Today, we will:

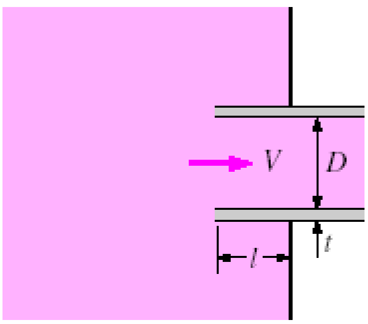
- Discuss major vs. minor losses in pipe flows
- Do some example problems – major and minor losses in pipe flows

Minor Losses

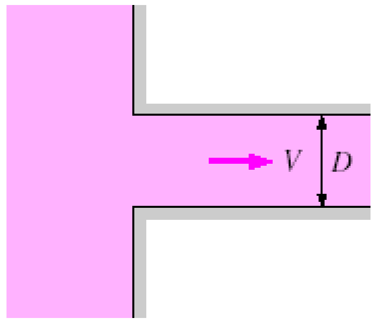
Here are some sample loss coefficients for various minor loss components. More values are listed in Table 8-4 of the Çengel-Cimbala textbook:

Pipe Inlet

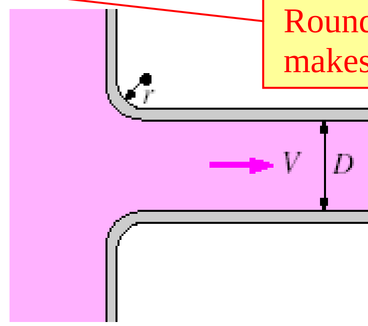
Reentrant: $K_L = 0.80$
($t \ll D$ and $l \approx 0.1D$)



Sharp-edged: $K_L = 0.50$



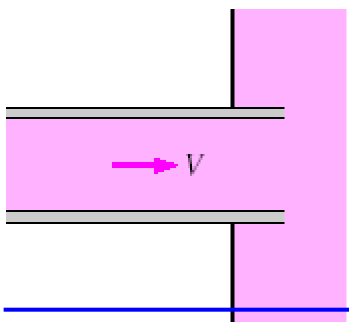
Well-rounded ($r/D > 0.2$): $K_L = 0.03$
Slightly rounded ($r/D = 0.1$): $K_L = 0.12$
(see Fig. 8–36)



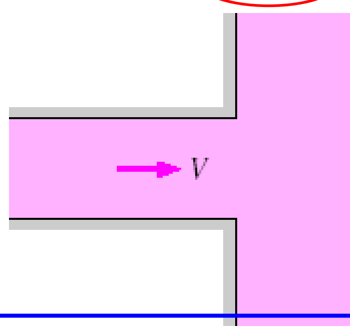
Rounding of an inlet makes a big difference.

Pipe Exit

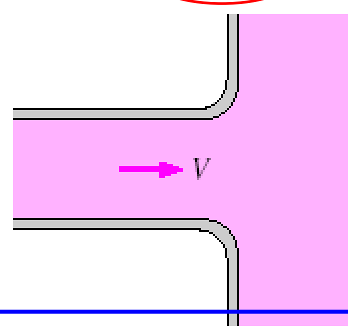
Reentrant: $K_L = \alpha$



Sharp-edged: $K_L = \alpha$



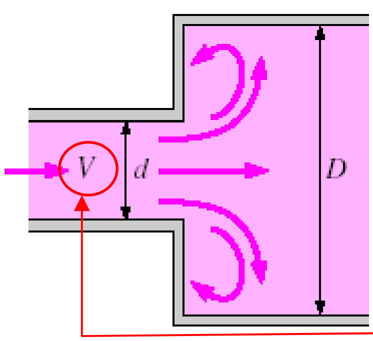
Rounded: $K_L = \alpha$



Rounding of an outlet makes no difference.

Sudden Expansion and Contraction (based on the velocity in the smaller-diameter pipe)

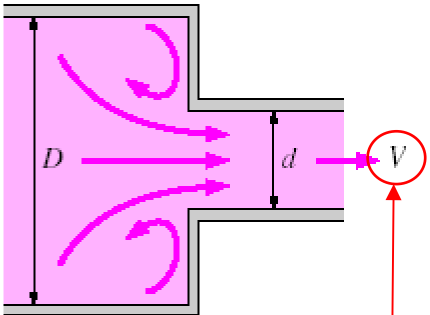
Sudden expansion: $K_L = \left(1 - \frac{d^2}{D^2}\right)^2 \alpha$

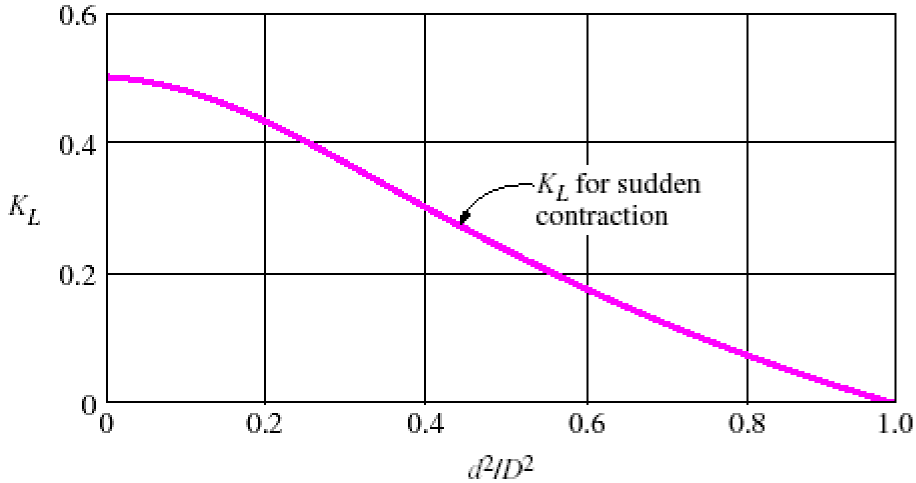


Note that the *larger velocity* (the velocity associated with the *smaller pipe section*) is used by convention in the equation for minor head loss, i.e.,

$$h_{L,\text{ minor}} = K_L \frac{V^2}{2g}.$$

Sudden contraction: See chart.

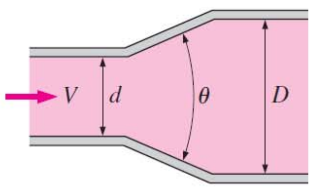




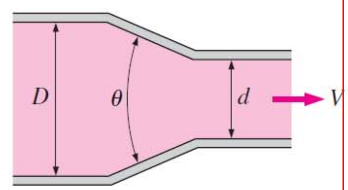
Note again that the *larger velocity* (the velocity associated with the *smaller pipe section*) is used by convention in the equation for minor head loss, i.e., $h_{L,\text{ minor}} = K_L \dfrac{V^2}{2g}$.

Gradual Expansion and Contraction (based on the velocity in the smaller-diameter pipe)

Expansion (for $\theta = 20°$):
$K_L = 0.30$ for $d/D = 0.2$
$K_L = 0.25$ for $d/D = 0.4$
$K_L = 0.15$ for $d/D = 0.6$
$K_L = 0.10$ for $d/D = 0.8$

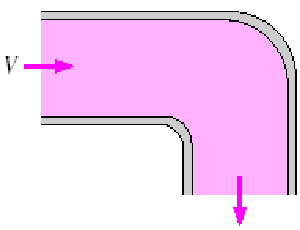


Contraction:
$K_L = 0.02$ for $\theta = 30°$
$K_L = 0.04$ for $\theta = 45°$
$K_L = 0.07$ for $\theta = 60°$

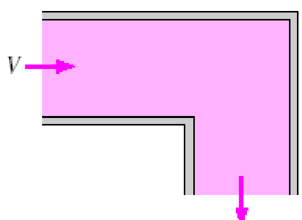


Bends and Branches

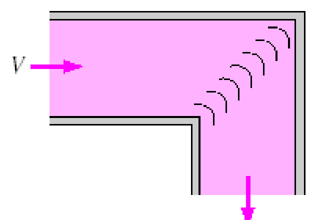
90° smooth bend:
Flanged: $K_L = 0.3$
Threaded: $K_L = 0.9$



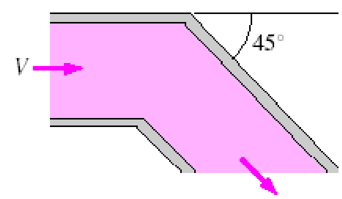
90° miter bend (without vanes): $K_L = 1.1$



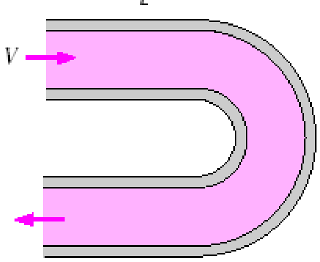
90° miter bend (with vanes): $K_L = 0.2$



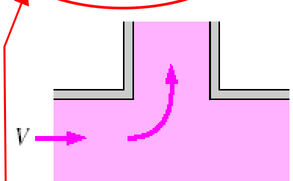
45° threaded elbow:
$K_L = 0.4$



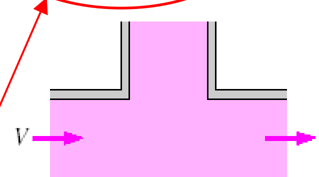
180° return bend:
Flanged: $K_L = 0.2$
Threaded: $K_L = 1.5$



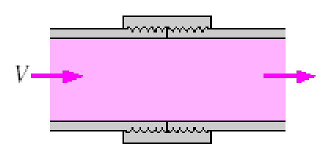
Tee (branch flow):
Flanged: $K_L = 1.0$
Threaded: $K_L = 2.0$



Tee (line flow):
Flanged: $K_L = 0.2$
Threaded: $K_L = 0.9$



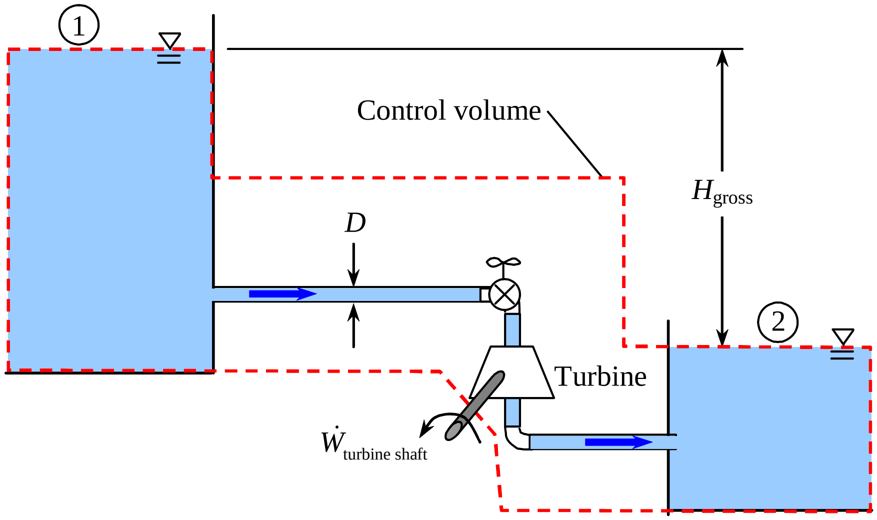
Threaded union:
$K_L = 0.08$



For tees, there are <u>two</u> values of K_L, one for *branch flow* and one for *line flow*.

Example Problem – Calculation of Turbine Shaft Power

Given: Water (ρ = 998. kg/m^3, μ = 1.00 × 10^{-3} kg/m·s) flows from one large reservoir to another, and through a turbine as sketched. The elevation difference between the two reservoir surfaces is H_{gross} = 120.0 m. The pipe is 5.0 cm I.D. cast iron pipe. The total pipe length is 30.8 m. The entrance is slightly rounded; the exit is sharp. There is one regular flanged 90-degree elbow, and one fully open flanged angle valve. The turbine is 81% efficient. The volume flow rate through the turbine is 0.0045 m^3/s.



To do: Calculate the shaft power produced by the turbine in units of kilowatts.

Solution:

- First we draw a control volume, as shown by the dashed line. We cut through the surface of both reservoirs (inlet 1 and outlet 2), where we know that the velocity is nearly zero and the pressure is atmospheric. We also slice through the turbine shaft. The rest of the control volume simply surrounds the piping system.
- We apply the head form of the energy equation from the inlet (1) to the outlet (2):

$$P_1 = P_2 = P_{atm}$$

$$\frac{P_1}{\rho g} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_{pump,u} = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_{turbine,e} + h_L$$

$$V_1 = V_2 \approx 0$$

- But by definition of turbine efficiency, $h_{turbine,\ e} = \frac{\dot{W}_{turbine\ shaft}}{\eta_{turbine}\dot{m}g}$ where $\dot{m} = \rho\dot{V}$. Also, since the reference velocity is the same for all the major and minor losses (the pipe diameter is constant throughout), we may use the simplified version of the equation for h_L, i.e., Eq. 8-59: $h_L = \frac{V^2}{2g}\left(f\frac{L}{D} + \sum K_L\right)$. Therefore, we solve the energy equation for the desired unknown, namely, turbine shaft power, $\dot{W}_{turbine\ shaft} = \eta_{turbine}\rho\dot{V}g\left[H_{gross} - \frac{V^2}{2g}\left(f\frac{L}{D} + \sum K_L\right)\right]$. This is our answer in variable form, but we still need to calculate the values of some of the variables.

The rest of this problem will be solved in class.