MET330

11.5 OIL IS FLOWING AT THE RATE OF 0.015 m^3/s IN THE SYSTEM SHOWN. DATA FOR THE SYSTEM IS AS FOLLOWS: $\gamma_{oil} = 8.8\ \frac{kN}{m^3}$ $\nu = 2.12 \times 10^{-5}\ \frac{m^2}{s}$

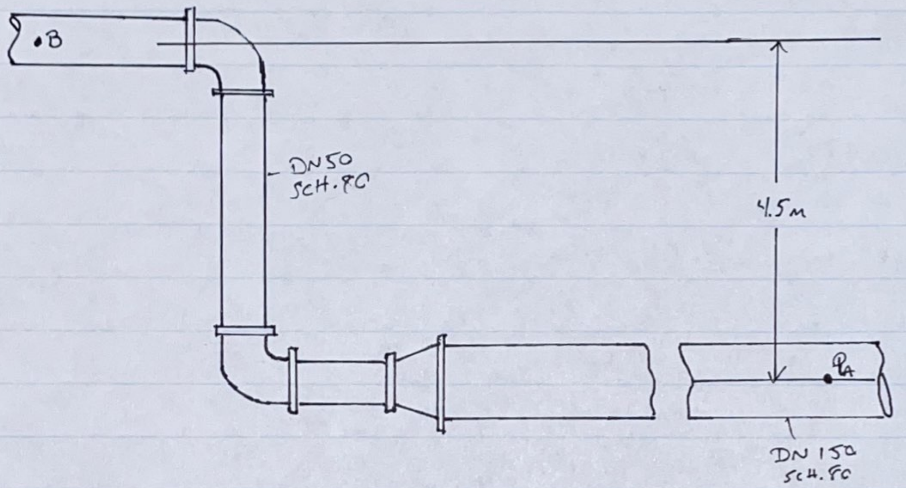
$L_A = 180\ m$ (DN 150) $A_A = 1.682 \times 10^{-2}\ m$

$L_B = 8\ m$ (DN 50) $A_B = 1.905 \times 10^{-3}\ m$

ELBOWS: LONG RADIUS TYPE

$P_B = 12.5\ MPa$

CONSIDERING ALL PIPE FRICTION AND MINOR LOSSES, CALCULATE THE PRESSURE AT A.



$V_A = \frac{Q}{A_A} = \frac{0.015\ \frac{m^3}{s}}{1.682 \times 10^{-2}\ m^2} = 0.8918\ \frac{m}{s}$

SOLUTION: $Q = 0.015\ \frac{m^3}{s}$, $A_B = 1.905 \times 10^{-3}\ m^2 \rightarrow V_B = \frac{Q}{A_B} = \frac{0.015\ m^3/s}{1.905 \times 10^{-3}\ m^2} = 7.874\ \frac{m}{s}$

$$\frac{P_A}{\gamma_{oil}} + \cancel{z_A}^{0} + \frac{V_A^2}{2g} + \cancel{h_A}^{0} - h_L = \frac{P_B}{\gamma_{oil}} + z_B + \frac{V_B^2}{2g} \rightarrow \frac{P_A}{\gamma_{oil}} = \frac{P_B}{\gamma_{oil}} + z_B + \frac{V_B^2}{2g} - \frac{V_A^2}{2g} + h_L$$

$N_{R_A} = \frac{V_A D_A}{\nu}$, $D_A = 146.3\ mm \rightarrow 0.1463\ m$, $N_{R_A} = \frac{(0.8918\ \frac{m}{s})(0.1463\ m)}{2.12 \times 10^{-5}\ \frac{m^2}{s}} = 6154.26$

$N_{R_B} = \frac{V_B D_B}{\nu}$, $D_B = 49.3\ mm \rightarrow 0.0493\ m$, $N_{R_B} = \frac{(7.874\ \frac{m}{s})(0.0493\ m)}{2.12 \times 10^{-5}\ \frac{m^2}{s}} = 18310.8$

$\frac{D_A}{\varepsilon} \rightarrow \frac{0.1463\ m}{4.6 \times 10^{-5}\ m} = 3180.43$, $\frac{D_B}{\varepsilon} = \frac{0.0493\ m}{4.6 \times 10^{-3}\ m} = 1071.74$ USING MOODY'S $\rightarrow f_A = 0.015$

$f_B = 0.019$

(PIPE A) $h_{L_A} = f_A \frac{L}{D} \cdot \frac{V_A^2}{2g} \rightarrow (0.015)\left(\frac{180\ m \cdot 0.8918^2\ \frac{m}{s}}{0.1463\ m \cdot (2 \times 9.81\ \frac{m}{s^2})}\right) = 0.748\ m$

(CONTRACTION) $h_{L_{CON.}} = K \frac{V_B^2}{2g} \rightarrow$ USING FIG. 10.8, pg 234 FOR SUDDEN CONTRACTION, $(0.37)\left(\frac{7.874^2\ \frac{m}{s}}{2 \times 9.81\ \frac{m}{s^2}}\right) = 1.169\ m$

(2 ELBOWS) $h_{L_{ELB.}} = K \frac{V_B^2}{2g} \rightarrow (20 \times 0.019)\left(\frac{7.874^2\ \frac{m}{s}}{2 \times 9.81\ \frac{m}{s^2}}\right) = 1.201\ m \times 2 = 2.402\ m$

(PIPE B) $h_{L_B} = f_B \frac{L}{D} \cdot \frac{V_B^2}{2g} \rightarrow (0.019)\left(\frac{8\ m \times 7.874^2\ \frac{m}{s}}{0.0493\ m\ (2 \times 9.81)}\right) = 9.743\ m$

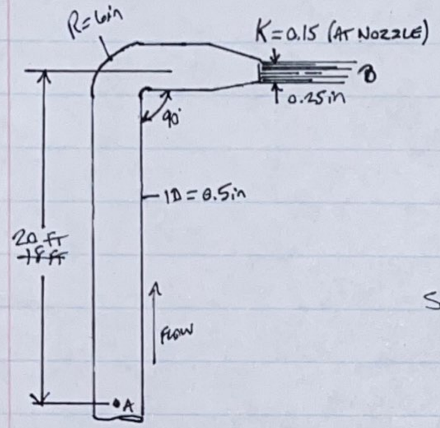
$$\frac{P_A}{\gamma_{oil}} = \frac{12.5 \times 10^6\ Pa}{8.8\ \frac{kN}{m^3}} + 4.5\ m + \frac{7.874^2\ \frac{m}{s}}{2(9.81)} + \left(\frac{-0.8918^2\ \frac{m}{s}}{2(9.81)}\right) + 0.748 + 1.169 + 2.402 + 9.743\ m$$

$P_A = (1442.14)(8.8 \times 10^3) = 1.269 \times 10^7\ Pa \rightarrow 12.69\ MPa$

$P_A = 12.69\ MPa$

MET 330

11.13 A DEVICE DESIGNED TO ALLOW CLEANING OF WALLS AND WINDOWS ON THE SECOND FLOOR OF HOMES IS SIMILAR TO THE SYSTEM SHOWN. DETERMINE THE VELOCITY OF FLOW FROM NOZZLE IF THE PRESSURE AT THE BOTTOM IS (A) 20 psig AND (B) 80 psig. THE NOZZLE HAS A LOSS COEFFICIENT (K) OF 0.15 BASED ON OUTLET VELOCITY HEAD. TUBE IS SMOOTH DRAWN ALUMINUM W/ ID = 0.5 in. THE 90° BEND HAS A RADIUS OF 6 in. TOTAL LENGTH OF STRAIGHT TUBE IS 20 FT. FLUID IS WATER @ 100 F.



P_A = (A) 20 psig, (B) 80 psig

GIVEN: WATER @ 100F → $\gamma = 62 \frac{lb}{ft^3}$, $\rho = 1.93 \frac{slugs}{ft^3}$,
SMOOTH DRAWN ALUMINUM

$D_A = 0.5\,in \cdot \frac{1\,ft}{12\,in} = 0.0417\,ft$, $A_A = \frac{\pi}{4}(0.0417\,ft)^2 = 0.00137\,ft^2$

$P_A = 20 \frac{lb}{in^2} \cdot \frac{144\,in^2}{1\,ft^2} = 2880 \frac{lb}{ft^2}$ $\qquad \nu = 7.37 \times 10^{-6} \frac{ft^2}{s}$ @ 100F

$= 80 \frac{lb}{in^2} \cdot (\;\;) = 11520 \frac{lb}{ft^2}$ $\qquad \varepsilon = 5 \times 10^{-6}$ (TABLE 8.2)

SOLUTION: SINCE Q (VOLUME FLOW RATE) AND V_A (INITIAL VELOCITY) ARE UNKNOWN, THIS IS A CLASS II SYSTEM. I WILL HAVE TO USE THE FOLLOWING EQUATION PRIOR TO SOLVING FOR VELOCITY,

(CH. 11) $$Q = -2.22 D^2 \sqrt{\frac{g D h_L}{L}} \cdot \log\left(\frac{1}{3.7 \frac{D}{\varepsilon}} + \frac{1.784 \nu}{D \sqrt{\frac{g D h_L}{L}}}\right)$$

SOLVING FOR LOSSES, $\frac{D}{\varepsilon} = \frac{0.0417\,ft}{5 \times 10^{-6}\,ft} = 8340$ (FOR USE IN Q EQUATION)

(A) $$\frac{P_A}{\gamma} + z_A + \frac{V_A^2}{2g} + h_A - h_L = \frac{P_B}{\gamma} + z_B + \frac{V_B^2}{2g} \rightarrow h_L = \frac{P_A}{\gamma} - z_B$$

$$= \frac{2880 \frac{lb}{ft^2}}{62 \frac{lb}{ft^3}} - 20\,ft = 26.452\,ft$$

$h_L = 26.452$ FT

$$Q = -2.22(0.0417\,ft)^2 \sqrt{\frac{(32.2 \times 0.0417 \times 26.452)}{20}} \cdot \log\left(\frac{1}{3.7(8340)} + \frac{1.784(7.37 \cdot 10^{-6})}{0.0417\sqrt{\frac{32.2 \times 0.0417 \times 26.452}{20}}}\right)$$

$Q = 0.042291 \frac{ft^3}{s}$

$V = \frac{Q}{A} \rightarrow \frac{0.042291 \frac{ft^3}{s}}{0.00137\,ft^2} = \underline{\underline{30.869 \frac{ft}{s}}}$

(B) $h_L = \frac{P_A}{\gamma} - z_B \rightarrow \frac{11520 \frac{lb}{ft^2}}{62 \frac{lb}{ft^3}} - 20\,ft = 165.806\,ft = h_L$

$$Q = -2.22(0.0417\,ft)^2 \sqrt{\frac{(32.2 \times 0.0417 \times 165.806)}{20}} \cdot \log\left(\frac{1}{3.7(8340)} + \frac{1.784(7.37 \times 10^{-6})}{0.0417\sqrt{\frac{(32.2 \times 0.0417 \times 165.806)}{20}}}\right)$$

$Q = 0.115557 \frac{ft^3}{s}$

$V = \frac{Q}{A} \rightarrow \frac{0.115557 \frac{ft^3}{s}}{0.00137\,ft^2} = \underline{\underline{84.348 \frac{ft}{s}}}$