Minor Losses in Pipes

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Introduction

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.

There are three types of forces that contribute to the total head in a pipe, which are elevation head, pressure head, and velocity head. Minor losses are directly related to the velocity head of a pipe, meaning that the higher the velocity head there is, the greater the losses will be. Units for minor losses are in length, such as feet or meters, the same as any of the three types of head.

A separate head loss coefficient, k, can be determined for every element leading to minor losses. K is a dimensionless parameter to help determine head loss. The coefficient is then multiplied by the velocity head to get the head loss as shown below in Equation-1:

$$Head\ Loss\ =\ Head\ Loss\ Coefficient\ *\ Velocity\ Head$$

$$h_L\ =\ k\ *\ \frac{V^2}{2g} \qquad \text{(Equation-1)}$$

Where $V\ =\ velocity$,

$g\ =\ gravity$

This head loss can be entered into the bernoulli equation (Equation-2) to keep an energy balance.

$$\frac{V_1^2}{2g}\ +\ z_1\ +\ \frac{P_1}{\gamma}\ =\ \frac{V_2^2}{2g}\ +\ z_2\ +\ \frac{P_2}{\gamma}\ +\ h_L \qquad \text{(Equation-2)}$$

Where $P\ =\ pressure$,

$\gamma\ =\ density\ of\ water$,

$z\ =\ height$

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. The effects of these usually do not play a major role in the overall losses of the pipe system individually, but can still add up quickly together.

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.

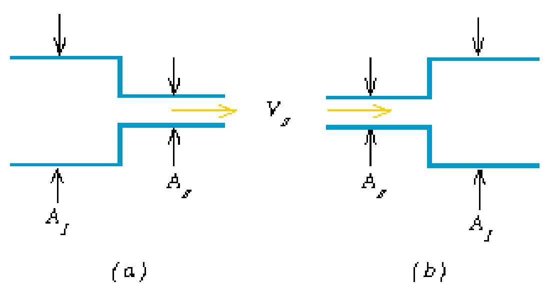


Figure-1: a) shows a sudden contraction of a pipe and b) shows a sudden expansion of a pipe (ae.metu.edu).

The head loss from sudden expansions and contractions depends on a difference in the pipe velocities. The k-value then relates these velocities to each other in relation to the pipe diameters. Figure-2 graphically shows the relationship between the diameters while Equation-3 numerically shows the relationship of the velocities to head loss.

$$h_L = \frac{(V_1 - V_2)^2}{2g} \qquad \text{(Equation-3)}$$

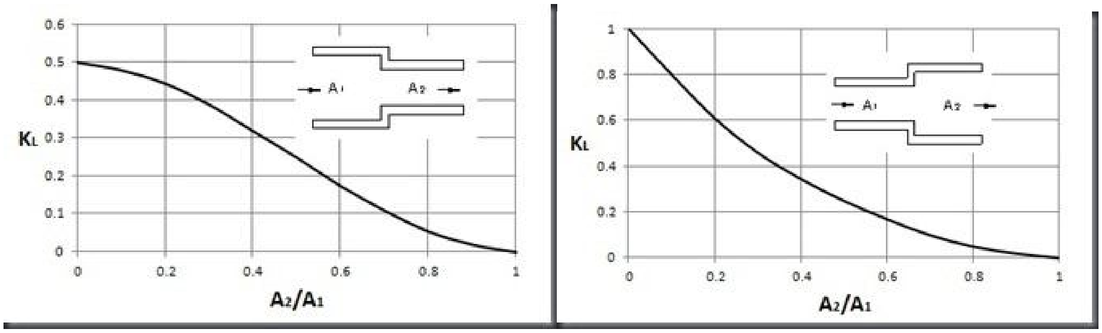


Figure-2: The k values due sudden contractions and expansions, respectively (vanoengineering.wordpress.com)

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.

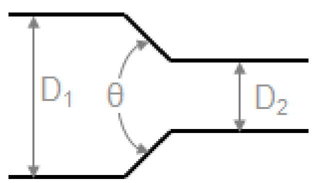


Figure-3: A diagram showing a gradual contraction of a pipe (neutrium.net).

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. When entering a pipe the losses depend on the shape of the entrance. The k-value for entrance losses these shapes and how the liquid flows into the pipe from the larger area. As shown in Figure-4, the k-values for entrance losses range from 0.04-0.8. Upon exiting a pipe the velocity is assumed to go down to zero which makes the loss equal to the velocity head. This total loss makes the k-value equal to 1 in all cases and is also displayed in Figure-4.

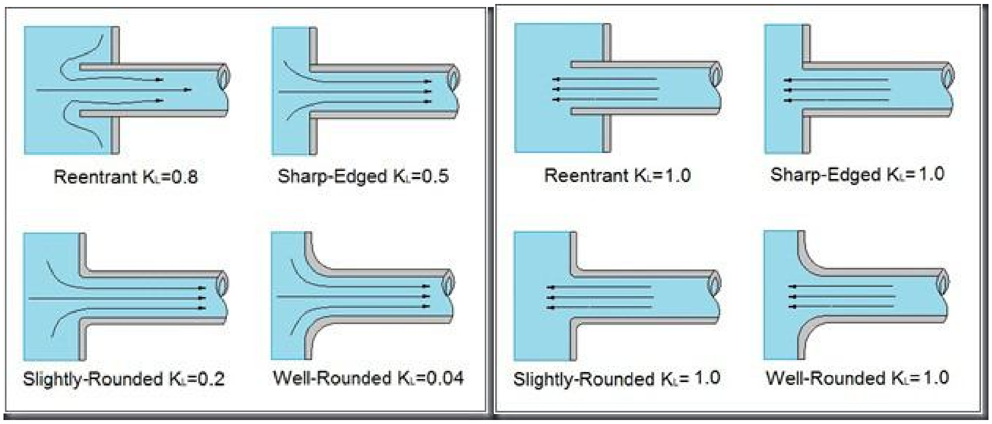


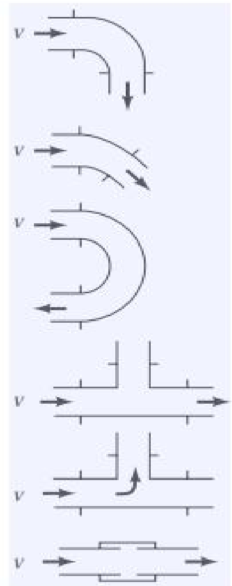
Figure-4: Four different types of entrance losses are shown on the left and four different types of exit losses are shown on the right (vanoengineering.wordpress.com).

Losses from Bends and Connections

Losses from bends are not all the same. There can be just a 45 degree bend or a 180 degree turn that can be sharp or gradual, threaded or unthreaded. All of these factors play an important role in the magnitude of losses. The lower the k-value for a bend, the smoother it is and the opposite is true for a high k-value bend. As seen in Figure-5 below, the threaded elbows have a much higher head loss coefficient than the flanged elbows. The flanged elbows allow for a smooth transition from one direction to another while the threaded elbows provide a rough surface for changing direction.

When a pipe splits into two or when two pipes converge into one, there will be minor losses. Mixing occurs when the two flows come together and that is only possible with turbulence. Tee's are a good example of this happening. One flow can come in and have two flows going out or two flows can be coming in with one going out. In either scenario there will be turbulence with the combining or splitting of the streams. Even simple connections with one flow going in and one flow going out without any change in direction lead to minor losses.

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. 8.36 for typical valve geometry

Figure-5: This table shows the k-values for many different bends, joints, and size changes (vanoengineering.wordpress.com)

Losses from Valves

Valves can cause almost no head loss at all to almost a complete loss of head. This depends on how the valve is position and what type of valve it is. If the valve is all the way open there will be a very small head loss coefficient such as the ball valve in Figure-5 with a k-value of 0.05. Such a small value shows that there is very little disturbance to the system when the valve is all the way open. That same ball valve can produce an enormous head loss coefficient if it is almost closed, again in Figure-5, the ball valve has a k-value of 210 when it is two thirds of the way closed. A value as large as that comes from water having to go around the parts of the valve and squeeze through the small opening causing a lot of energy to be lost to turbulence at the valve.

Other types of Valves, such as the globe valve shown in Figure-6, are not almost negligible when completely open. The globe valve has a head loss coefficient of 10 when it is fully open due to the path of the water. A lot of turbulence is created when liquid is going through the pipe because it is forced to turn upwards and fit through a small opening and then turn to continue its path down the pipe.

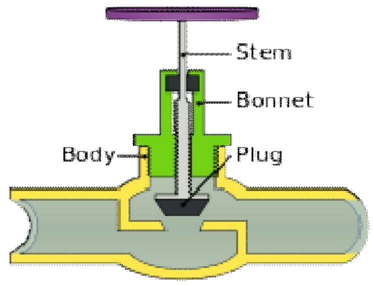
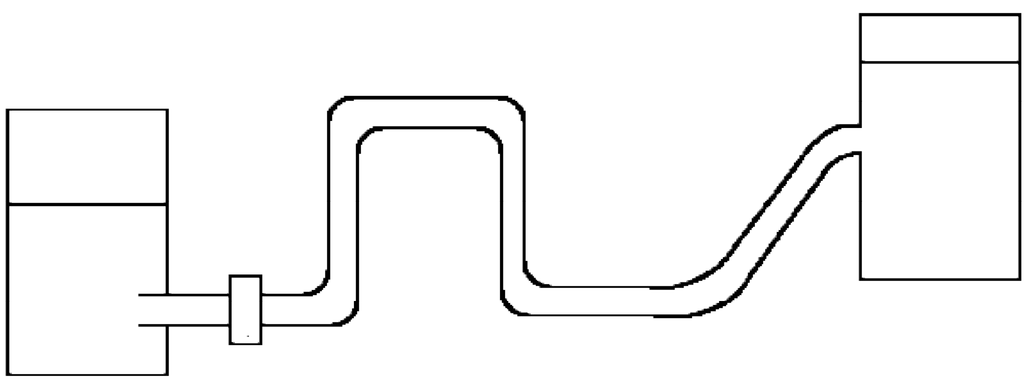
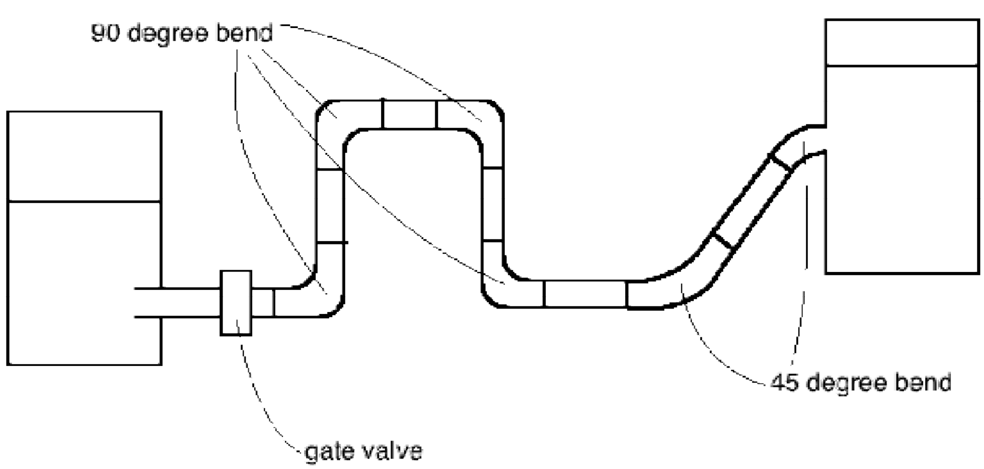


Figure-6: A Globe Valve that is fully open (wikipedia.com).

Exercises

01. Identify the types of minor losses in the figure below and their respectively head loss coefficient.





$K_{ENTRANCE} = 1.0$

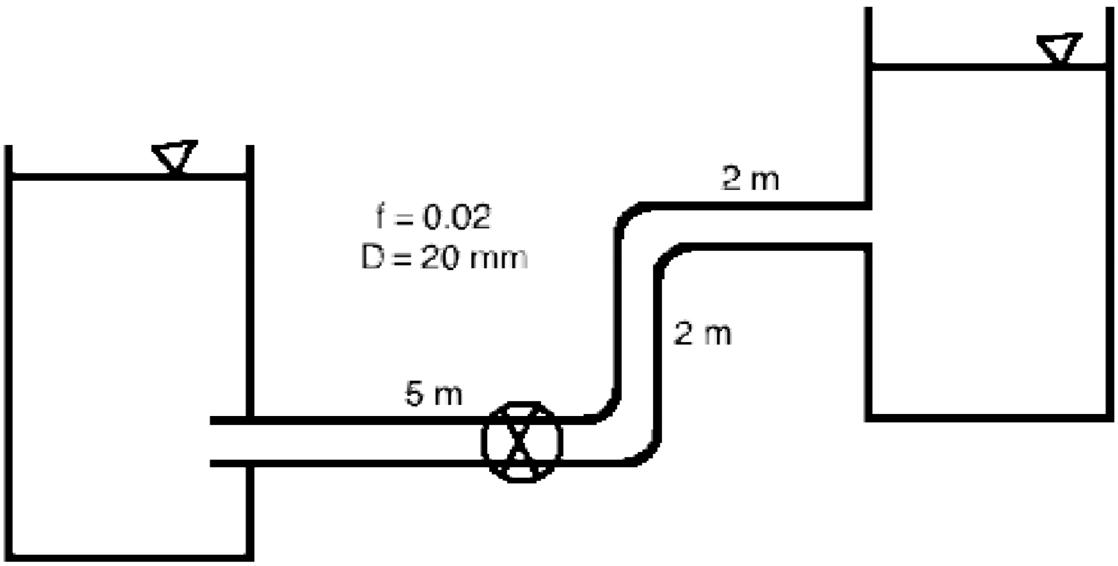
$K_{GATE\ VALVE} = 0.2$

$K_{90°\ ELBOW} = 0.9$

$K_{45°\ ELBOW} = 0.4$

$K_{EXIT} = 1.0$

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



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

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

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

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

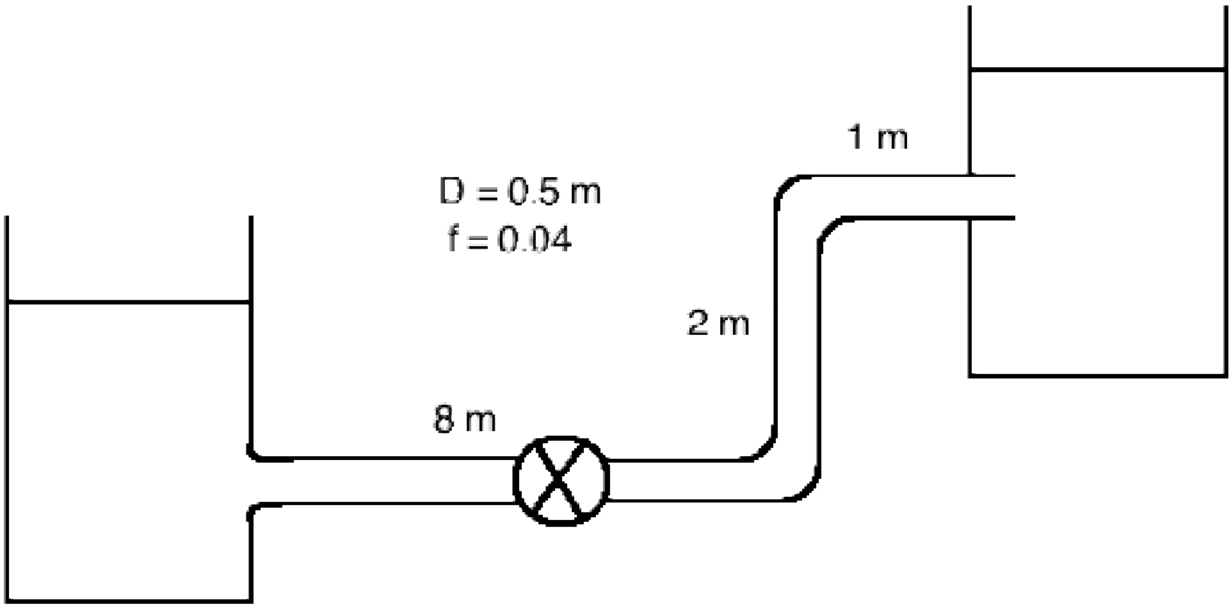
$$v = 5.776\ m/s$$

$$Q = Av$$

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

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

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



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

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

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

$$Q = vA$$

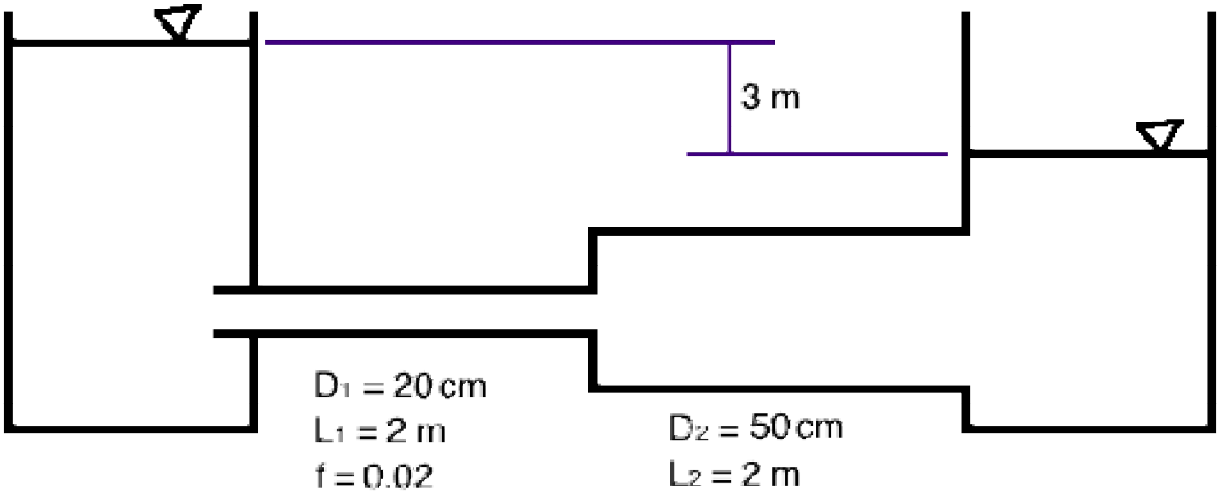
$$60\frac{l}{s} = 0.06\frac{m^3}{s} = v\frac{\pi}{4}(0.15)^2$$

$$v = 3.4\ m/s$$

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

$$H = 6.32\ m$$

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,

$$Q_1 = Q_2$$

$$v_1A_1 = v_2A_2$$

$$v_1D_1^2 = v_2D_2^2$$

$$v_2 = \frac{v_1{D_1}^2}{{D_2}^2} = 0.4^2\ v_1$$

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

$$v_1 = 5.497\ m/s$$

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

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

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

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