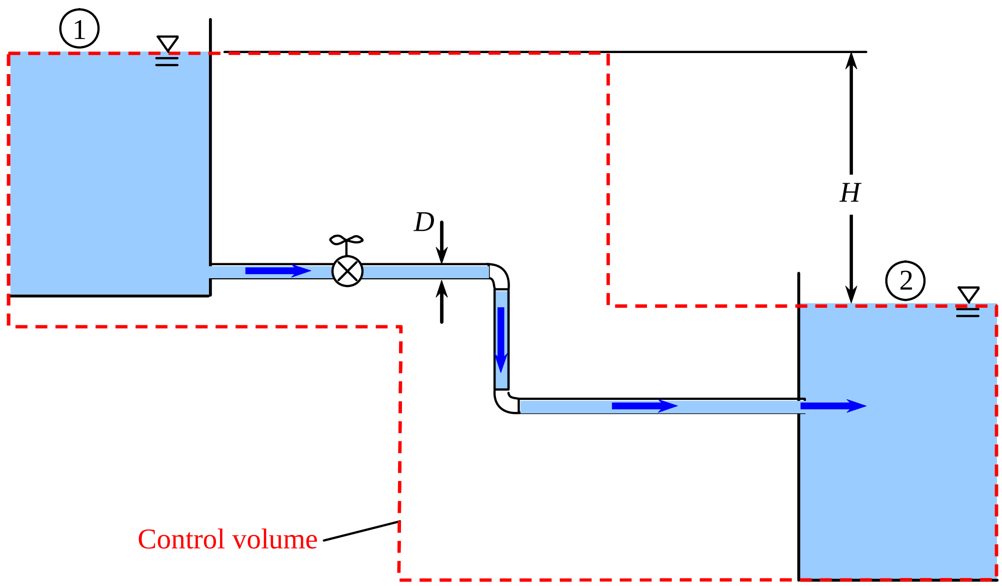
Today, we will:

- Do more example problems – major and minor losses in pipe flows
- Discuss diffusers and show a flow loop demonstration

Example Problem – Major and Minor Losses in a Piping System

Given: Water (ρ = 998. kg/m^3, μ = 1.00 × 10^{-3} kg/m·s) flows *by gravity alone* from one large tank to another, as sketched. The elevation difference between the two surfaces is H = 35.0 m. The pipe is 2.5 cm I.D. with an average roughness of 0.010 cm. The total pipe length is 20.0 m. The entrance and exit are sharp. There are two regular threaded 90-degree elbows, and one fully open threaded globe valve.



To do: Calculate the volume flow rate through this piping system.

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. 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):

$$\boxed{P_1 = P_2 = P_{\text{atm}}}$$

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

$$\boxed{V_1 = V_2 \approx 0}$$

Therefore, the energy equation reduces to $\boxed{h_L = z_1 - z_2 = H}$

- Next, we add up all the irreversible head losses, both major and minor. 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:

$$\boxed{h_L = \left(f\frac{L}{D} + \sum K_L \right)\frac{V^2}{2g}}, \ \& \ \boxed{\text{Re} = \frac{\rho D V}{\mu}} \ \boxed{\dot{V} = V\frac{\pi D^2}{4}} \ \boxed{\frac{\varepsilon}{D} = \frac{0.010 \text{ cm}}{2.5 \text{ cm}} = 0.004}$$

- We also need either the Moody chart or one of the empirical equations that can be used in place of the chart (e.g., the Colebrook equation).

The rest of this problem will be solved in class. (2)

Minor losses (table 8.4)

$$\Sigma K_L = \underset{\text{inlet}}{0.50} + \underset{\text{2 elbows}}{2(0.90)} + \underset{\text{globe valve}}{10} + \underset{\alpha \text{ @ exit}}{1.05}$$

(assume fully developed turb. flow @ exit of pipe)

$$\underline{\Sigma K_L = 13.35}$$

Iteration is required:

Solution A: ("by hand")

· Solve (2) for V →

$$\boxed{V = \sqrt{\frac{2gH}{f\,L/D + \Sigma K_L}}} \quad (3)$$

· Iteration procedure

Moody chart or Colebrook eq

$\left(\frac{\varepsilon}{D} = 0.004\right)$

Guess f (–)	Calc. V from (3) m/s	Calc Re (–)	Look up f @ this Re (–)
guess → 0.03	4.287	1.070×10^5	0.029
0.029	4.334	1.081×10^5	0.0294
0.0294	4.315	1.077×10^5	0.02943
0.02943	4.314	1.076×10^5	0.02943

CONVERGED!

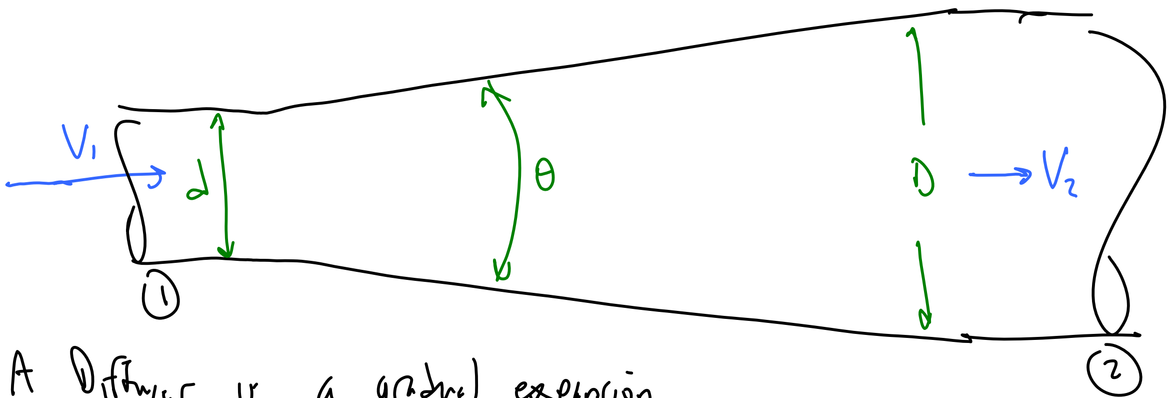
Finally $\dot{V} = V\dfrac{\pi D^2}{4} = \left(4.314\ \frac{m}{s}\right)\dfrac{\pi(0.025\ m)^2}{4} = \boxed{2.12 \times 10^{-3}\ m^3/s = \dot{V}}$

Solution B – Use EES or Matlab ...

See pdf file & EES file on website

D. Diffusers (Yes there is a free lunch!)

1. Introduction



· A Diffuser is a gradual expansion

· A diffuser has a minor loss coefficient eg. Table 8.4

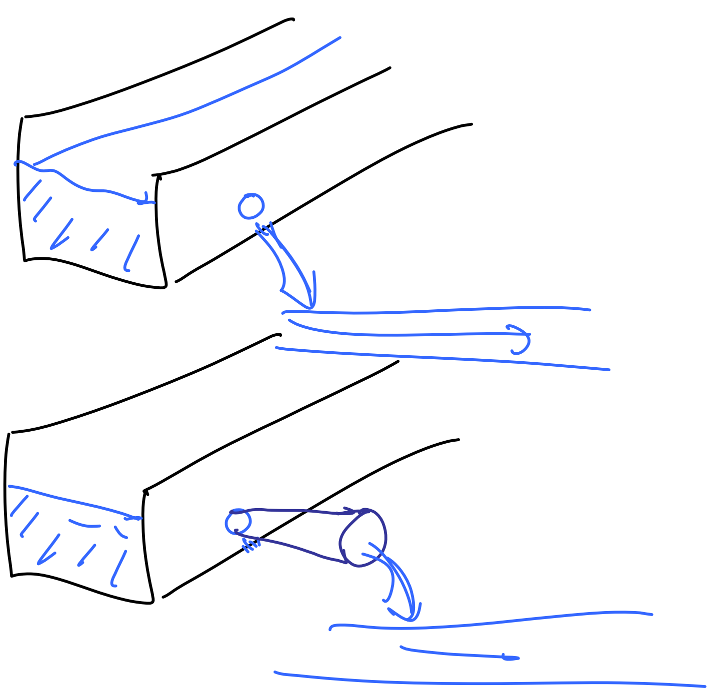
for $\frac{d}{D} = 0.6$ & $\theta = 20°$, $K_L = 0.15$

based on V_1 the larger V

· However, even taking the minor loss into account, P still rises through the diffuser!

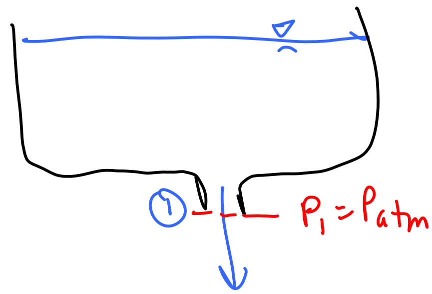
$$\boxed{P_2 > P_1}$$

Roman aqueduct



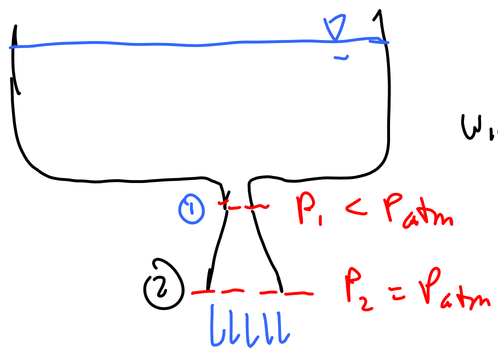
Our demo:

No diffuser



with diffuser added

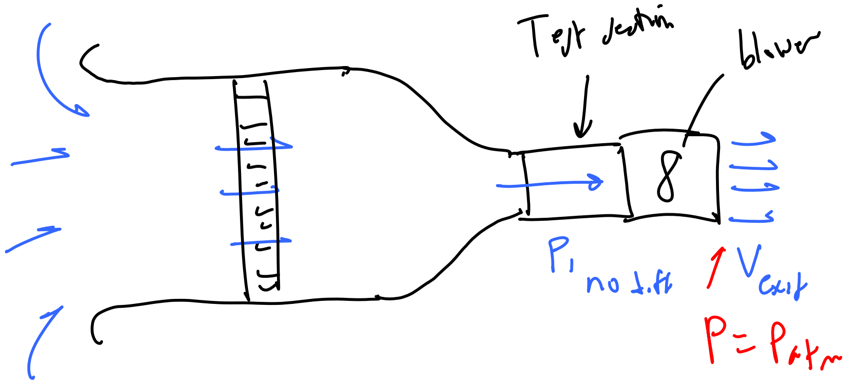
Higher flow rate "for free"

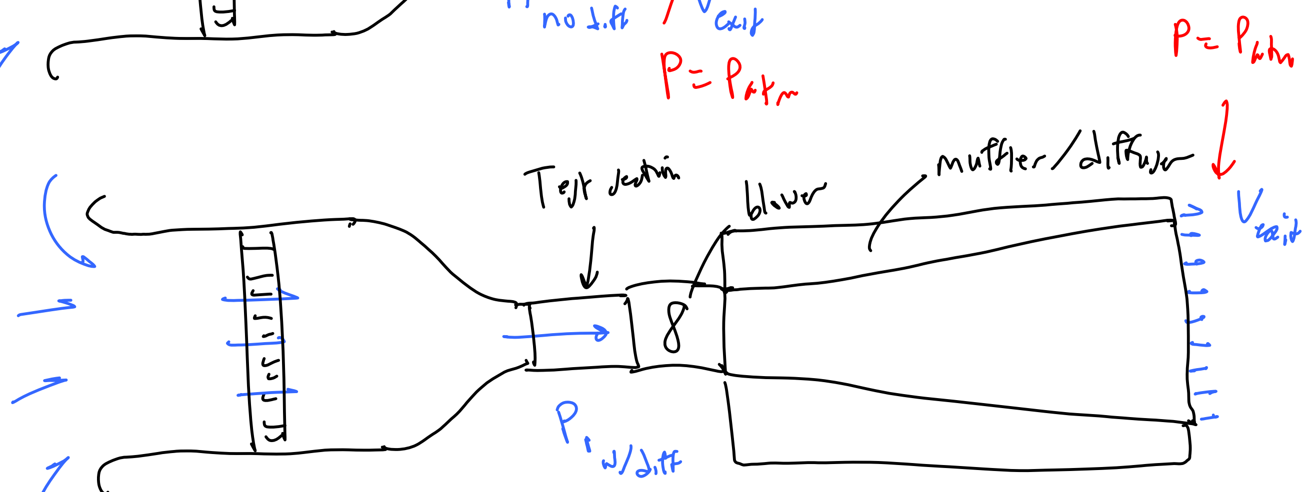


$P_2 > P_1$ in a diffuser

Practical Examples

- Wind tunnel in Fluids lab:

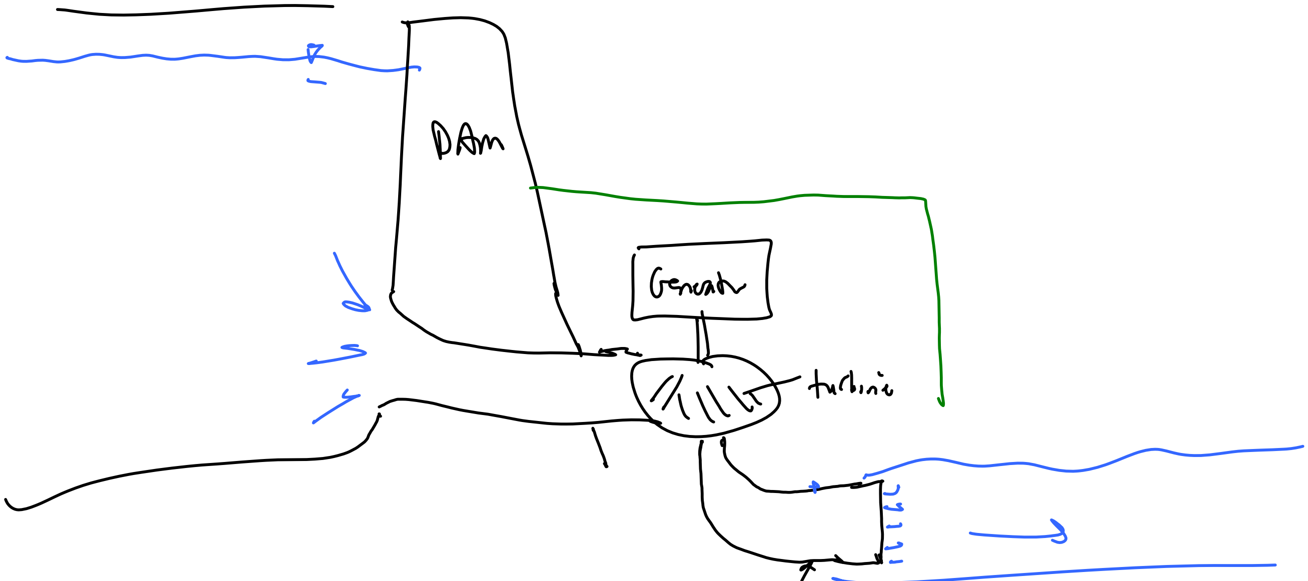




$\boxed{V_{w/diffuser} > V_{w/o\ diffuser} \text{ @ test section}}$

$P_1\ w/diff < P_1\ no\ diff$ $\therefore$ Velocity increases

· Hydraulic dam



DRAFT TUBE

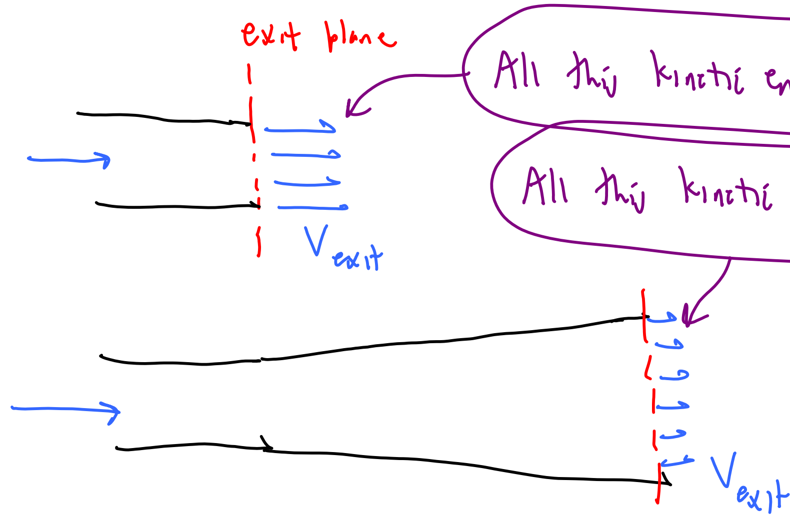
(diffuser + elbow) → increases volume flow rate

∴ increases $\dot{W}$ (power)

Another way to explain a diffuser:

Without

With



All this kinetic energy is "wasted"

All this kinetic energy is "wasted"

BUT,

since V_{exit} is smaller, the wasted k.e. is smaller

Less waste means higher efficiency! (for "free")