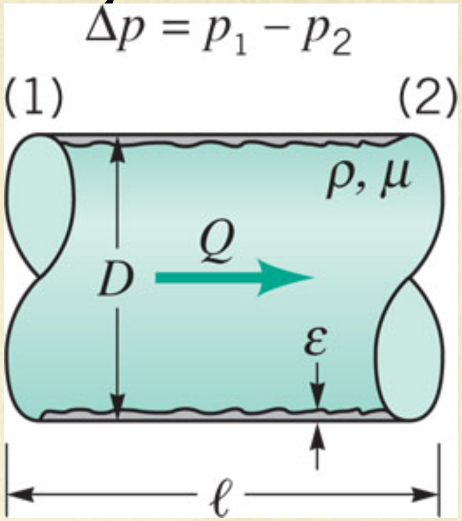
$$V = \frac{\pi R^2 V_c}{2\pi R^2} = \frac{V_c}{2} = \frac{\Delta p D^2}{32\mu\ell}$$

What about Turbulent Flow



Typically: $\frac{\bar{u}}{V_c} = \left(1 - \frac{r}{R}\right)^{1/n}$ n is between 6 and 10

Dimensional Analysis



- Pressure Drop depends on
  - Mean velocity V
  - Diameter D
  - Pipe length l
  - Wall Roughness ε
  - Viscosity μ
  - Density ρ

$$\Delta p = F(V, D, \ell, \varepsilon, \mu, \rho)$$

- By dimensional Analysis

$$\frac{\Delta p}{\frac{1}{2}\rho V^2} = \tilde{\phi}\left(\frac{\rho V D}{\mu}, \frac{\ell}{D}, \frac{\varepsilon}{D}\right)$$

- Pressure drop must increase linearly with length of tube

$$\frac{\Delta p}{\frac{1}{2}\rho V^2} = \frac{l}{D} f\left(\mathrm{Re}, \frac{\varepsilon}{D}\right)$$

Friction factor – look up in table

- Recall from chapter 5

$$\frac{p_{\text{out}}}{\gamma} + \frac{V_{\text{out}}^2}{2g} + z_{\text{out}} = \frac{p_{\text{in}}}{\gamma} + \frac{V_{\text{in}}^2}{2g} + z_{\text{in}} + h_s - h_L$$

- Therefore we can say that (part of) the loss in a pipe is

$$h_{L,major} = \frac{l}{D}\frac{V^2}{2g} f\left(\mathrm{Re}, \frac{\varepsilon}{D}\right)$$

Moody Diagram (Friction Factor)

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

For laminar

$$f = \frac{64}{\mathrm{Re}}$$

For non-laminar flow approximately true that

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\mathrm{Re}}\right]$$

Roughness (Typical)

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

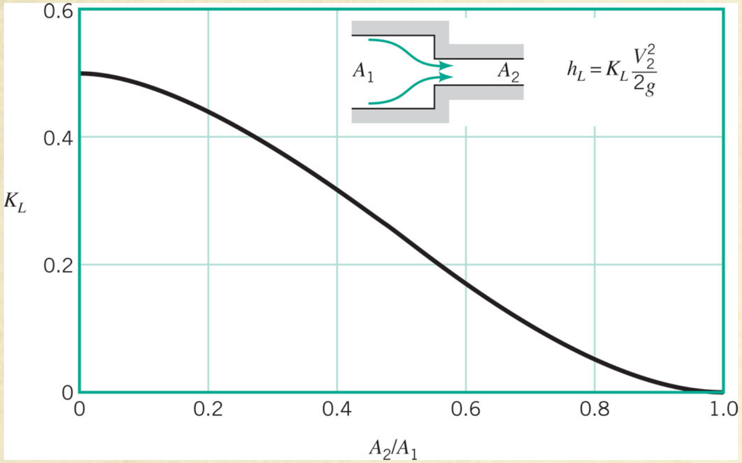
Minor Losses

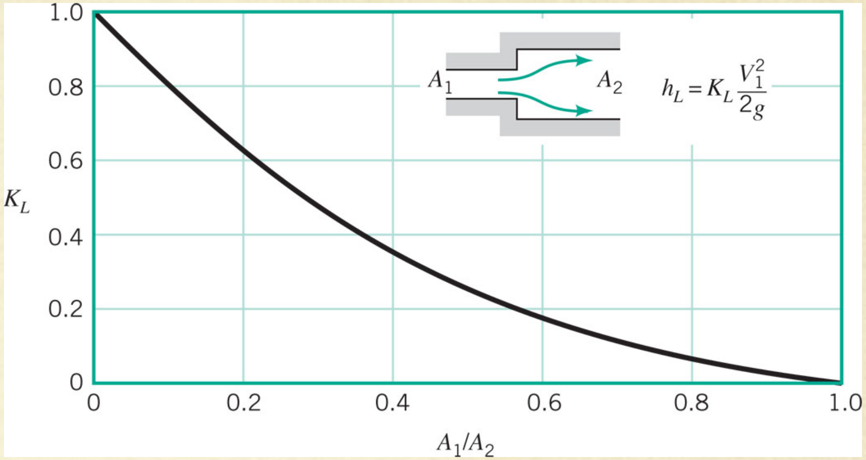
$$h_{L,\min} = K_L \frac{V^2}{2g}$$

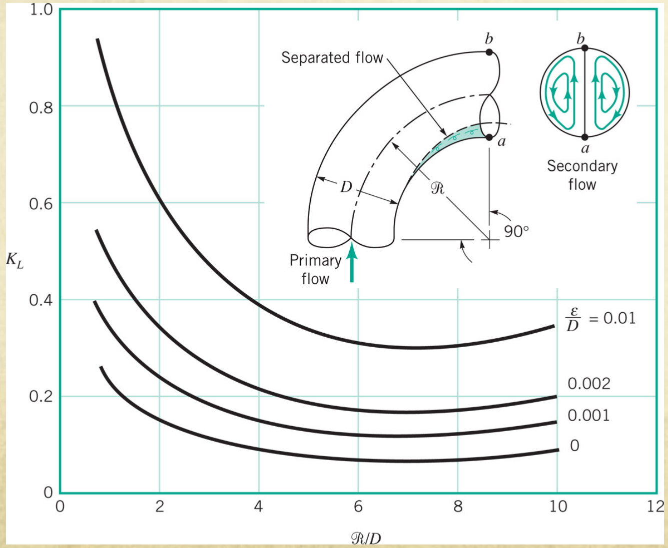
K_L depends on the flow (expansion, contraction, bend, etc)

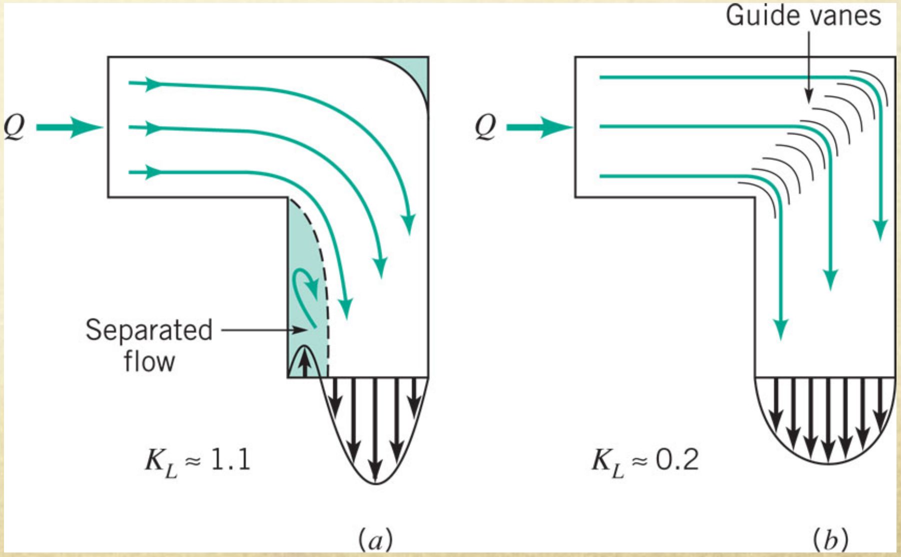
$$h_L = h_{L\,\text{major}} + h_{L\,\text{minor}}$$

Minor Losses





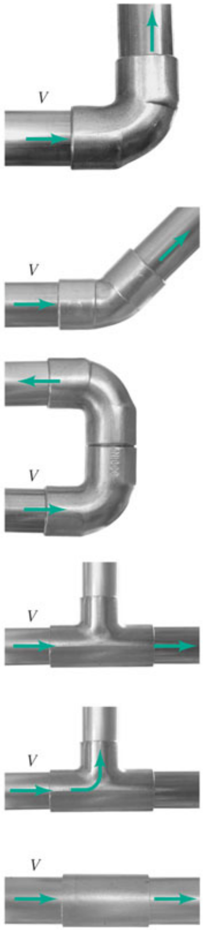




Minor Losses

Loss Coefficients for Pipe Components $h_L = K_L(V^2/2g)$. (Data from Refs. 4, 6, 11.)

Component	K_L
a. Elbows	
Regular 90°, flanged	0.3
Regular 90°, threaded	1.5
Long radius 90°, flanged	0.2
Long radius 90°, threaded	0.7
Long radius 45°, flanged	0.2
Regular 45°, threaded	0.4
b. 180° return bends	
180° return bend, flanged	0.2
180° return bend, threaded	1.5
c. Tees	
Line flow, flanged	0.2
Line flow, threaded	0.9
Branch flow, flanged	1.0
Branch flow, threaded	2.0
d. Union, threaded	0.08
***e. Valves**	
Globe, fully open	10
Angle, fully open	2
Gate, fully open	0.15
Gate, $\frac{1}{4}$ closed	0.26
Gate, $\frac{1}{2}$ closed	2.1
Gate, $\frac{3}{4}$ closed	17
Swing check, forward flow	2
Swing check, backward flow	∞
Ball valve, fully open	0.05
Ball valve, $\frac{1}{3}$ closed	5.5
Ball valve, $\frac{2}{3}$ closed	210



*See Fig. 8.18 for typical valve geometry.

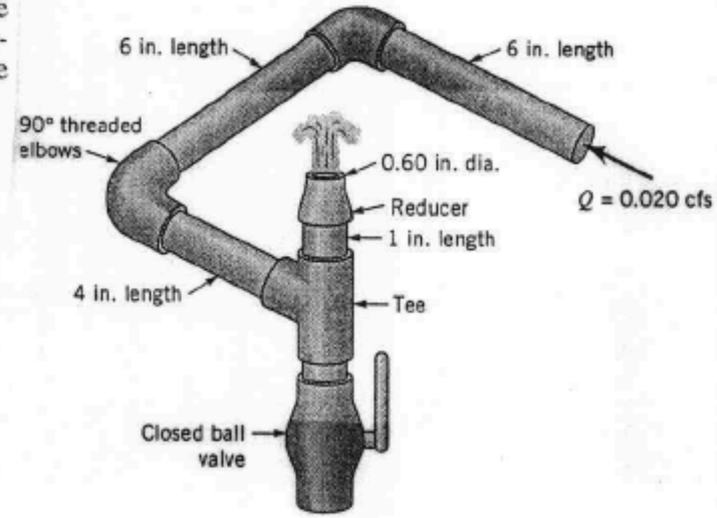
Sample Problem

8.35 Gasoline flows in a smooth pipe of 40-mm diameter at a rate of 0.001 m^3/s. If it were possible to prevent turbulence from occurring, what would be the ratio of the head loss for the actual turbulent flow compared to that if it were laminar flow?

Sample Problem

8.51

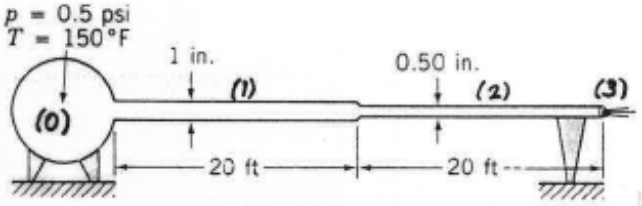
8.51 Water flows steadily through the 0.75-in.-diameter galvanized iron pipe system shown in **Video V8.13** and Fig. P8.51 at a rate of 0.020 cfs. Your boss suggests that friction losses in the straight pipe sections are negligible compared to losses in the threaded elbows and fittings of the system. Do you agree or disagree with your boss? Support your answer with appropriate calculations.



Sample Problem

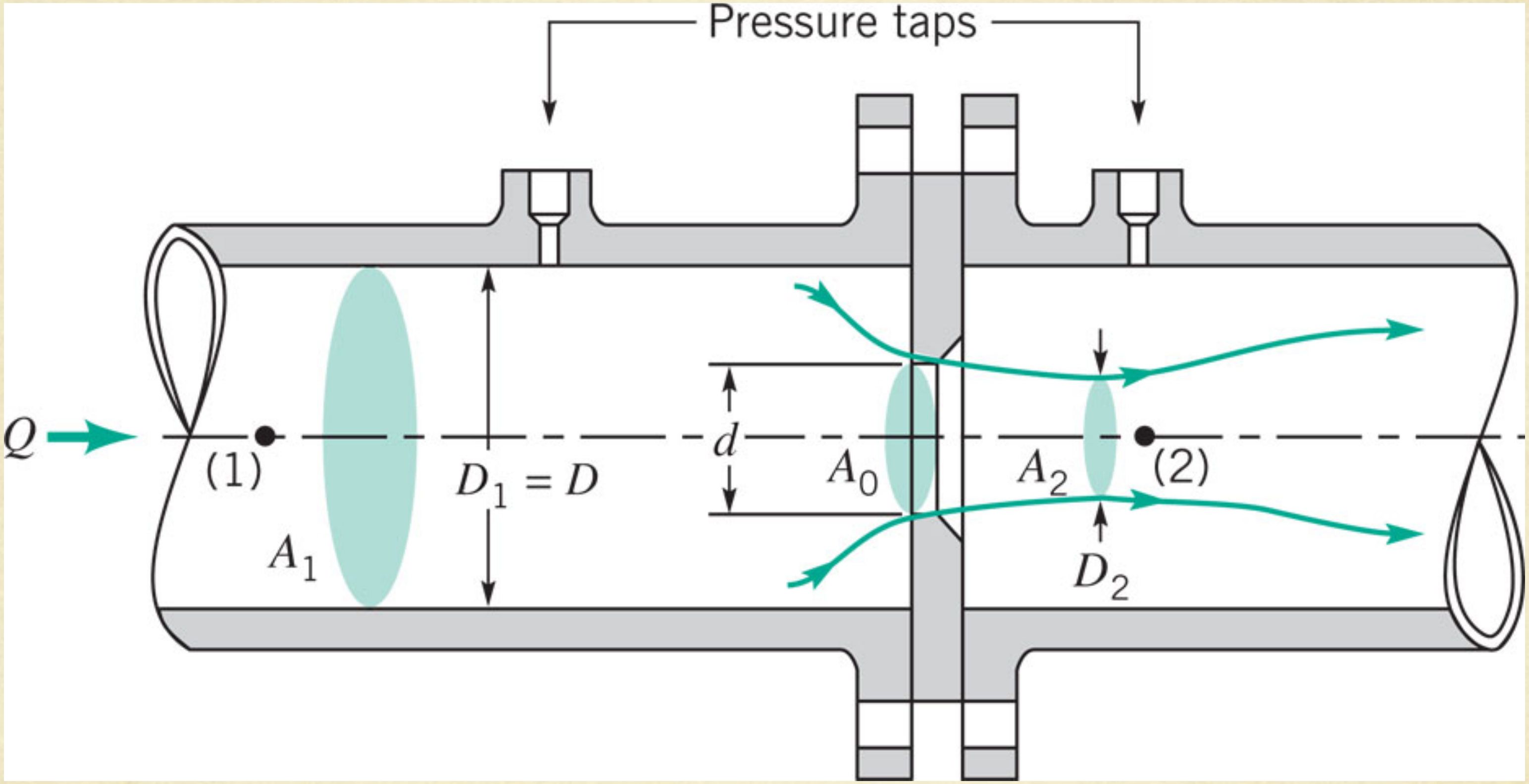
8.82

8.82 Air, assumed incompressible, flows through the two pipes shown in Fig. P8.82 Determine the flowrate if minor losses are neglected and the friction factor in each pipe is 0.020. Determine the flowrate if the 0.5-in.-diameter pipe were replaced by a 1-in.-diameter pipe. Comment on the assumption of incompressibility.



■ FIGURE P8.82

Pipe Flow Measurement

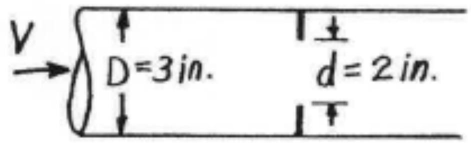


$$Q = CQ_{ideal} = CA_0\sqrt{\frac{2(p_1 - p_2)}{\rho(1 - \beta^4)}}$$

C is a constant that depends on geometry

Sample Problem

8.99 A 2-in.-diameter orifice plate is inserted in a 3-in.-diameter pipe. If the water flowrate through the pipe is 0.70 cfs, determine the pressure difference indicated by a manometer attached to the flow meter.



More Problems

Single Pipe – Determine Pressure Drop

8.59

8.59 The pressure at section (2) shown in Fig. P8.59 is not to fall below 60 psi when the flowrate from the tank varies from 0 to 1.0 cfs and the branch line is shut off. Determine the minimum height, h, of the water tank under the assumption that (a) minor losses are negligible, (b) minor losses are not negligible.

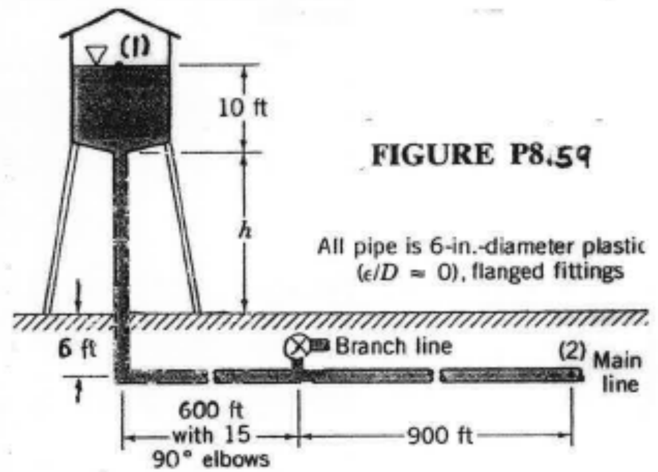
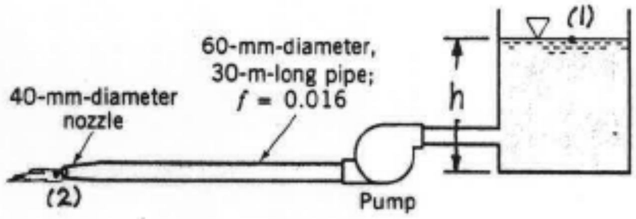


FIGURE P8.59

Single Pipe – Determine Flowrate

8.81

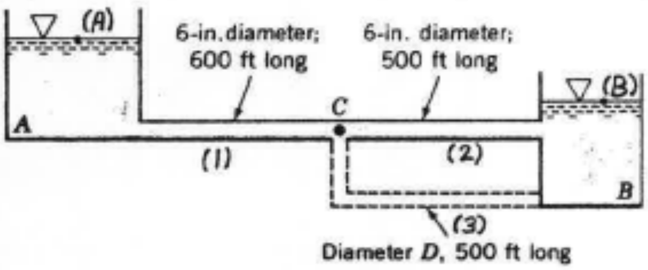
8.81 The pump shown in Fig. P8.81 adds 25 kW to the water and causes a flowrate of 0.04 m^3/s. Determine the flowrate expected if the pump is removed from the system. Assume $f = 0.016$ for either case and neglect minor losses.



■ FIGURE P8.81

Single Pipe – Determine Diameter

8.89 The flowrate between tank *A* and tank *B* shown in Fig. P8.89 is to be increased by 30% (i.e., from Q to $1.30Q$) by the addition of a second pipe (indicated by the dotted lines) running from node *C* to tank *B*. If the elevation of the free surface in tank *A* is 25 ft above that in tank *B*, determine the diameter, *D*, of this new pipe. Neglect minor losses and assume that the friction factor for each pipe is 0.02.

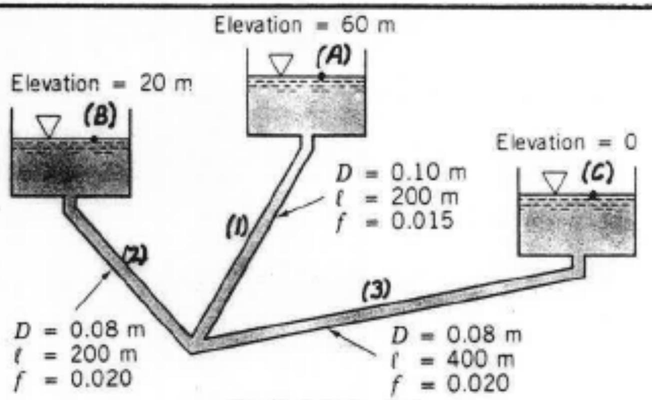


■ FIGURE P8.89

Multiple Pipe Systems

8.92

8.92 The three water-filled tanks shown in Fig. P8.92 are connected by pipes as indicated. If minor losses are neglected, determine the flowrate in each pipe.



■ FIGURE P8.92