The problems discussed for this chapter pertained to series pipeline systems. Before solving any problem, it is important to determine which class the system falls into; I, II, or III. Class I is used when the system is completely identified, and the objective is to determine the pressure, head, or elevation. Class II is used when the volumetric flow rate is the objective when given the elevations, pipe sizes, valves and fittings, and allowable pressure drops. Lastly, class II is used when the general system layout and desired flow rate are known, but the pipe size is what is to be determined. In terms of equations, the only real new ones in this chapter are 11-3 and 11-8 (below). All the equations learned previously (Bernoulli's, continuity, Darcy's, etc.) are still used.

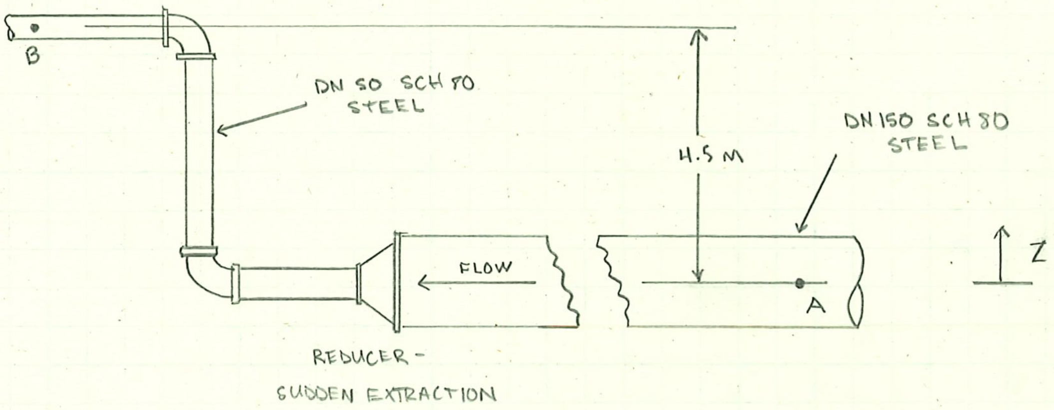
$$Q = -2.22D^2\sqrt{\frac{gDh_L}{L}\log\left(\frac{1}{\frac{3.7D}{\epsilon}}+\frac{1.784v}{D\sqrt{\frac{gDh_L}{L}}}\right)} \tag{11-3}$$

$$D = 0.66\left[\epsilon^{1.25}\left(\frac{LQ^2}{gh_L}\right)^{4.75}+vQ^{9.4}\left(\frac{L}{gh_L}\right)^{5.2}\right]^{0.04} \tag{11-8}$$

Most of the problems are straightforward when examined carefully. For a class III, where the objective is to determine pipe size, excel is frequently used to compute multiple iterations.

11.5

CALCULATE PRESSURE AT A FOR THE SYSTEM



DATA AND VARIABLES:

$Q = 0,016 \ m^3/s$

$\gamma_{OIL} = 8,80 \ kN/m^3$

$\nu = 2,12 \times 10^{-5} \ m^2/s$

$L_A = 180 \ m$

$L_B = 8 \ m$

LONG-RADIUS ELBOWS

$P_B = 12,5 \ MPa$

$A_A = 1,682 \times 10^{-2} \ m^2$

$A_B = 1.905 \times 10^{-3} \ m^2$

$D_A = 0.1463 \ m$

$D_B = 0.0493 \ m$

SOLUTION:

USING BERNOULLI'S:

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + \cancel{Z_A}^{0} - h_L = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B$$

$$\Rightarrow \frac{P_A}{\gamma} = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B - \frac{V_A^2}{2g} + h_L$$

VELOCITY AT EACH POINT:

$$V_A = \frac{Q}{A_A} = \frac{0.015 \ m^3/s}{0.01682 \ m^2} = \underline{0.8918 \ m/s}$$

$$V_B = \frac{Q}{A_B} = \frac{0.015 \ m^3/s}{0.001905 \ m^2} = \underline{7.874 \ m/s}$$

REYNOLD'S NUMBER, N_R, AT EACH POINT:

$$N_{RA} = \frac{V_A D_A}{\nu} = \frac{(0.8918)(0.1463)}{2.12 \times 10^{-5}} = 6154$$

$$N_{RB} = \frac{V_B D_B}{\nu} = \frac{(7.874)(0.0493)}{2.12 \times 10^{-5}} = 18311$$

BOTH ARE TURBULENT

RELATIVE ROUGHNESS OF PIPES

$$\frac{D_A}{\varepsilon} = \frac{0.1463}{4.6 \times 10^{-5}} = 3180$$

$$\frac{D_B}{\varepsilon} = \frac{0.0493}{4.6 \times 10^{-5}} = 1072$$

USING MOODY'S

$f_A = 0.016$

$f_B = 0.019$

DETERMINING LOSSES:

FOR PIPE A:

$$h_{LA} = f_A \frac{V_A^2 L}{2g D_A} = 0.016 \frac{(0.8918)^2(180)}{(2 \times 9.81)(0.1463)} = \underline{0.798 \text{ M}}$$

PIPE B:

$$h_{LB} = f_B \frac{V_B^2 L}{2g D_B} = 0.019 \frac{(7.874)^2(8)}{(2 \times 9.81)(0.0493)} = \underline{9.743 \text{ M}}$$

ELBOWS:

$$h_{LELBOW} = 20 f_B \frac{V_B^2}{2g} = (20 \times 0.019) \frac{7.874^2}{2 \times 9.81} = 1.2 \text{ M} \leftarrow$$

MULTIPLY BY 2 FOR BOTH ELBOWS

$$h_{LELBOW} = 1.2 \times 2 = \underline{2.4 \text{ M}}$$

CONTRACTION:

$$\frac{D_A}{D_B} = \frac{0.1463}{0.0493} = 2.97 \quad \text{AND} \quad V_B = 7.874$$

USING FIGURE 10.8, $K = 0.38$

$$h_{LCONT} = K \frac{V_B^2}{2g} = 0.38 \frac{7.874^2}{2 \times 9.81} = \underline{1.2 \text{ M}}$$

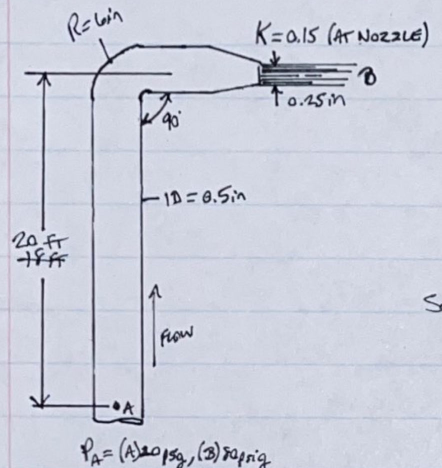
PLUGGING EVERYTHING BACK INTO BERNOULLI'S:

$$\frac{P_A}{8.80 \text{ KN/M}^3} = \frac{12.5 \times 10^6 \text{ PA}}{8.80 \text{ KN/M}^3} + \frac{(7.874 \text{ M/S})^2}{2 \times 9.81 \text{ M/S}^2} + 4.5 \text{ M} - \frac{(0.8918 \text{ M/S})^2}{2 \times 9.81 \text{ M/S}^2} + 0.798 \text{ M}$$
$$+ 9.743 \text{ M} + 2.4 \text{ M} + 1.2 \text{ M}$$

$$P_A = 12.691 \times 10^6 \text{ PA} = \boxed{12.691 \text{ MPA}}$$

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.



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

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

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

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

SOLUTION: SINCE Q (VOLUME FLOWRATE) 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) $$Q = -2.22 D^2 \sqrt{\frac{gDh_L}{L}} \cdot \log\left(\frac{1}{3.7\frac{D}{\varepsilon}} + \frac{1.784\nu}{D\sqrt{\frac{gDh_L}{L}}}\right)$$

SOLVING FOR LOSSES, $\frac{D}{\varepsilon} = \frac{0.0417 ft}{5\times10^{-6} ft} = 8340$ (FOR USE IN Q EQUATION)

(A) $$\frac{P_A}{\gamma} + \cancelto{0}{z_A} + \cancelto{Eq.}{\frac{V_A^2}{2g}} + \cancelto{N/A}{h_A} - h_L = \cancelto{0psig}{\frac{P_B}{\gamma}} + z_B + \cancelto{Eq.}{\frac{V_B^2}{2g}} \rightarrow h_L = \frac{P_A}{\gamma} - z_B$$

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

$h_L = 26.452\,FT$

$$Q = -2.22(0.0417ft)^2\sqrt{\frac{(32.2\times0.0417\times26.452)}{20}} \cdot \log\left(\frac{1}{3.7(8340)} + \frac{1.784(7.37\cdot10^{-6})}{0.0417\sqrt{\frac{32.2\times0.0417\times26.452}{20}}}\right)$$

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

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

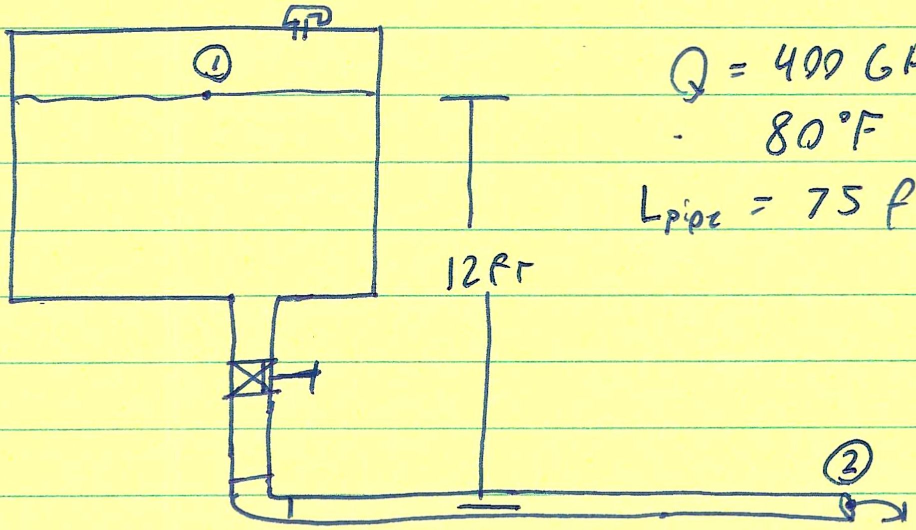
(B) $$h_L = \frac{P_A}{\gamma} - z_B \rightarrow \frac{11520\frac{lb}{ft^2}}{62\frac{lb}{ft^3}} - 20ft = 165.806\,ft = h_L$$

$$Q = -2.22(0.0417ft)^2\sqrt{\frac{(32.2\times0.0417\times165.806)}{20}} \cdot \log\left(\frac{1}{3.7(8340)} + \frac{1.784(7.37\times10^{-6})}{0.0417\sqrt{\frac{(32.2\times0.0417\times165.806)}{20}}}\right)$$

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

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

11-20



Q = 400 GPM

80°F

$L_{pipe} = 75$ ft

$$\frac{\cancel{P_1}}{\cancel{\gamma}} + \frac{\cancel{V_1^2}}{\cancel{2g}} + z_1 = \frac{\cancel{P_2}}{\cancel{\gamma}} + \frac{V_2^2}{2g} + \cancel{z_2} + h_L$$

$$Q = VA \qquad V = \frac{Q}{A}$$

$$z_1 = \frac{\left(\frac{Q}{A}\right)^2}{2g} + h_L$$

$$h_L = f\frac{L}{D}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g}$$

$$h_L = \left(f\frac{L}{D} + K_{valve} + K_{elbow}\right)\frac{V^2}{2g}$$

$$z_1 = \frac{V^2}{2g} + \frac{V^2}{2g}\left(f\frac{L}{D} + K_{valve} + K_{elbow}\right)$$

$$z_1 = \frac{V^2}{2g}\left(1 + f\frac{L}{D} + K_{valve} + K_{elbow}\right)$$

$$z_1 = \frac{\cancel{\left(\frac{Q}{A}\right)}^2}{2g}\left(f\frac{L}{D} + K_{valve} + K_{elbow}\right)$$

$$z_1(2g) = \cancel{\left(\frac{Q}{A}\right)^2}\left(f\frac{L}{D} + K_{valve} + K_{elbow} + K_{inlet}\right)\frac{16Q^2}{\pi D^4}$$

Use Excel

$D = 0.372\,ft$ ∴ 4in schedule 40 is closest without going below 40 GPM

Q	0.8912	ft^3/s
L	75	ft
z1	12	ft
Density	62.146	lb-s^2/ft^4
Dynamic Viscosity	0.0000177	lb-s/ft^2
Roughness	0.00015	ft

Diameter (ft)	Reynolds	Velocity (ft/s	f	kvalve	kelbow	kinlet	LHS	RHS	% diff
0.372	98538628	75.443817	0.01919314	6.52566752	0.575794193	0.5	772.8	771.2619	0.20%