ENGSC 3233
Chapter 8, Lecture 4

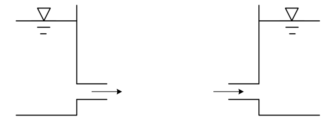
This period
Minor losses
Noncircular conduits

Hint for today

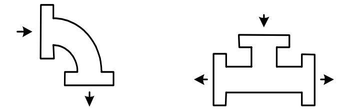
Minor Losses

Minor losses are all the frictional energy losses that come from fittings, entrances and exits. Many times they are the *largest* cause of friction in a pipe system.

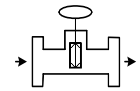
inlets and outlets



elbows and tees,



valves



expansions and contractions

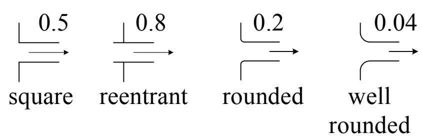
There is no adequate theory to predict these losses. We use the empirical relation

$$h_L = K_L \frac{V^2}{2g} \quad \text{(minor losses)}$$

for a complex pipe systems with several fittings and various length of pipe we would sum them up

$$h_L = \sum f \frac{l}{D} \frac{V^2}{2g} + \sum K_L \frac{V^2}{2g}$$

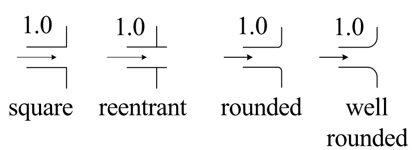
Inlets
Friction is a strong function of the inlet shape.



Use Figure 8.22 page 438

Outlets

Friction is *not* a function of outlet shape.



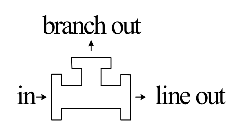
For all outlets $K_L = 1.0$

Elbows and Tees
Function of fitting shape and connection. Flanged connections have less friction than threaded ones.

Use Table 8.2 page 445

Elbows Long radius elbows have less loss than standard 90^o.

Tees: Loss is a function of line (straight) or branch, (turning) flow.



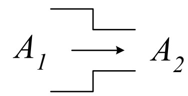
Valves: Valves are used to both shutoff and regulate flow. The loss is a function of the valve type and its setting.

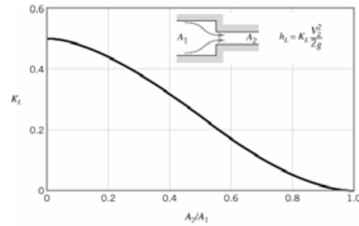
Table 8.2 page 445

There are several types of valves,

Globe
Gate
Swing check
Ball
Butterfly

Contractions: Use Figure 8.26 page 440

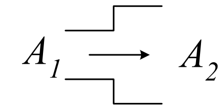




Note the velocity used is the *smaller* pipe, V_2

$$h_L = K_L \frac{V_2^2}{2g}$$

Expansions



Use the equation

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

Don't use figure 8.27

Note the velocity used is the *smaller* pipe, V_1

$$h_L = K_L \frac{V_1^2}{2g}$$

Example: A pipe system is made of 4” flanged steel pipe. Find K_L for:

Sharp edge inlet: *Figure 8.22* K_L =
Well rounded outlet: *Constant for all outlets,* K_L =
90 degree regular elbow: *Table 8.2* K_L =
T; branch flow: K_L =
T; line flow: K_L =
Gate value 1/2 closed: K_L =

4" to 6" sudden expansion *use equation* :

$$K_L = (1 - \frac{A_1}{A_2})^2 = (1 - \frac{\pi 4"^2 / 4}{\pi 6"^2 / 4})^2 = 0.31$$

4" to 6" sudden contraction *use Figure 8.26*:

$$\frac{A_2}{A_1} = \frac{\pi 4"^2 / 4}{\pi 6"^2 / 4} = 0.444$$

From Figure 8.26

$$, K_L = 0.35$$

Example: A pipe system. What are the minor losses?

4” nominal Schedule 80, steel, threaded connections

I.D.$_{4"}$ = 9.72 cm, $A_{4"}$ = 74.2 cm2
Q = 0.0002 m3/s
$V_{4"} = Q/A_{4"}$ = 0.0002/74.2 x10-6
= 2.7 m/s
I.D.$_{6"}$= 14.6 cm, $A_{6"}$ = 168 cm2
$V_{6"} = Q/A_{6"}$ = .0002/168 x 10-6
=1.19 m/s

Entrance

K_L = 0.04 (well rounded, r/d = 0.2)

Elbows

K_L = 0.64 (regular)
K_L = 0.23 (long)

Expansion use equation not figure

$$K_L = (1 - A_1/A_2)^2 = 0.56$$

Exit

K_L = 1.0

Sum minor losses

$$h_L = \sum K_L \frac{V^2}{2g} = \sum_{4"} K_L \frac{V_{4"}^2}{2g} + \sum_{6"} K_L \frac{V_{6"}^2}{2g}$$

$$= (.04 + .64 + 0.23 + .56)\frac{(2.7 m/s)^2}{2*9.81 m/s^2} + 1*\frac{(1.19 m/s)^2}{2*9.81 m/s^2}$$

h_L = 0.55 m + 0.06 m = 0.61 m

Example: Determine pipe diameter required to obtain a given flow at a between two reservoirs.
(Given Q & h_L , find D)

$$\frac{V_1^2}{2g} + \frac{p_1}{\rho g} + z_1 = \frac{V_2^2}{2g} + \frac{p_2}{\rho g} + z_2 + h_L$$

$$h_L = z_1 - z_2$$

$$h_L = \sum \frac{fL}{D}\frac{V^2}{2g} + \sum K_L \frac{V^2}{2g}$$

Note D is constant so V = constant

$$h_L = (\sum \frac{fL}{D} + \sum K_L)\frac{V^2}{2g}$$

Continuity

$$V = Q/A = 4Q/\pi D^2$$

Put it all together

$$h_L = (\sum \frac{fL}{D} + \sum K_L)\frac{8Q^2}{\pi D^4 g} = z_2 - z_1$$

Minor losses

$$\sum K_L = K_{L\,entrance} + K_{L\,exit} + 2*K_{L_{elbow}} + K_{L_{valve}}$$

$$\sum K_L = 0.8 + 1.0 + 2*0.3 + 0.15 = 2.55$$

There are two unknowns, f and D, but $f = \phi(D)$.

Find D with known Q and h_L

1. Assume a value of D. (Usually make a guess so that V = 1 m/s or 3 ft/s for liquids, 3x more for gasses.)
2. Calculate V and Re.
3. Determine f from Moody diagram.
4. Compute h_L from
$$h_L = (\sum \frac{fL}{D} + \sum K_L)\frac{8Q^2}{\pi D^4 g}$$
5. Compare computed h_L with know value.
6. If computed h_L not equal to true value, repeat.

Noncircular conduits: Many conduits are square or rectangular. Friction losses can be computed in noncircular ducts by use of the *hydraulic diameter*,

$D_h = 4\ A/P$ $\quad$ $P =$ "wetted perimeter"

Circle: $D_h = \frac{4A}{P} = \frac{4\pi(D^2/4)}{\pi D} = D$

Square: $D_h = \frac{4A}{P} = \frac{4S^2}{4S} = S$

Rectangle: $D_h = \frac{4A}{P} = \frac{4ab}{2(a+b)}$

Reynolds Number use D_h: $\mathrm{Re}_h = \frac{\rho V D_h}{\mu}$

Example: A plastic, 0.2 x 0.5 m air duct with $Q = 0.3\mathrm{m}^3/\mathrm{s}$. What is h_L per meter of length?

$$D_h = \frac{4A}{P} = \frac{4ab}{2(a+b)} = \frac{4 \cdot 0.2 \cdot 0.5}{2(0.2+0.5)} = 0.29m$$

$V = Q/A = 0.3\mathrm{m}^3/\mathrm{s}/(0.2\mathrm{m}*0.5\mathrm{m}) = 3.0\ \mathrm{m/s}$

$$\mathrm{Re}_h = \frac{\rho V D_h}{\mu} = \frac{1.23\frac{kg}{m^3}3\frac{m}{s}0.29m}{1.79\times10^{-5}\frac{\mathrm{Ns}}{\mathrm{m}^2}} = 60{,}000$$

$\varepsilon/D_h = 0 \rightarrow$ *f = 0.013 from Moody diagram*

$$\frac{h_L}{L} = \frac{f}{D_h}\frac{V^2}{2g} = \frac{0.013}{0.29m}\frac{(3m/s)^2}{2\cdot 9.81m/s^2} = 0.021\frac{m}{m}$$

in pressure units

$$\frac{\Delta p}{L} = \frac{h_L}{L}\rho g = 0.021 \cdot 1.23 \cdot 9.81 = 0.25\ N/(m^2 - m)$$

For noncircular conduits

1. Calculate hydraulic diameter, $D_h = 4\ A/P$
2. Use D_h for D in **Re**, D-W, and f calculations.
3. Note that continuity remains, $Q = VA$, where A is the true area of the conduit.

Example:

What would be the maximum laminar flow and friction loss in the proceeding duct?

$$\mathrm{Re}_h = \frac{\rho V D_h}{\mu} = 2{,}100$$

$$V = \frac{2{,}300 \cdot \mu}{\rho D_h} = \frac{2{,}100 \cdot 1.79\times10^{-5}}{1.23 \cdot 0.29} = 0.10m/s$$

$$f = \frac{64}{\mathrm{Re}_h} = \frac{64}{2{,}100} = 0.025$$

$$\frac{h_L}{L} = \frac{f}{D_h}\frac{V^2}{2g} = \frac{0.025}{0.29}\frac{0.10^2}{2\cdot 9.81} = 4.5x10^{-5}m/m$$