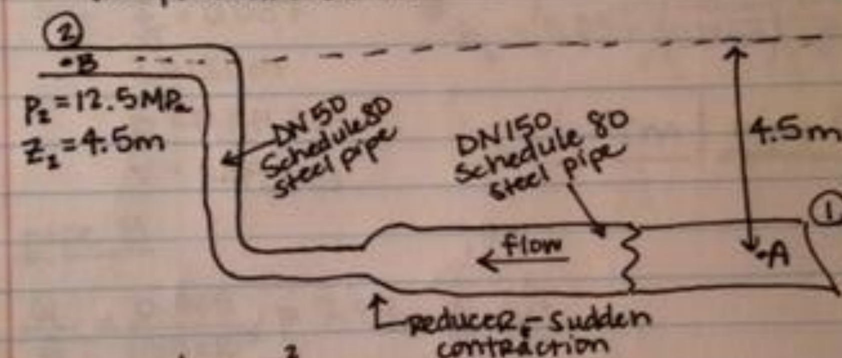
11.5 Oil is flowing at the rate of 0.015 m^3/s in the system shown in the figure. Data for the system are as follows:

- oil specific weight (γ) = 8.80 kN/m^3
- oil kinematic viscosity = 2.12×10^{-5} m^2/s
- length of DN 150 pipe = 180 m
- length of DN 50 pipe = 80 m
- elbows are long radius type ($\frac{L_e}{D} = 20$)
- pressure at B = 12.5 MPa

Considering all pipe friction & minor losses, calculate the pressure at A.



$$h_L = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

$$\text{Reynolds \#} = \frac{\text{fluid velocity} \times \text{I.D.}}{\text{kinematic viscosity}}$$

2.12×10^{-5} m^2/s

$$\frac{Q}{A} = v$$

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(\frac{D}{\epsilon})} + \frac{5.74}{R_e^{0.9}}\right)\right]^2}$$

(11.5 continued)

pipe A

$$\frac{Q}{A} = \frac{0.015}{1.682\times10^{-2}} = 0.89\,m/s \quad (v)$$

$$\text{Reynolds} = \frac{0.89 \times 0.1463}{2.12\times10^{-5}} = 6154.23 \Rightarrow \text{turbulent flow}$$

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(975.3)} + \frac{5.74}{6154.23^{0.9}}\right)\right]^2} = 0.037$$

$$\varepsilon = 1.5\times10^{-4} \ldots \frac{D}{\varepsilon} = 975.3$$

so... $f_T = 0.037$
$L = 180m$
$D = 0.1463m$
$V = 0.89\,m/s$

$$* \; h_L = (0.037)\left(\frac{180}{0.1463}\right)\left(\frac{0.89^2}{2(9.81)}\right)$$

$\boxed{h_L = 1.84m}$ **pipe A**

pipe B

$$\frac{Q}{A} = \frac{0.015}{1.905\times10^{-3}} = 7.87\,m/s \quad (v)$$

$$\text{Reynolds} = \frac{7.87 \times 0.0493}{2.12\times10^{-5}} = 18301.46 \Rightarrow \text{turbulent flow}$$

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(328.7)} + \frac{5.74}{18301.46^{0.9}}\right)\right]^2} \qquad \frac{D}{\varepsilon} = \frac{0.0493}{1.5\times10^{-4}}$$

$$f_T = 0.032$$

$$* \; h_L = (0.032)\left(\frac{8}{0.0493}\right)\left(\frac{7.87^2}{2(9.81)}\right)$$

so... $f_T = 0.032$
$L = 8m$
$D = 0.0493m$
$V = 7.87\,m/s$

$\boxed{h_L = 16.39\,m}$ **pipe B**

(11.5 continued)

elbows 90° long Radius 2 elbows

$\frac{L_e}{D} = 20$ f = same as pipe B = 0.032

$K = 20(0.032)$ $v = 7.87$

$* h_L = K\left(\frac{v^2}{2g}\right) = (0.64)(3.1568) = \boxed{2.02\ m}$

$\boxed{2 \text{ elbows} \rightarrow 4.04\ m \text{ total}}$

sudden contraction

$\frac{D_1}{D_2} = \frac{.150\ m}{.5\ m} = 3$; $v_2 = 7.87$, so $K = 0.37$

$h_L = 0.37\left(\frac{7.87^2}{2g}\right) = \boxed{1.17m}$

total losses:

pipe A → 1.84m
pipe B → 16.39m
both elbows → 4.04m
sudden contraction → 1.17 m

Bernoulli's

$$\frac{P_1}{8.80} + \frac{0.89^2}{19.62} - 1.84 - 16.39 - 4.04 - 1.17 = \frac{12,500}{9.80} + 4.5 + \frac{7.87^2}{19.62}$$

$$\frac{P_1}{8.8} + 0.04 - 23.44 = 1,420 + 4.5 + 3.1568$$

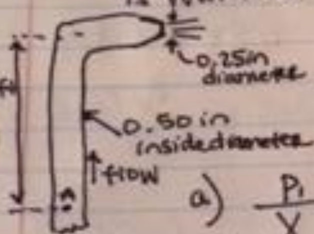
$$\frac{P_1}{8.8} = 1451.6$$

(pressure at A) ~~$P_1 = 2.86$ MPa~~

$P_1 = 12,773.7$ kPa or $\boxed{12.77\ MPa}$

81.

<u>11.13</u> A device designed to allow cleaning of walls & windows on the second floor of homes is similar to the system shown. Determine the velocity of flow from the nozzle if the pressure at the bottom is a) 20 psig & b) 80 psig. The nozzle has a loss coefficient K of 0.15 based on the outlet velocity head. The tube is smooth drawn aluminum & has an ID of 0.50in. The 90° bend has a radius of 6.0 in. The total length of straight tube is 20.0ft. The fluid is water at 100°F.



A = point 1

nozzle = point 2

a) $\frac{P_1}{\gamma} + \cancel{z_1} + \frac{v_1^2}{2g} - h_L = z_2 + \frac{v_2^2}{2g} + \cancel{\frac{P_2}{\gamma}}$

$\frac{20\frac{lb}{in^2}}{0.215\,lb/in^3} + \frac{v_1^2}{772.8\,in/s^2} - h_L = 216in + \frac{v_2^2}{772.8\,in/s^2}$

~ 54.63

$h_{tube} = f\left(\frac{240in}{0.50in}\right)\left(\frac{v^2}{772.8\,in/s^2}\right) - f(185369)$ Drawn tubing → $\varepsilon = 5.0\times10^{-}$

$A_{tube} = \pi r^2 = \pi(0.25)^2 = \underline{0.196in^2}$ $\quad A_{noz} = \pi(.125^2) = \underline{0.049\,in^2}$

$h_L = K\frac{v^2}{2g}$ — 0.15@nozzle

$v_2^2 = 772.8\,in/s^2\left(93.02in + \frac{v_1^2}{772.8\,in/s^2} - h_L - 216\right.$

$v_2^2 = 71885.856\,in^2/s^2 + v_1^2 - 772.8h_L - 166924.8\,in^2/s^2$

$v_2^2 = v_1^2 - 772.8h_L - 95038.944\,in^2/s^2$

v_1 — 54.63

$$\frac{P_1}{\gamma} + \cancel{z_1}^{\phi} + \frac{v_1^2}{2g} + h_A - h_L = \frac{\cancel{P_2}^{\phi}}{\cancel{\gamma}} + z_2 + \frac{v_2^2}{2g}$$

$g = 32.2\ ft/s^2 \rightarrow$ convert to inches $=$ ~~2.68 in/s²~~ $386.4\ in/s^2$

$P_1 = 20\ psig$; $80\ psig$ $\quad z_1 = \phi \quad z_2 = 18ft \rightarrow$ convert to inches $216 in$

$\gamma = 62.0\ lb/ft^3$ @ $100°F$

Dynamic viscosity $(\eta) = 1.42 \times 10^{-5}\ lb\text{-}s/ft^2$

Kinematic viscosity $(\nu) = 7.37 \times 10^{-6}\ ft^2/s$

Density $(\rho) = 1.93\ slugs/ft^3$ $\quad$ * $\boxed{\text{find } V_2}$

$$\frac{20\frac{lb}{in^2}}{0.215\frac{lb}{in^3}} + \phi + \frac{v_1^2}{2(386.4\ in/s^2)} + h_A - h_L = \frac{P_2}{\gamma} + 216in + \frac{v_2^2}{2(386.4)}$$

same

$\frac{62\ lb}{ft^3} \cdot \frac{1ft}{12in}$

$\downarrow$

93.02 in

$v_1 = \frac{Q}{A}$?

h_{intake}

h_{bend}

$h_{nozzle} = K\left(\frac{v_2^2}{2g}\right)$

$P_2 = \phi$?

$R_e =$ velocity $\times$ diameter $\times$ density $\times \frac{1}{\text{dyn. visc.}}$

$h_L = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$

how do I solve for anything without velocity or flow?

49:50 a) 32.44 ft/s
b) 81.44 ft/s

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} \cancel{+z_1} - h_L = z_2 + \frac{v_2^2}{2g}$$

$$\frac{20\frac{lb}{in^2}}{\frac{\cancel{93.02}\,lb}{0.215\,in^3}} + \frac{v_1^2}{2(386.4\,in/s^2)} - h_L = 216in + \frac{v_2^2}{2(386.4)}$$

$$772.8\left(93.02\,in + \frac{v_1^2}{772.8} - h_L - 216in\right) = v_2^2$$

$$h_L = K\frac{v^2}{2g}$$

$$h_{tube} = f\,\frac{240in}{0.50in}\,\frac{v^2}{772.8}$$

$$f\,(480)\frac{v^2}{772.8} = 0.15\,\frac{v^2}{772.8}$$

$$\frac{f(0.62)\,v^2}{0.62\,v^2} = \cancel{0.15}\ \frac{0.000194\,\cancel{v^2}}{0.62\,\cancel{v^2}}$$

$$\boxed{f = 0.00031}$$

$$\boxed{h_{nozzle} = 0.15\,\frac{v_2^2}{772.8}}$$

Drawn tubing $\varepsilon = 5.0\times10^{-6}$ ft

$$\frac{0.5\,in}{5.0\times10^{-6}\times12}$$