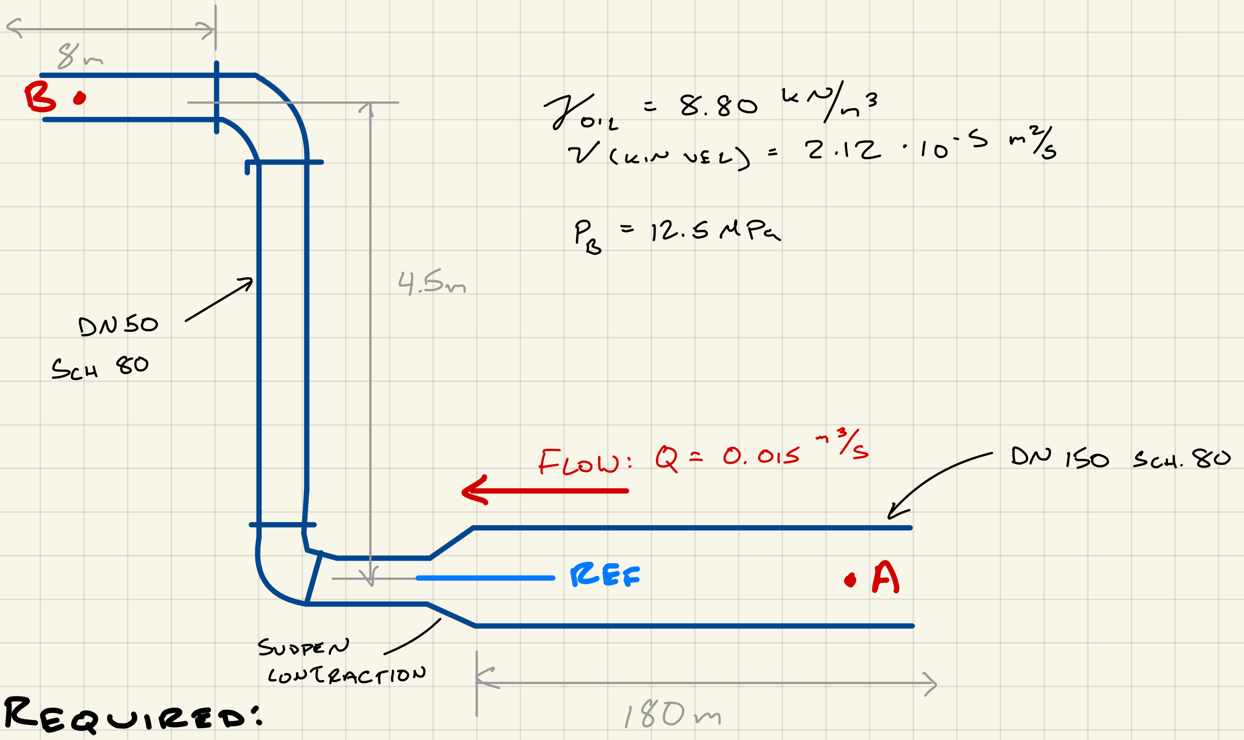
11-5 **GIVEN:**

OIL IS FLOWING IN THE FOLLOWING SYSTEM:



$\gamma_{oil} = 8.80\ kN/m^3$

ν (KIN VEL) $= 2.12 \cdot 10^{-5}\ m^2/s$

$P_B = 12.5\ MPa$

REQUIRED:

CALCULATE P @ A, CONSIDERING ALL MAJOR AND MINOR LOSSES

SOLUTION:

- START W/ BERNOULLI'S EQUATION. USING POINT A AND POINT B, W/ REFERENCE LOCATION MARKED ON DRAWING.

$$\cancel{h_p} + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + \cancel{z_1} = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + h_L + z_2$$

- SOLVE FOR OUR POINT OF INTEREST, P_A:

$$P_A = P_B + \left(\frac{V_B^2 - V_A^2}{2g} + h_L + z_2\right)\gamma \quad \text{———} \quad (1)$$

- 2 UNKNOWNS: P_A, h_L • FLOW RATE IS GIVEN AND CONSTANT, V_A AND V_B CAN BE CALCULATED.

- SUM UP h_L:

MAJOR LOSSES:

2x PIPES: 180m DN 150, 12.5m DN 50

MINOR LOSSES:

REDUCER (DN 150 - DN 50), 2x LONG RADIUS ELBOWS

11-5 CONT

PIPE LOSSES: $f \dfrac{L}{D} \dfrac{v^2}{2g}$

REDUCER LOSSES: $k \left(\dfrac{v_2^2}{2g} \right)$

ELBOW LOSSES: $20 f_T$

- TO CALCULATE PIPE LOSSES, MUST HAVE REYNOLDS NUMBER AND RELATIVE ROUGHNESS TO USE MOODY'S DIAGRAM:

$$Re = \frac{vD}{\nu} \qquad RR = \frac{D}{\varepsilon}$$

- MUST CALCULATE v_A AND v_B:

$$Q = vA \quad \therefore \quad v = \frac{Q}{A}$$

$$v_A = \frac{(0.015\ m^3/s)}{(0.01682\ m^2)} = \boxed{0.892\ m/s} \qquad v_B = \frac{(0.015\ m^3/s)}{(0.001905\ m^2)} = \boxed{7.87\ m/s}$$

$$Re_{,A} = \frac{(0.892\ m/s)(0.1463\ m)}{(2.12 \cdot 10^{-5}\ m^2/s)} = \boxed{6.16 \cdot 10^3}$$

$$Re_{,B} = \frac{(7.87\ m/s)(0.0493\ m)}{(2.12 \cdot 10^{-5}\ m^2/s)} = \boxed{1.83 \cdot 10^4}$$

$$RR_A = \frac{(0.1463\ m)}{(4.6 \cdot 10^{-5}\ m)} = \boxed{3180} \qquad RR_B = \frac{(0.0493\ m)}{(4.6 \cdot 10^{-5}\ m)} = \boxed{1071}$$

- USE MOODYS DIAGRAM FOR f_A AND f_B:

$$f_A = \boxed{0.036} \qquad f_B = \boxed{0.029}$$

- ELBOW f_T IS COMPLETE TURBULANCE f VALUE @ RR.

$$RR_B = 1071, \quad f_T = \boxed{0.0198}$$

- FOR SUDDEN REDUCTION, K IS FOUND FROM CHART 10.8 (p. 234) USING DIAMETER RATIO AND EXIT v:

$$\frac{D_1}{D_2} = \frac{D_A}{D_B} = \frac{(0.1463\ m)}{(0.0493\ m)} = \boxed{2.97}$$

$$v_{exit} = v_B = \boxed{7.87\ m/s}$$

$$K = \boxed{0.367}$$

11-5 CONT

- SOLVE AND SUM h_L:

LARGE PIPE:

$$h_{L_1} = f_A \frac{L_A}{D_A}\frac{v_A^2}{2g} = (0.036)\frac{(180\,m)}{(0.1463m)}\frac{(0.892\,m/s)^2}{2(9.81\,m/s^2)} = \boxed{1.80\,m}$$

SMALL PIPE:

$$h_{L_2} = f_B \frac{L_B}{D_B}\frac{v_B^2}{2g} = (0.029)\frac{(12.5\,m)}{(0.0493m)}\frac{(7.87\,m/s)^2}{2(9.81\,m/s^2)} = \boxed{23.21\,m}$$

ELBOWS:

$$h_{L_3} = h_{L_4} = K\frac{v_B^2}{2g} = 20\,f_t\frac{v_B^2}{2g} = 20(0.0198)\frac{(7.87\,m/s)^2}{(2\cdot 9.81\,m/s^2)} = \boxed{1.25\,m}$$

REDUCER:

$$h_5 = K\left(\frac{v_2^2}{2g}\right) = (0.367)\frac{(7.87\,m/s)^2}{2(9.81\,m/s^2)} = \boxed{1.16\,m}$$

$$h_L = h_1 + h_2 + 2h_3 + h_5 = (1.8m) + (28.81m) + 2(1.25m) + (1.16m)$$

$$= \boxed{34.27\,m}$$

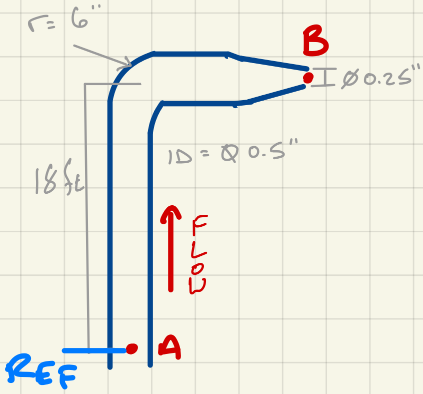
- SOLVE (1):

$$P_A = (12{,}500\,kPa) + \left(\frac{7.87\,m/s^2 - 0.892\,m/s^2}{2(9.81\,m/s^2)} + (34.27\,m) + (4.5\,m)\right)(8.8\,kN/m^3)$$

$$= 12{,}805\,kPa = \boxed{12.87\,MPa}$$

11-13 **Given:**

A device designed to clean 2nd story walls + windows is presented below:



Total length of straight tube: 20'

Fluid: H_2O @ 100°F

K @ nozzle = 0.15

Pipe: Smooth Drawn Alum

Required:

Determine the velocity of flow from the nozzle if

a) $P_{@BOT} = 20$ psig
b) $P_{@BOT} = 80$ psig

Solution:

- Start w/ Bernoulli's equation, using points A and B, w/ REF marked on drawing

$$\cancel{h_p} + \frac{V_A^2}{2g} + \frac{P_A}{\gamma} + \cancel{z_1} = \frac{V_B^2}{2g} + \cancel{\frac{P_B}{\gamma}} + h_L + z_2$$

- V_A, V_B and h_L are unknown
- Repace V in terms of Q and A. Q is constant:

$$Q = VA \quad \therefore \quad V = \frac{Q}{A}$$

$$\frac{Q^2}{A_A^2 \cdot 2g} + \frac{P_A}{\gamma} = \frac{Q^2}{A_B^2 \cdot 2g} + h_L + z_2$$

- Solve for Q in terms of h_L

$$\frac{Q^2}{\left(\pi\left(\frac{0.0417\,ft}{2}\right)^2\right)^2 \cdot 2(32.2\,ft/s^2)} + \frac{(2880\,psf)}{(62\,lb/ft^3)}$$
$$= \frac{Q^2}{\left(\pi\left(\frac{0.0208}{2}\right)^2\right)^2 \cdot 2(32.2\,ft/s^2)} + h_L + (18\,ft)$$

11-13 Cont

$$8325.11\,Q^2 + 46.45\,ft = 134487\,Q^2 + h_L + 18\,ft$$

$$Q^2 = \frac{28.45\,ft - h_L}{126162\ ft^5/s^2} \quad \text{———} \quad (2)$$

- CREATE EQUATION FOR h_L IN TERMS OF Q:

MAJOR LOSSES:

$$\text{PIPE FRICTION} = f\frac{L}{D}\frac{v^2}{2g} = f\frac{L}{D}\frac{Q^2}{A^2 \cdot 2g}$$

MINOR LOSSES:

$$\text{ELBOW} = 30 f_T \frac{v^2}{2g} = 30 f_T \frac{Q^2}{A^2 \cdot 2g}$$

$$\text{NOZZLE} = 0.15\frac{v^2}{2g} = 0.15\frac{Q^2}{A^2 \cdot 2g}$$

- f FOR A SMOOTH PIPE IS A FUNCTION OF REYNOLD'S NUMBER:

$$f = \frac{64}{Re} \qquad Re = \frac{vD}{\nu} \qquad \therefore\ f = \frac{64\nu A}{QD}$$

- BUILD h_L EQUATION:

$$A = \pi\left(\frac{D}{2}\right)^2 = \pi\left(\frac{0.0417\,ft}{2}\right)^2 = \boxed{0.00137\,ft^2}$$

$$h_L = \frac{64\nu \cancel{A}}{\cancel{Q}D}\frac{L}{D}\frac{Q^{\cancel{2}}}{A^{\cancel{2}}2g} + 30\cdot\frac{64\nu\cancel{A}}{\cancel{Q}D}\cdot\frac{Q^{\cancel{2}}}{A^{\cancel{2}}2g} + 0.15\frac{Q^2}{A^2\cdot 2g}$$

$$= \frac{64\cdot\nu\cdot L\cdot Q}{D^2\cdot 2g\cdot A} + 30\cdot\frac{64\cdot\nu\cdot Q}{D\cdot 2g\cdot A} + 0.15\frac{Q^2}{A^2\cdot 2g}$$

$$= \frac{64\cdot(7.37\cdot 10^{-6}\,ft^2/s)\cdot(20\,ft)\cdot Q}{(0.0417\,ft)^2\cdot 2(32.2\,ft/s^2)\cdot(0.00137\,ft^2)} + \frac{30\cdot 64\cdot(7.37\cdot 10^{-6}\,ft^2/s)\cdot Q}{(0.0417\,ft)\cdot 2(32.2\,ft/s^2)(0.00137\,ft^2)}$$

$$+ \frac{0.15\,Q^2}{(0.00137\,ft^2)^2\cdot 2(32.2\,ft/s^2)} = 61.49\,Q + 3.85\,Q + 1241\,Q^2$$

$$= 65.34\,Q + 1241\,Q^2$$

11-13 cont

- REPLACE h_L IN (2):

$$Q^2 = \frac{28.45\ ft - (65.34Q + 1241Q^2)}{126162\ ft^5/s^2}$$

- CREATE QUADRATIC FORMULA:

$$127403\,Q^2 + 65.34Q - 28.45$$

$$Q = \boxed{0.01469\ ft^3/s}$$

- SOLVE FOR V_B:

$$V_B = \frac{Q}{A_B} = \frac{(0.01469\ ft^3/s)}{\pi\left(\frac{0.0208\ ft}{2}\right)^2} = \boxed{43.23\ ft/s}$$ FOR a)

- FOR b) $P_A = 80$ psig:

$$127403\,Q^2 + 65.34\,Q - 167.806 = 0$$

$$Q = 0.036\ ft^3/s$$

- SOLVE FOR V_B:

$$V_B = \frac{Q}{A_B} = \frac{(0.036\ ft^3/s)}{\pi\left(\frac{0.0208\ ft}{2}\right)^2} = \boxed{105.9\ ft/s}$$ FOR b)