PIPE FLOW

Losses in Pipe

It is often necessary to determine the head loss, $h_{L,}$ that occur in a pipe flow so that the energy equation, can be used in the analysis of pipe flow problems.

The overall head loss for the pipe system consists of the head loss due to viscous effects in the straight pipes, termed the major loss and denoted $h_{L\text{-}major}$.

The head loss in various pipe components, termed the minor loss and denoted $h_{L\text{-}minor}$.

That is ;

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

The head loss designations of “major” and “minor” do not necessarily reflect the relative importance of each type of loss.

For a pipe system that contains many components and a relatively short length of pipe, the minor loss may actually be larger than the major loss.

Major Losses

The head loss, $h_{L\text{-}major}$ is given as ;

$$h_{L-major} = f\,\frac{\ell}{D}\frac{V^2}{2g}$$

where f is friction factor.

Above mention equation is called the *Darcy-Weisbach* equation. It is valid for any fully developed, steady, incompressible pipe flow, whether the pipe is horizontal or on hill

Friction factor for laminar flow is ;

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

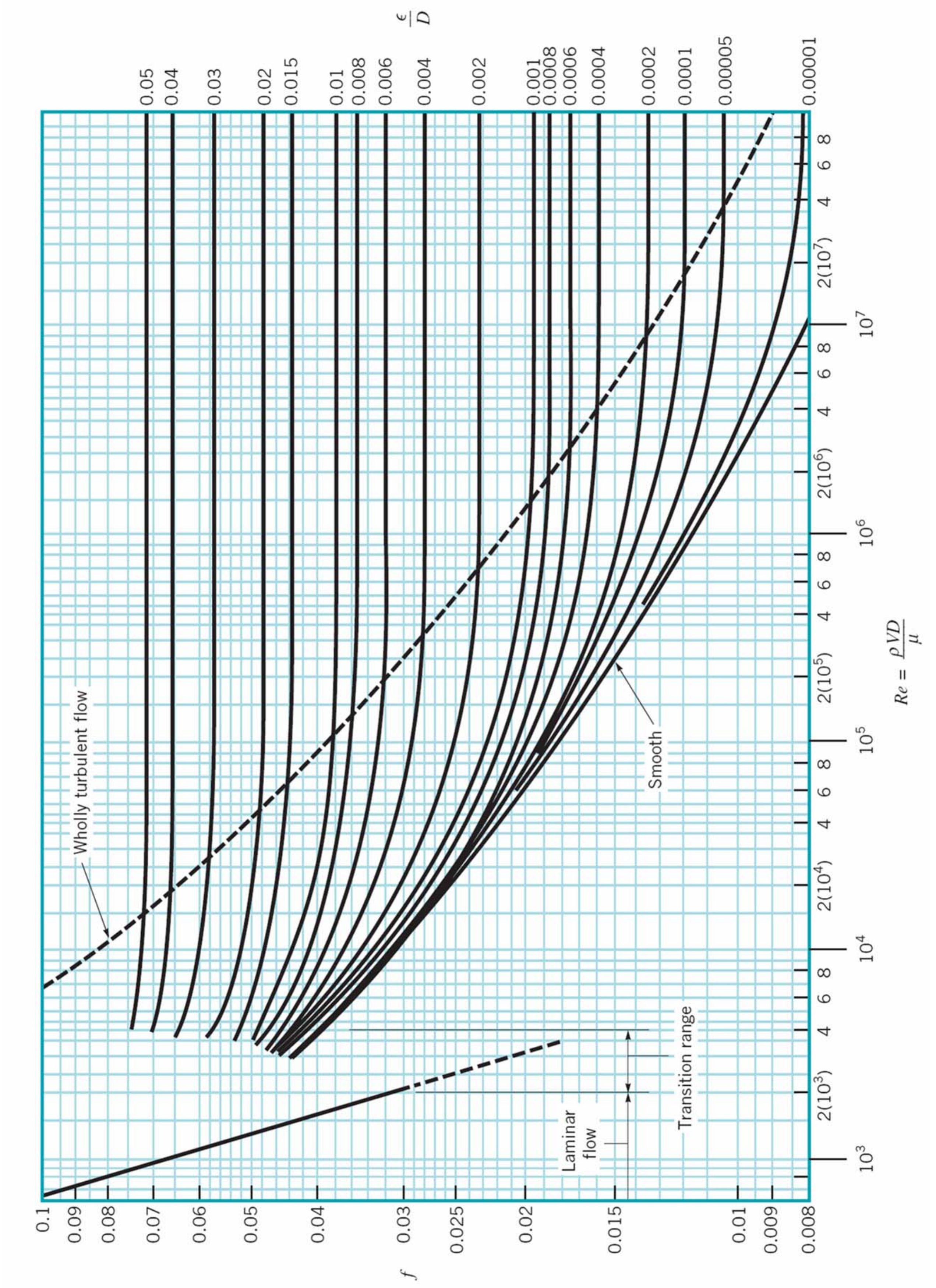
Friction factor for turbulent flow is based on *Moody* chart.

It is because, in turbulent flow, Reynolds number and relative roughness influence the friction.

Reynolds number, $\mathrm{Re} = \dfrac{\rho V D}{\mu}$

Relative roughness $= \dfrac{\varepsilon}{D}$

(relative roughness is not present in the laminar flow)


f
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
$\frac{\epsilon}{D}$
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.00001
10^3
$2(10^3)$
4
6
8
10^4
$2(10^4)$
10^5
$2(10^5)$
10^6
$2(10^6)$
10^7
$2(10^7)$
$Re = \frac{\rho VD}{\mu}$
Wholly turbulent flow
Laminar flow
Transition range
Smooth

The *Moody* chart is universally valid for all steady, fully developed, incompressible pipe flows.

The following equation from *Colebrook* is valid for the entire non-laminar range of the *Moody* chart. It is called *Colebrook formula*.

$$\frac{1}{f} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

Minor Losses

The additional components such as valves and bend add to the overall head loss of the system, which is turn alters the losses associated with the flow through the valves.

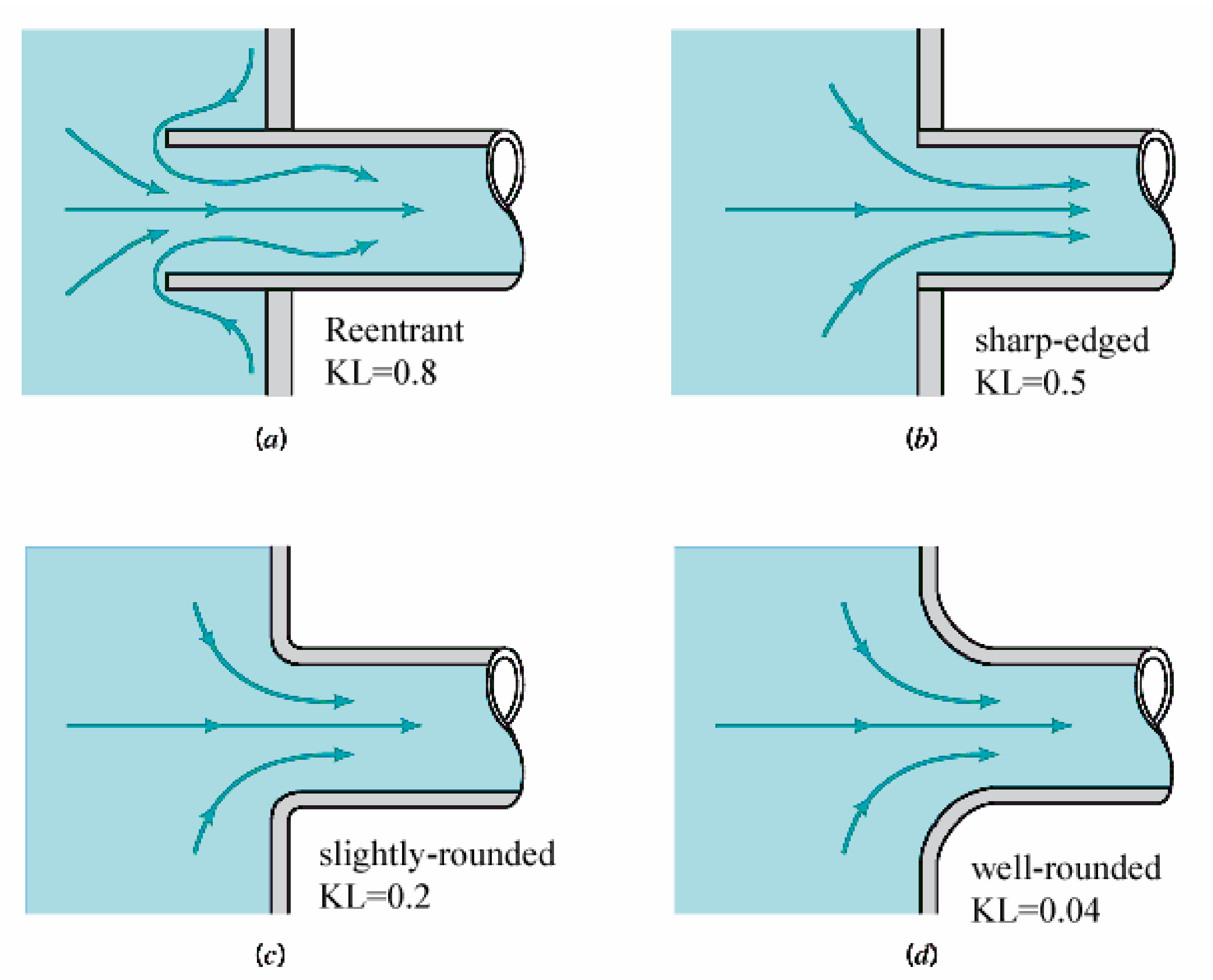
Minor losses termed as ;

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

where K_L is the loss coefficient.

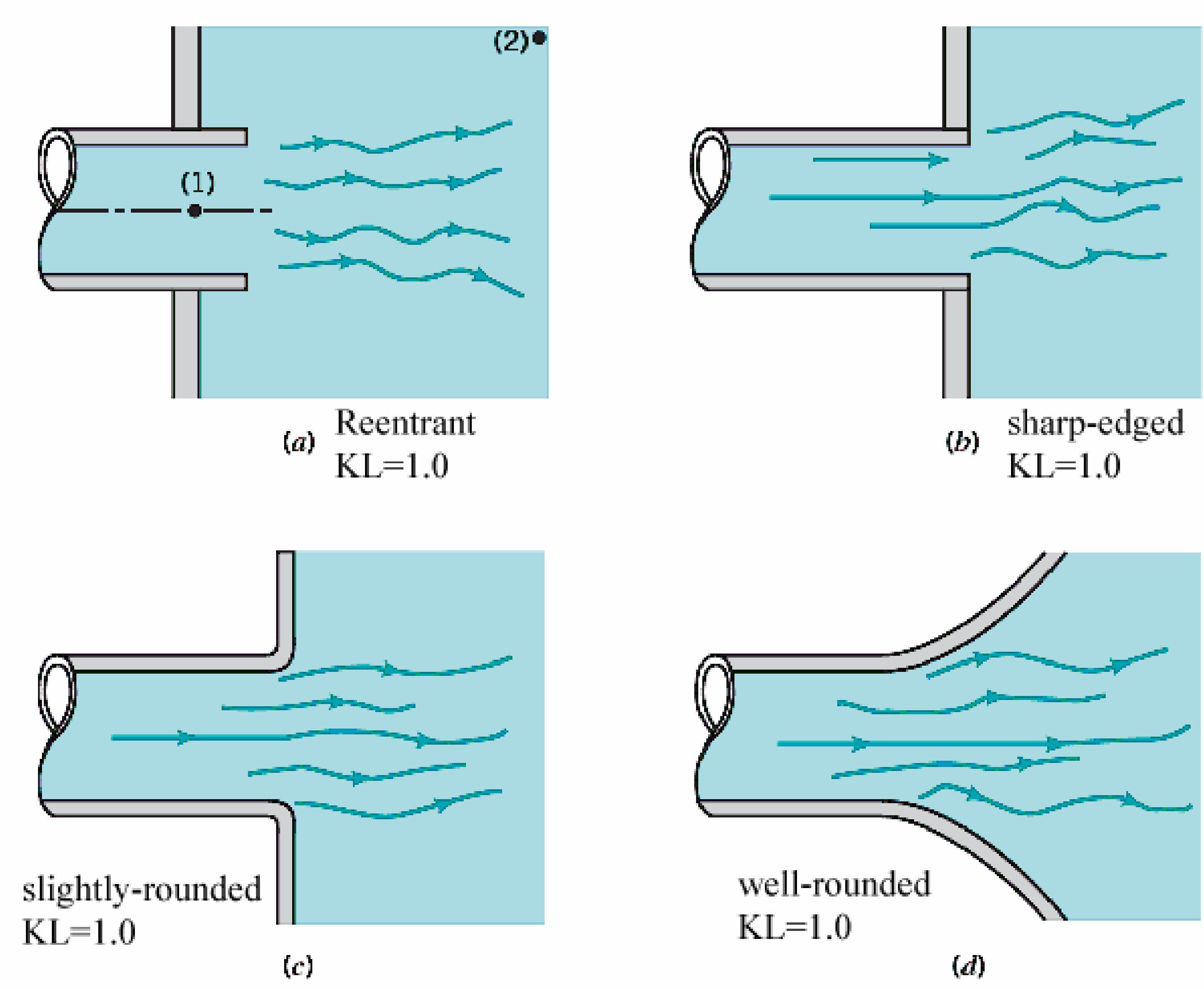
Each geometry of pipe entrance has an associated loss coefficient.

Entrance flow conditions and loss coefficient.



$$\text{Condition:} \quad \frac{A_1}{A_2} = 0 \quad \text{or} \quad \frac{A_1}{A_2} = \infty$$

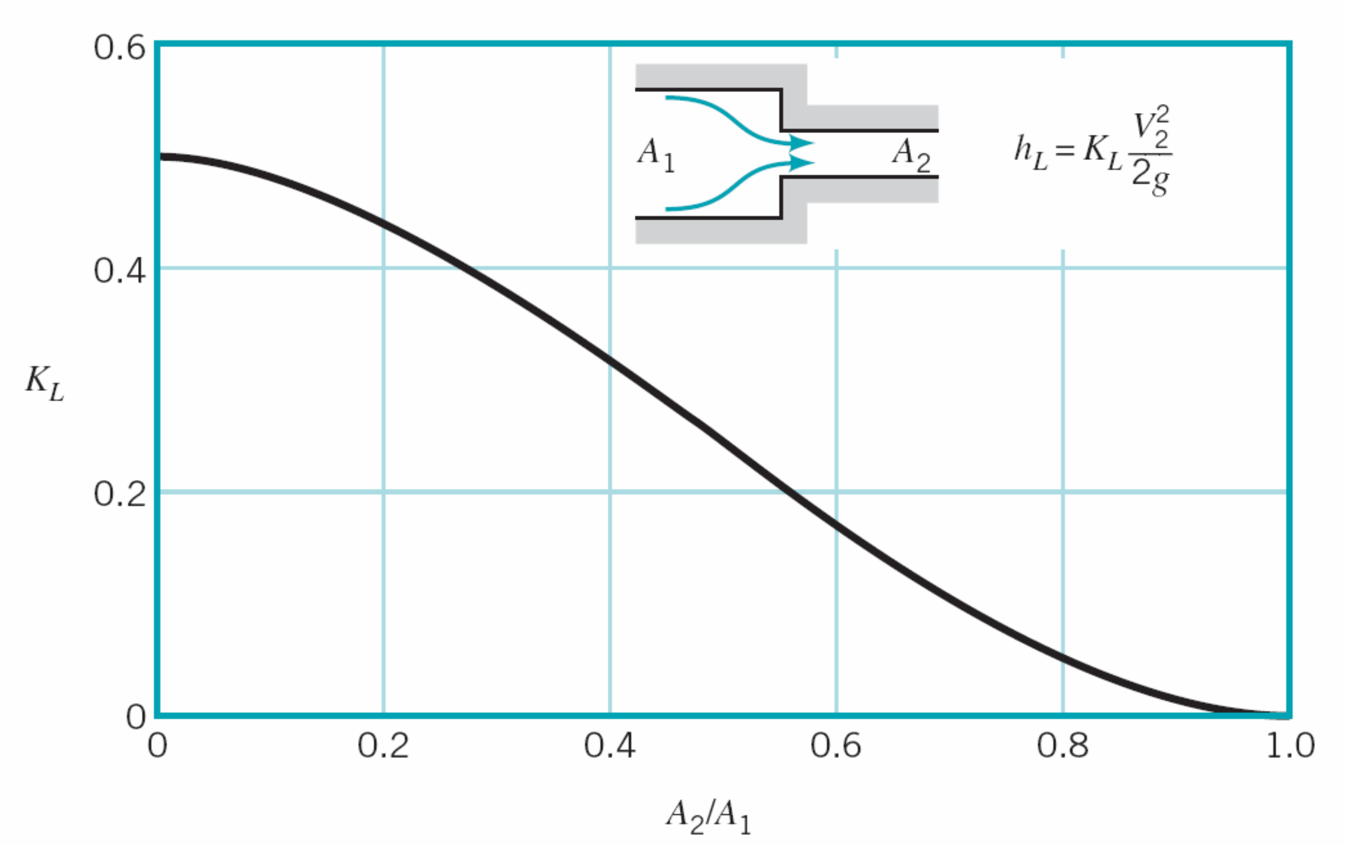
Exit flow conditions and loss coefficient.



Condition: $\frac{A_1}{A_2} = 0$ or $\frac{A_1}{A_2} = \infty$

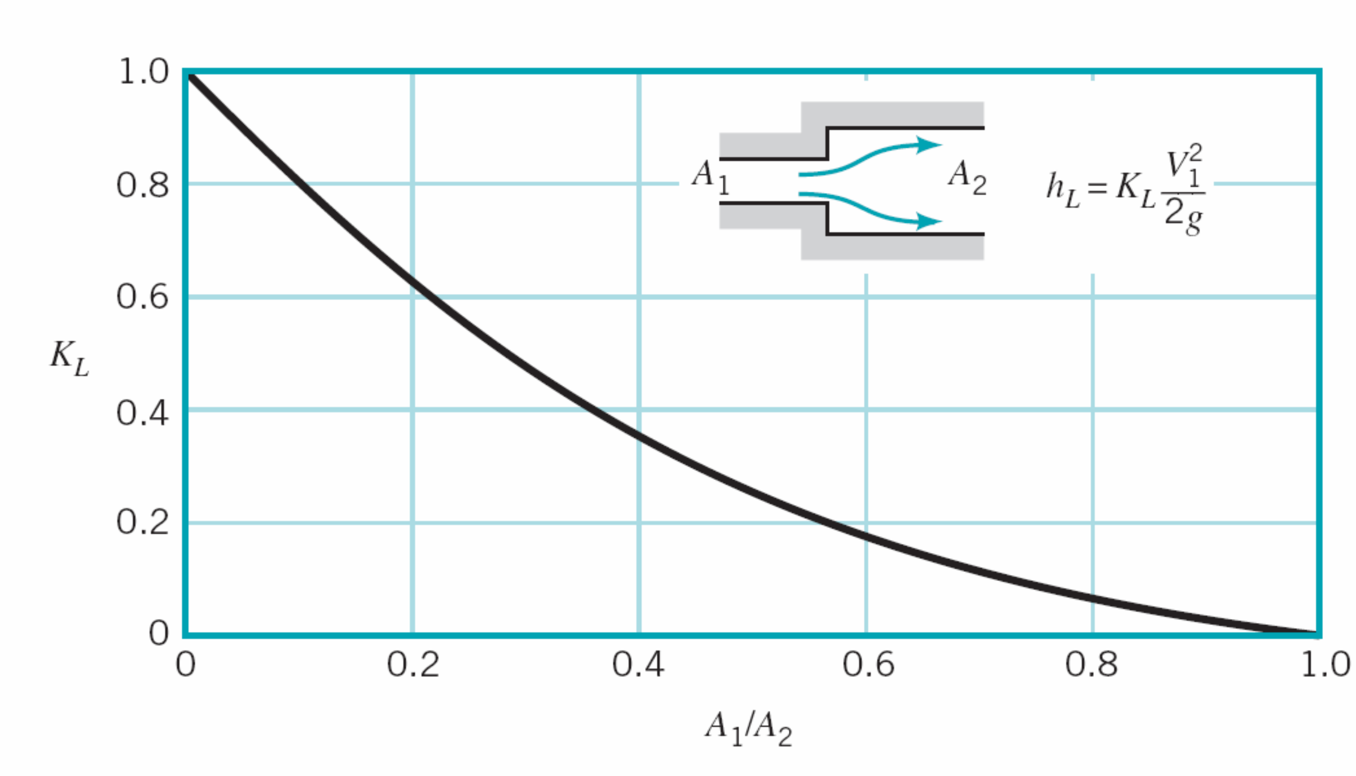
Losses also occur because of a change in pipe diameter

For sudden contraction:



$$K_L = \left(1 - \frac{A_2}{A_1}\right)^2 = \left(1 - \frac{A_2}{A_c}\right)^2 = \left(1 - \frac{1}{C_c}\right)^2$$

For sudden expansion



$$K_L = \left(1 - \frac{A_1}{A_2}\right)^2$$

EXAMPLE 1

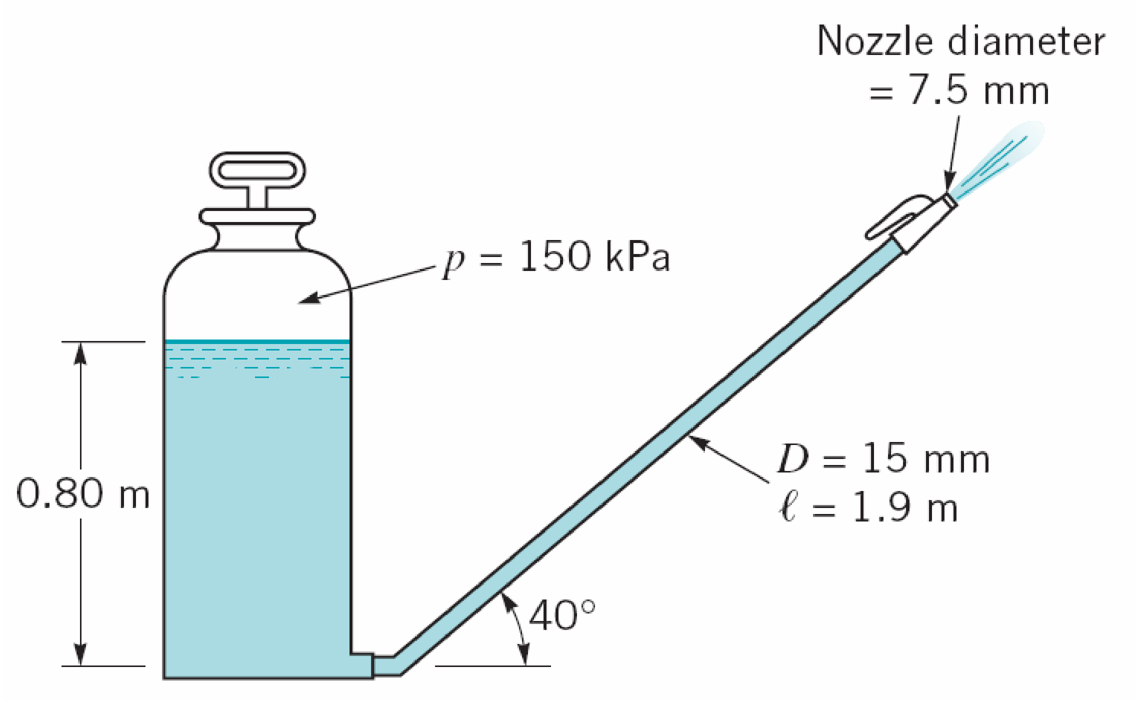


Figure 1

Water flows from the nozzle attached to the spray tank shown in Figure 1. Determine the flowrate if the loss coefficient for the nozzle (based on upstream conditions) is 0.75 and the friction factor for the rough hose is 0.11.

EXAMPLE 2

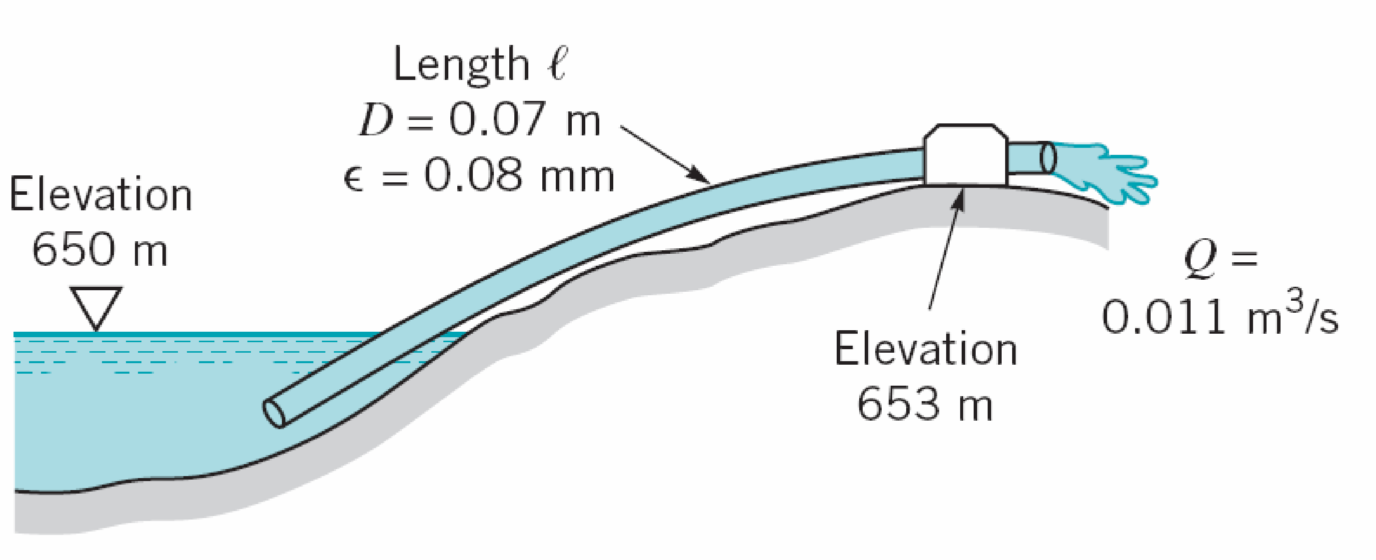


Figure 2

Water at 10 degree Celsius is pumped from a lake shown in Figure 2. If flowrate is 0.011m3/s, what is the maximum length inlet pipe, *l*, that can be used without cavitations occurring.

EXAMPLE 3

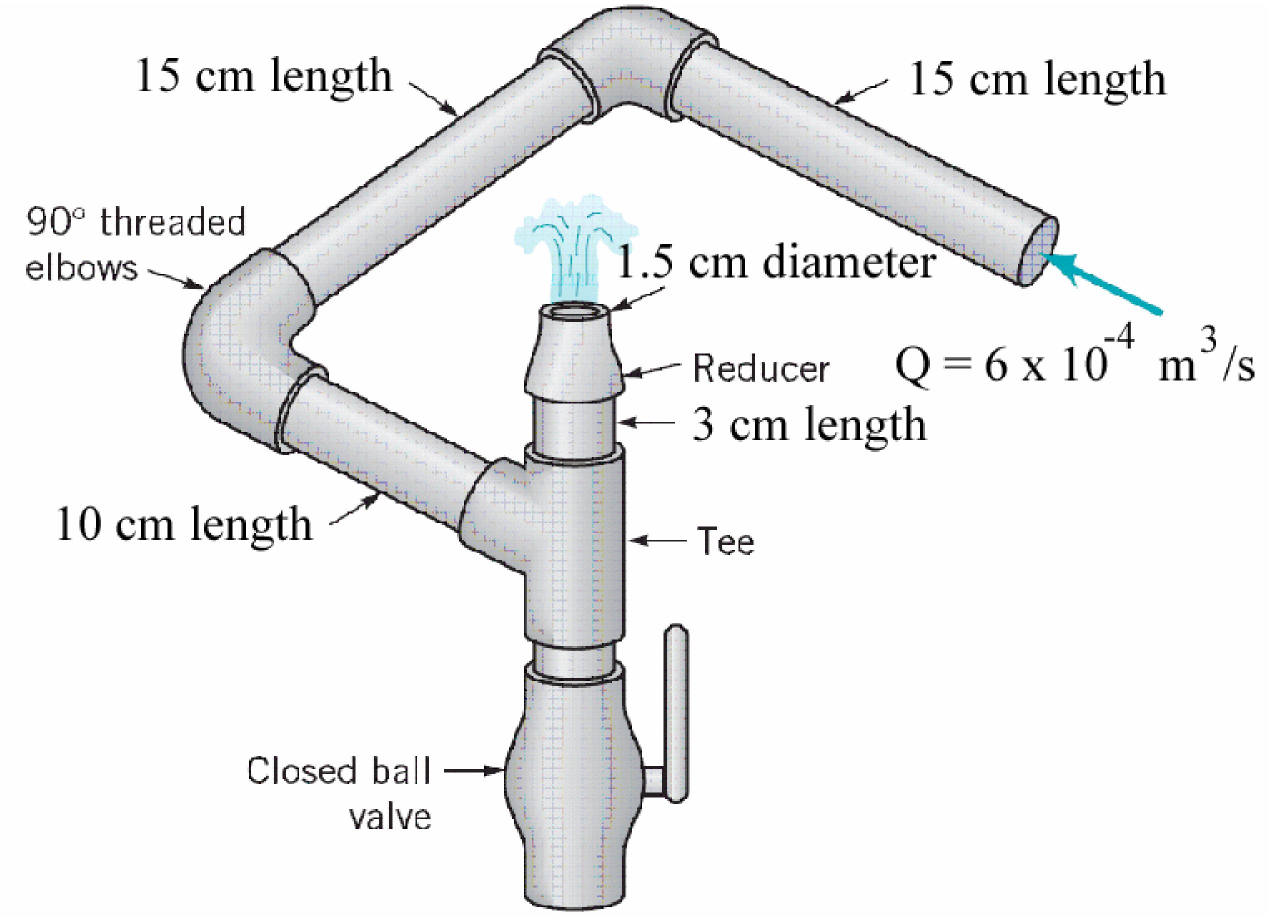


Figure 3

Water flows steadily through the 2.5cm diameter galvanized iron pipe system shown in Figure 3 at rate $6 \times 10^{-4} m^3/s$. 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.

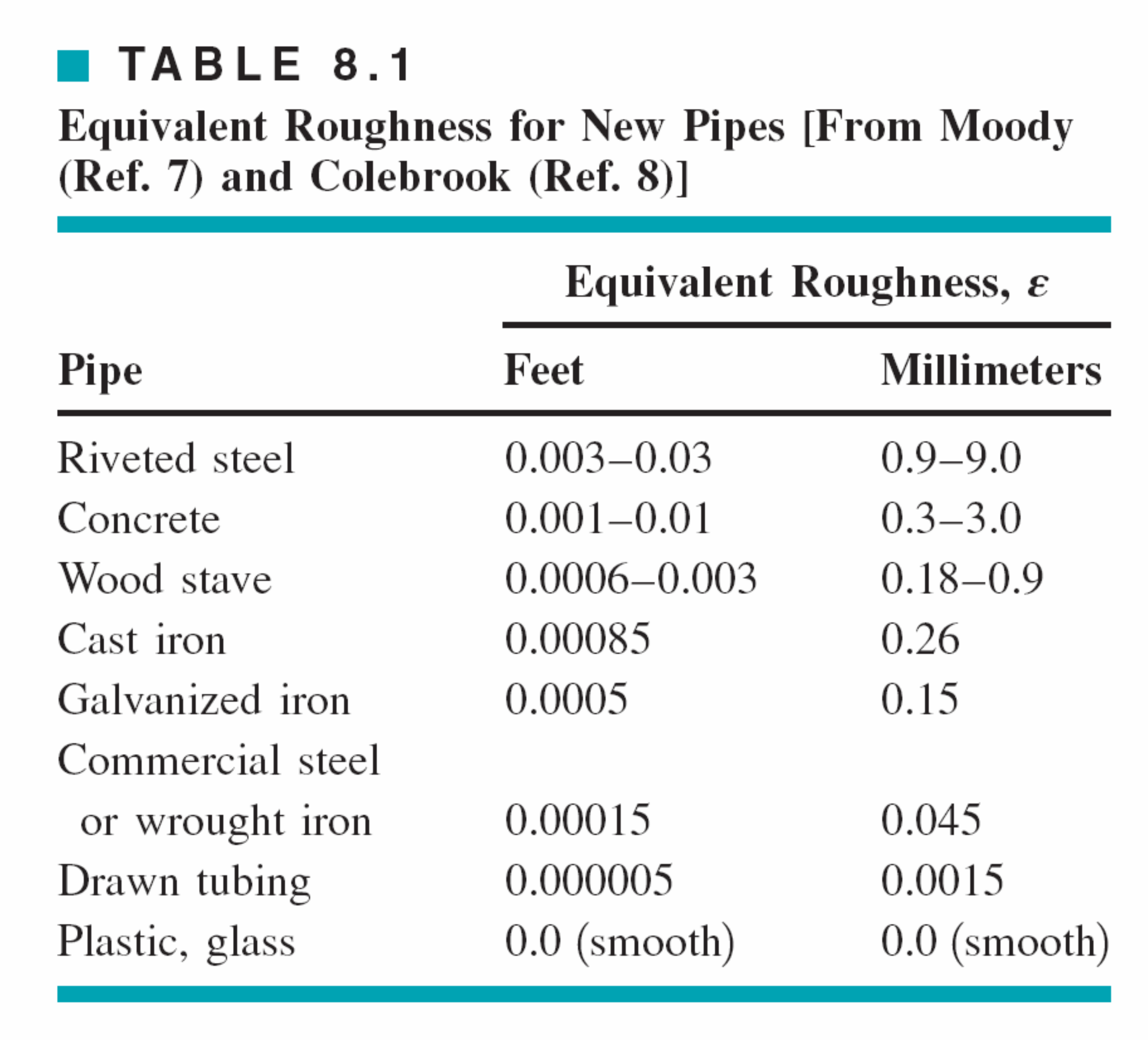


TABLE 8.1

Equivalent Roughness for New Pipes [From Moody (Ref. 7) and Colebrook (Ref. 8)]

	Equivalent Roughness, ε	
Pipe	**Feet**	**Millimeters**
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Wood stave	0.0006–0.003	0.18–0.9
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.045
Drawn tubing	0.000005	0.0015
Plastic, glass	0.0 (smooth)	0.0 (smooth)