Minor Head Losses

Minor losses in pipes come from changes and components in a pipe system. This is different from major losses because those come from friction in pipes over long spans. If the pipe is long enough the minor losses can usually be neglected as they are much smaller than the major losses. Even though they are termed "minor", the losses can be greater than the major losses, for example, when a valve is almost closed the loss can be almost infinite or when there is a short pipe with many bends in it.

The general equation for this type of head loss in pipes with the same diameter and velocity both upstream and downstream of the non-uniformity is

$$h_L = h` = k\frac{V^2}{2g}$$

Where k is an empirical minor loss coefficient.

Types of Minor Losses

There are many different types of systems that can cause minor losses in a pipe. Bends, expansions, contractions, valves, fittings, and meters are a few of them.

1. Expansion / Contraction Losses

   Expansions are defined as when the flow in a pipe goes from a small area to a larger area and the velocity slows down. It is the exact opposite for contractions, the flow goes from a larger pipe to a smaller one and the velocity increases. Sudden expansions and contractions are when the angle between the two pipe sizes is equal to 90 degrees. The loss or energy is due to turbulence, or eddies, formed at the point where the pipe sizes change. Figure-1 below shows sudden contractions and expansions.

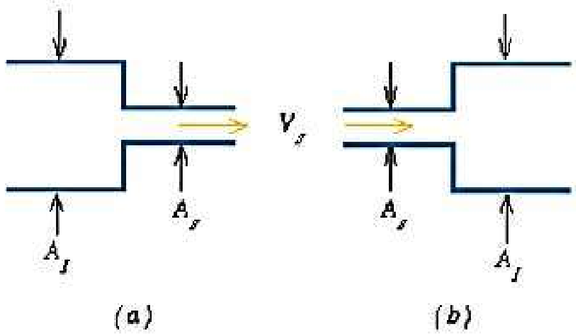
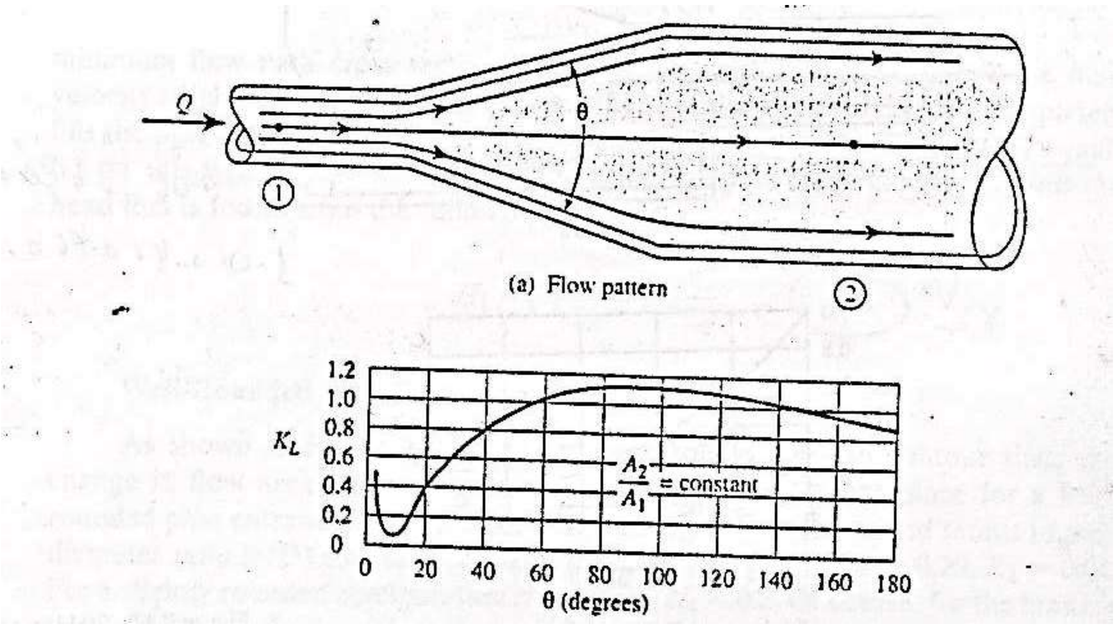


Figure-1: a) shows a sudden contraction of a pipe and b) shows a sudden expansion of a pipe (ae.metu.edu).

h_c' $\rightarrow h_c' = k_c \frac{V_2^2}{2g}$ (V_2, velocity in the smaller pipe)

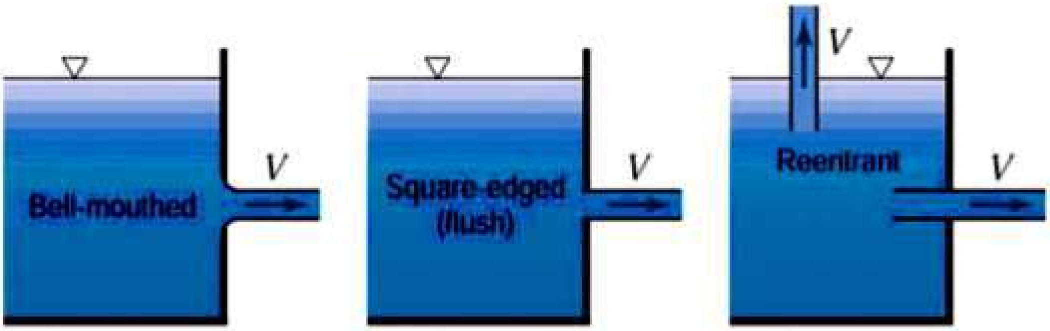
2.Gradual expansions or contractions

Gradual expansions or contractions are when the angle between the two pipe sizes is between 0 and 90 degrees. The k-value not only depends on the ratio of pipe sizes but for the angle as well. A gradual contraction is shown below in Figure-3.



3. Entrance / Exit Losses

Entrance losses come from when liquid enters a pipe from a much larger pipe or tank of some sort. Exit losses are opposite and come from liquid leaving a pipe and entering a much larger pipe or tank



(a) $k_e = 0.04$ (b) $k_e = 0.5$ (c) $k_e = 0.8$

4. Losses from fittings ,valves, Bends and Connections

Losses from them are not all the same. There can be just a 45 degree bend or a180 degree turn that can be sharp or gradual, threaded or unthreaded.

h_c' $\rightarrow h_c' = k\dfrac{V^2}{2g}$

Empirical – function of type

Threaded Pipe Fittings (Table 8.3)

Fitting	k
Globe valve, wide open	10
Angle valve, wide open	5
Close-return bend	2.2
T, through side outlet	1.8
Short-radius elbow	0.9
Medium-radius elbow	0.75
Long-radius elbow	0.60
45° elbow	0.42
Gate valve, wide open	0.19
half open	2.06

EXAMPLE1:

Water at 60°F flows from the large reservoir into a pipeline at a rate of 250 gpm, as shown in Figure 7.34. Compare the total minor losses with the total major losses. The total length of the 3-in.-diameter commercial steel pipe is 50 ft.

Solution First, calculate the head loss for the pipe (a major loss):

$$v = \frac{Q}{A} = \frac{250\,\dfrac{\text{gal}}{\text{min}} \times \dfrac{231\text{ in.}^3}{1\text{ gal}} \times \dfrac{1\text{ ft}^3}{1728\text{ in.}^3} \times \dfrac{1\text{ min}}{60\text{ s}}}{\dfrac{\pi}{2}\left(\dfrac{3}{12}\text{ ft}\right)^2} = 11.3\,\frac{\text{ft}}{\text{s}}$$

$$N_R = \frac{vD}{\nu} = \frac{11.3\,\dfrac{\text{ft}}{\text{s}} \times \dfrac{3}{12}\text{ ft}}{1.21 \times 10^{-5}\,\dfrac{\text{ft}^2}{\text{s}}} = 2.33 \times 10^5$$

$$\frac{\varepsilon}{D} = \frac{0.00015\text{ ft}}{\dfrac{3}{12}\text{ ft}} = 0.0006$$

From the Moody diagram, $f = 0.0195$, so

$$H_{L\,\text{pipe}} = f\frac{L}{D}\frac{v^2}{2g} = 0.0195 \times \frac{50\text{ ft}}{\dfrac{3}{12}\text{ ft}} \times \frac{\left(11.3\,\dfrac{\text{ft}}{\text{s}}\right)^2}{2 \times 32.2\,\dfrac{\text{ft}}{\text{s}^2}} = 7.73\text{ ft}$$

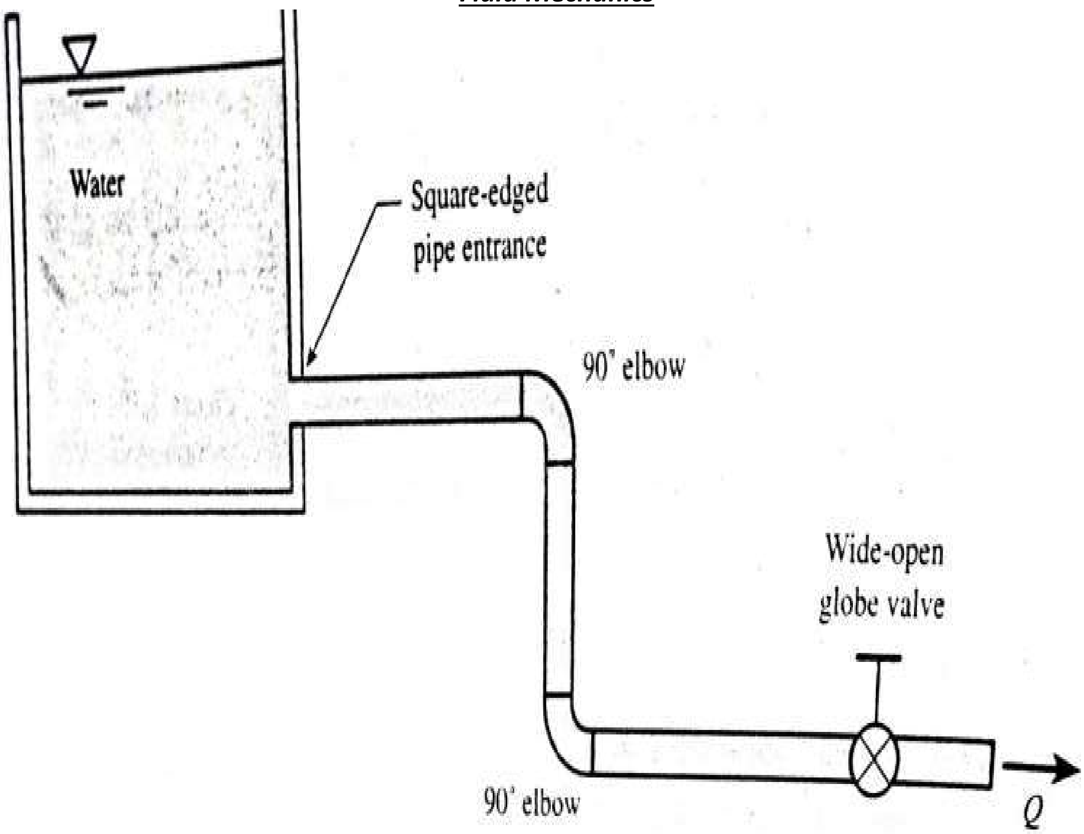


Figure 7.34 System for Example 7-15.

Next, calculate the total head loss for the valves and fittings:

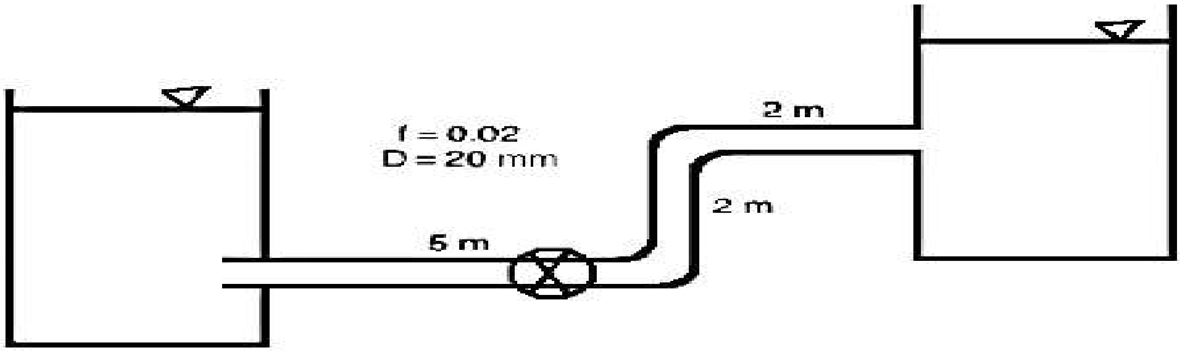
$$H_{L\,\text{valves and fittings}} = H_{L\,\text{pipe entrance}} + 2H_{L\,90^\circ\text{elbow}} + H_{L\,\text{globe valve}}$$

$$= (K_{L\,\text{pipe entrance}} + 2K_{L\,90^\circ\text{elbow}} + K_{L\,\text{globe valve}})\frac{v^2}{2g}$$

$$= (0.5 + 2 \times 0.75 + 10.0)\frac{\left(11.3\frac{\text{ft}}{\text{s}}\right)^2}{2 \times 32.2\frac{\text{ft}}{\text{s}^2}} = 23.8\,\text{ft}$$

Thus, for this system, the minor losses are about three times greater than the major losses. Of course, if the length of the pipe were sufficiently larger or if a gate valve were used instead of a globe valve, major losses would exceed the minor losses.

02. Calculate the flow Q and the velocity v. Consider H = 25 m.



$$H = k\,\frac{v^2}{2g}$$

$$H = (k_{ENTRANCE} + k_{GLOBE\ VALVE} + k_{PIPE} + k_{ELBOW} + k_{EXIT})\,\frac{v^2}{2g}$$

$$25 = \left[1.0 + 10 + \frac{0.02(5 + 2 + 2)}{0.2} + 2 \times 0.9 + 1.0\right]\frac{v^2}{2g}$$

$$25 = 14.7\,\frac{v^2}{2g}$$

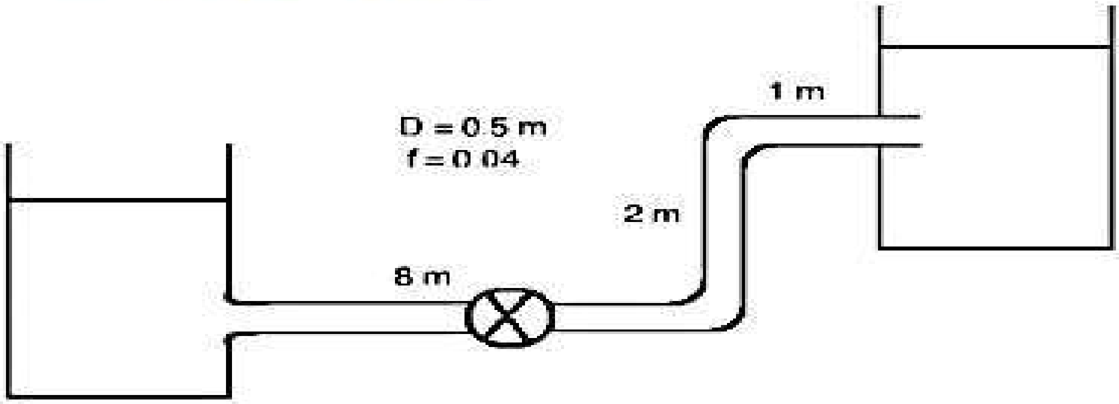
$$v = 5.776\ m/s$$

$$Q = Av$$

$$Q = \frac{\pi}{4}(0.2)^2 \times 5.776$$

$$Q = 0.181\ m^3/s$$

03. Determine the head loss (H) for Q = 60 l/s.



$$H = k\,\frac{v^2}{2g}$$

$$H = (k_{ENTRANCE} + k_{ANGLE\ VALVE} + k_{PIPE} + k_{ELBOW} + k_{EXIT})\,\frac{v^2}{2g}$$

$$H = \left[0.04 + 5 + \frac{0.04(8 + 2 + 1)}{0.15} + 2 \times 0.9 + 1.0\right]\frac{v^2}{2g}$$

$$Q = vA$$

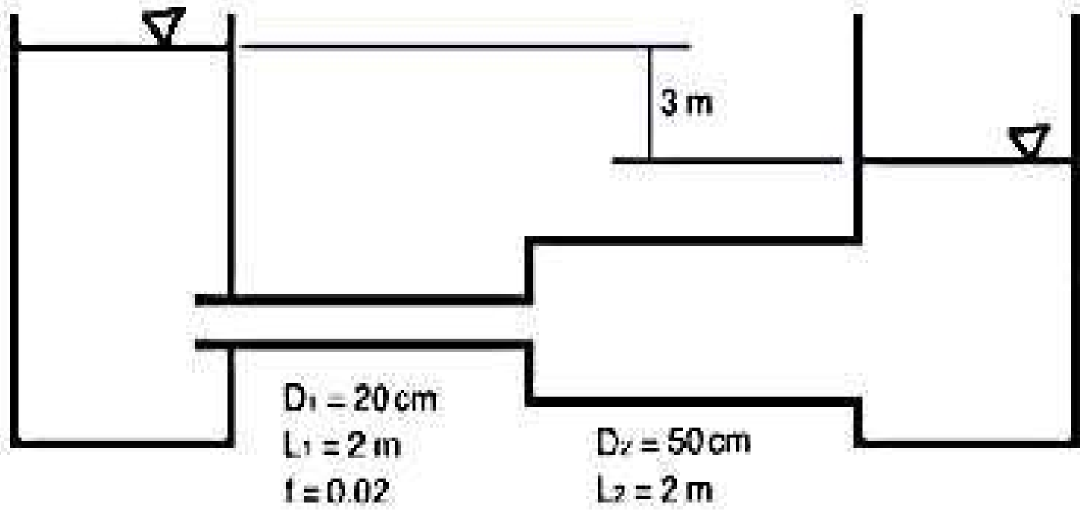
$$60\frac{l}{s} = 0.06\frac{m^3}{s} = v\frac{\pi}{4}(0.15)^2$$

$$v = 3.4\ m/s$$

$$H = \left[0.04 + 5 + \frac{0.04(8 + 2 + 1)}{0.15} + 2 \times 0.9 + 1.0\right]\frac{(3.4)^2}{2g}$$

$$H = 6.32\ m$$

04. For H = 3 m, calculate Q_1 and Q_2.



$$H = k\frac{v_1^2}{2g} + k\frac{v_2^2}{2g}$$

$$H = (k_{ENTRANCE} + k_{PIPE\,1} + k_{EXPANSION\,PIPE\,1-2})\frac{v_1^2}{2g} + (k_{PIPE\,2} + k_{EXIT})\frac{v_2^2}{2g}$$

$$3 = \left[1.0 + \frac{0.02(2)}{0.2} + 0.72\right]\frac{v_1^2}{2g} + \left[\frac{0.02(2)}{0.5} + 1.0\right]\frac{v_2^2}{2g}$$

Knowing the continuity equation,

$$Q_1 = Q_2$$

$$v_1A_1 = v_2A_2$$

$$v_1D_1^2 = v_2D_2^2$$

$$v_2 = \frac{v_1D_1^{\,2}}{D_2^{\,2}} = 0.4^2\,v_1$$

$$3 = \left[1.0 + \frac{0.02(2)}{0.2} + 0.72\right]\frac{v_1^2}{2g} + \left[\frac{0.02(2)}{0.5} \times 0.4^4 + 1.0 \times 0.4^4\right]\frac{v_1^2}{2g}$$

$$v_1 = 5.497\ m/s$$

$$v_2 = \frac{v_1D_1}{D_2} = 0.4\,v_1 = 0.4 \times 5.497 = 2.199\ m/s$$

$$Q_1 = 5.497 \times \frac{\pi}{4}(0.2)^2 = 0.173\ m^3/s$$

$$Q_2 = 2.199 \times \frac{\pi}{4}(0.5)^2 = 0.432\ m^3/s$$