HW #2.3 | MET 330 | STEVEN BLEA | A

CHPT. 11.5

Given: Oil is flowing at a rate $0.015 \frac{m^3}{s}$.

System Data: Oil specific weight = $8.80 \frac{kN}{m^3}$

oil kinematic viscosity = $2.12 \times 10^{-5} \frac{m^2}{s}$

Length of DN 150 pipe = 180 m

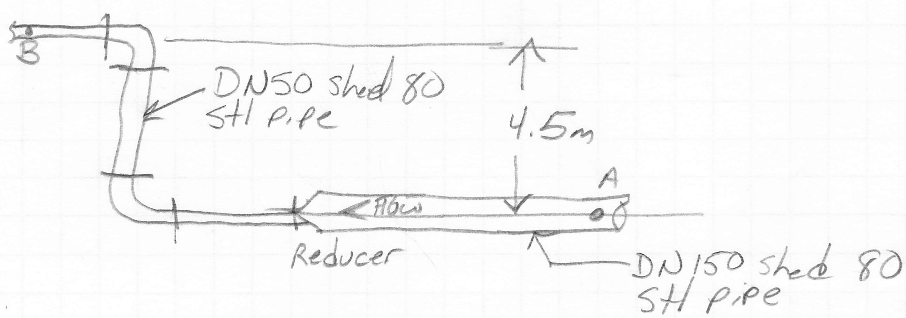
Length of DN 50 pipe = 8 m

elbows are long radius type

Pressure @ B = 12.5 MPa

find: considering all pipe friction and minor losses, calculate the pressure at A.

Drawing:



Solution: from www.Saylor.org

DN50 sch 80(xs) pipe ID = 49.3 mm = 0.0493m

DN150 sch 80 (xs) pipe ID = 146.3mm = 0.1463m

we need to calculate cross section of each pipe at points A and B.

Pipe A: $A_a = \frac{\pi * D_a^2}{4} = \frac{\pi * .1463^2}{4} = 0.01682\ m^2$

pipe B: $A_b = \frac{\pi * D_b^2}{4} = \frac{\pi * 0.0493^2}{4} = 0.001905\ m^2$

Using eq $V_a = \frac{Q_a}{A}$ we can find velocity of fluid in pipe A.

Q_a is given above

$V_a = \frac{0.015 \frac{m^3}{s}}{0.01682 m^2} = 0.8918 \frac{m}{s}$

Pipe B:

$V_b = \frac{0.015 \frac{m^3}{s}}{0.001905} = 7.874 \frac{m}{s}$

Using same flow rate we can find velocity in pipe B.

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Prob 11.5 cont

Now we need to find Reynolds number of side A using

$$N_{Ra} = \frac{V_a \times D_a}{(\mu/\rho)}$$

$\mu/\rho = \frac{\text{viscosity}}{\text{desity}}$ we will use, Kinematic Viscosity for $\frac{\mu}{\rho}$

$V_a = 0.8918\ m/s$
$D_a = 0.1463\ m$
$(\mu/\rho) = 2.12 \times 10^{-5}\ \frac{m^2}{s}$

SIDE A:

$$N_{Ra} = \frac{0.8918 \times 0.1463}{2.12 \times 10^{-5} \frac{m^2}{s}} = \underline{6154}$$

Calculating the $\frac{D_a}{\varepsilon}$ ratio we have $\frac{D_a}{\varepsilon} = \frac{0.1463\,m}{4.60\times10^{-5}\,m} = \underline{3180}$

wall roughness of 4.60×10^{-5}m for ε from pg 274 for steel pipe

Using MOODYS chart we have: $f_{sa} = 0.035$
$f_T = 0.0153$

Doing the same for side B:

$$N_{Ra} = \frac{V_a \times D_a}{(\mu/\rho)} = \frac{7.87 \times 0.0493}{2.12\times10^{-5}} = \underline{18300}$$

$$\frac{D_b}{\varepsilon} = \frac{0.0493}{4.6\times10^{-5}} = 1072$$

$f_{sb} = 0.028$
$f_T = 0.019$

Calc friction loss in Pipe:

$$h_1 = f_{sa} * \frac{L_a}{D_a} * \frac{V_a^2}{2g} \Rightarrow h_1 = 0.035 * \frac{180}{0.1463} * \frac{0.892^2}{2\times9.81} = \underline{1.746\,m}$$

SIDE B: $h_2 = f_{sb} * \frac{L_b}{D_b} * \frac{V_b^2}{2g} \Rightarrow h_2 = 0.028 * \frac{8}{0.0493} * \frac{7.87^2}{2\cdot9.81} = \underline{14.343\,m}$

Losses in elbows: each elbow is eq to 20ft pipe

$$h_3 = 2\times20 * f_T * \frac{V_b^2}{2g} \Rightarrow h_3 = 2*20*0.019*\frac{7.87^2}{2*9.81} = \underline{2.399\,m}$$

Loss in reducer: $h_4 = 0.37 * \frac{V_b^2}{2*g} \Rightarrow h_4 = 0.37*\frac{7.87^2}{2*9.81} = \underline{1.168\,m}$

Total Losses $= h_1 + h_2 + h_3 + h_4 = \underline{19.65693\,m}$

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PROBLEM 11.3 cont

Now to get pressure @ A (P_A) Reorganize equation from text is:

$$P_A = \gamma\left[h_L + \frac{P_B}{\gamma} + (z_B - z_A) + \left(\frac{v_B^2}{2g} - \frac{v_A^2}{2g}\right)\right]$$

substitute know values:

$$P_A = 8.80\left[19.65693 + \frac{12.5\times10^6}{8.80} + 4.5 + \left(\frac{0.897^2}{2\times9.81} - \frac{7.87^2}{2\times9.81}\right)\right]$$

$$\boxed{P_A = 12.74\ \text{Mpa}}$$

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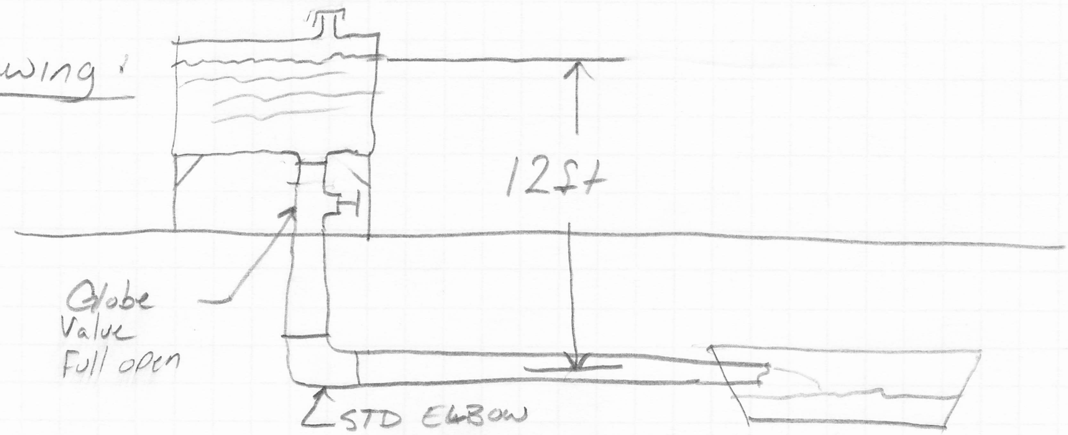
Problem 11.20

Given: A tank is to be drained to sewer. Determine size of new sch 40 steel pipe that will carry at least 400 gal/min of water at 80°F through system. Total length of pipe is 75 ft

Find: size of new sch 40 steel pipe to carry 400 gpm @ 80°F

Drawing:



Solution: working through example from textbook solutions:

energy balance between bottom of tank and end of pipe

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g} \qquad P_1 = \gamma h_1 \;\&\; P_2 = \gamma h_2$$

$$\frac{\gamma h_1}{\gamma} = z_1 + \frac{V_1^2}{2g} - h_z = \frac{\gamma h_2}{\gamma} + z_2 + \frac{V_2^2}{2g}$$ simplified now becomes

$h_1 + z_1 - h_L = h_2 + z_2$ subst. known values:

$(12 - x) + x - h_L = 0 + 0 \Rightarrow h_L = \underline{12 ft}$

Roughness for steel pipe (ε) is: 1.5×10^{-4} ft

Kinematic velocity (ν) @ 80°F from book is 9.15×10^{-6} ft²/s

Now calculate Diameter of pipe (D) using eq. 11-8 from pg 279

$$D = 0.66\left(\varepsilon^{1.25}\left(\frac{LQ^2}{gh_L}\right)^{4.75} + \nu Q^{9.4}\left(\frac{L}{gh_L}\right)^{5.2}\right)^{0.04}$$

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Subst. known values you get:

$$D = 0.66\left[(1.5\times10^{-4})^{1.25}\left(\frac{(75)\times(0.50)^2}{32.2\times12}\right) + (9.15\times10^{-6})(0.50)^{9.4}\times\left(\frac{75}{32.2\times12}\right)^{5.2}\right]^{0.04}$$

$$D = 0.66\left[(2.295\times10^{-9}) + (6.12\times10^{-10})\right]^{0.04} = \boxed{0.301\text{ ft}}$$