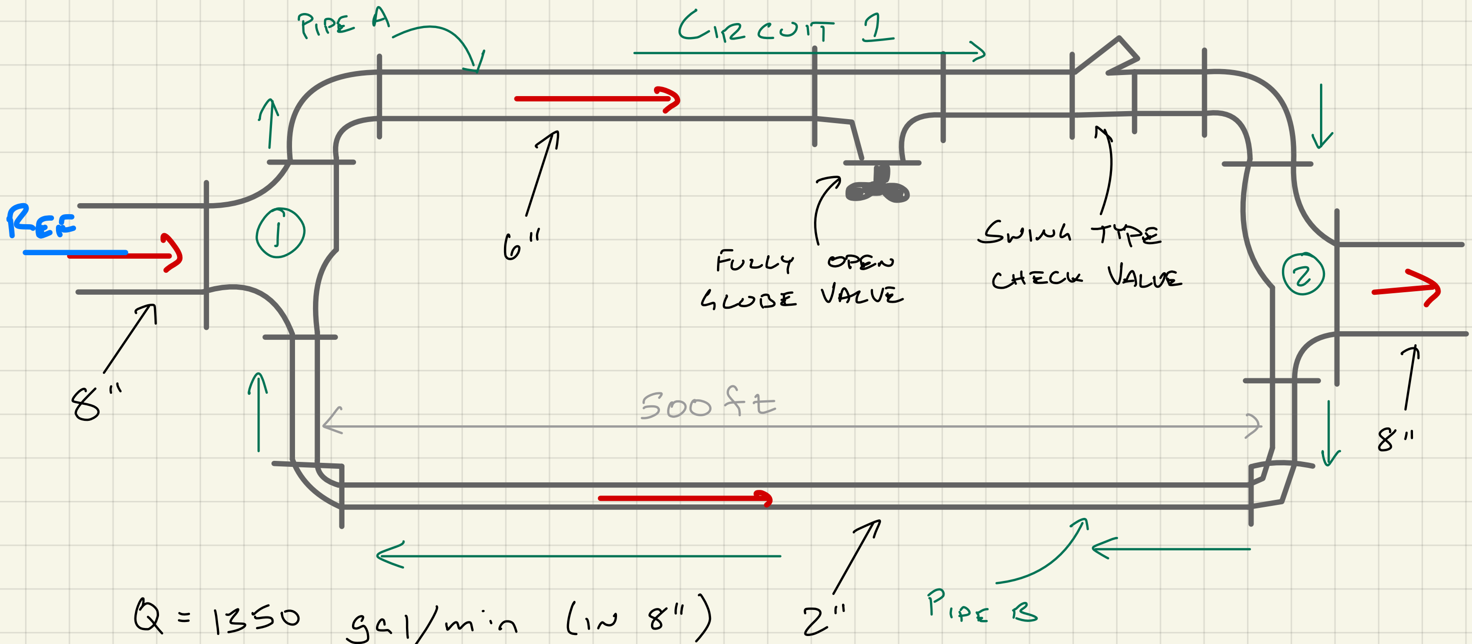
12-7 **Given:**

Benzene is flowing in the system below:



$Q = 1350$ gal/min (in 8")

$Sg_{Ben} = 0.87$

$T = 140°F$

All pipes = Sch 40

$\nu = 7.41 \cdot 10^{-6}$ ft²/s

$\gamma = 54.55$ lb/ft³

Required

Calculate the volume flow rate in the 6" and 2" pipes using the Cross technique

Solution:

• Step by step Hardy Cross Method:

1. $h = kQ^2$ • Set up headloss equations for each pipe

$$K = \frac{8(L + \Sigma L_e) f}{\pi^2 g D^5}$$

• This is the k for $h = kQ^2$, minor losses are accounted for w/ Le

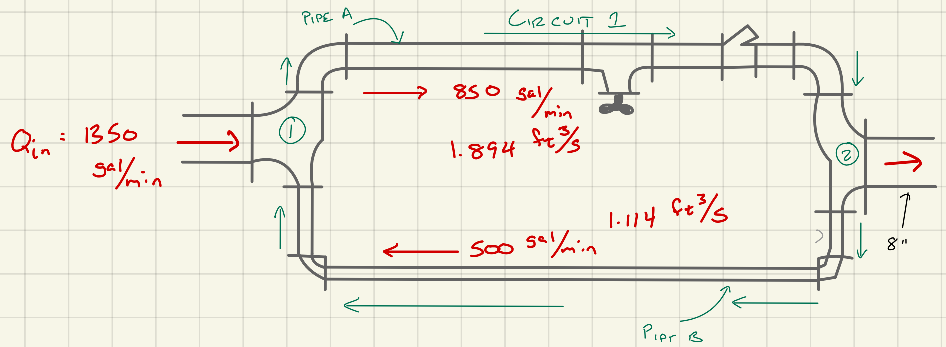
$Le_{elb} = 30$ $Le_{globe} = 340$ $Le_{valve} = 100$ • Minor losses in pipe A

$$k_A = \frac{8(500\text{ft} + (2 \cdot 30 + 340 + 100)\text{ft}) f_A}{\pi^2 (32.2 \text{ ft/s}^2)(0.5\text{ft})^5}$$

$$k_B = \frac{8(500\text{ft}) f}{\pi^2 (32.2 \text{ ft/s}^2)(0.1667\text{ ft})^5}$$

2. Geuss flow rate for each branch so that the total equals the flow out of the junction

12-7 cont



- Guessed 850 gal/min for Pipe A, 500 for Pipe B
  - Pipe B is going to the left, so its value will be negative going forward.

3. Divide series into closed loops

- This particular series only has a single loop, labeled Circuit 1

4. For each pipe, calculate the head loss w/ assumed Q.

Pipe A:

$$h_A = \frac{8\left(500\,ft + (2\cdot 30 + 340 + 100)\,ft\right) f_A}{\pi^2 (32.2\,ft/s^2)(0.5\,ft)^5} \cdot \left(1.894\,ft^3/s\right)^2$$

$$= 2889.64\, f_A$$

$$f_A = \frac{0.25}{\left(\log\left(\frac{1}{3.7\cdot D/\varepsilon} + \frac{5.47}{Re^{0.9}}\right)\right)^2}$$

$$= \frac{0.25}{\left(\log\left(\frac{1}{3.7\cdot 3333} + \frac{5.47}{(6.51\cdot 10^5)^{0.9}}\right)\right)^2}$$

$$= \boxed{0.016}$$

$$Re = \frac{VD}{\nu} = \frac{4Q\cdot D}{\pi D^2 \cdot \nu}$$

$$= \frac{4\left(1.894\,ft^3/s\right)\cdot(0.5\,ft)}{\pi\,(0.5)^2 \cdot 7.41\cdot 10^{-6}\,ft^2/s} = 6.51\cdot 10^5$$

$$\frac{D}{\varepsilon} = \frac{0.5\,ft}{1.5\cdot 10^{-4}\,ft} = 3333$$

$$h_A = 2889.64 \cdot 0.016 = \boxed{46.23\,ft}$$

Pipe B:

$$h_B = \frac{8(500\,ft)(0.019)}{\pi^2(32.2\,ft/s^2)(0.1667\,ft)^5} \cdot \left(1.114\,ft^3/s\right)^2 = \boxed{2305.42\,ft}$$

$$f_B = \frac{0.25}{\left(\log\left(\frac{1}{3.7\cdot 1111} + \frac{5.47}{(1.15\cdot 10^6)^{0.9}}\right)\right)^2}$$

$$= 0.019$$

$$Re = \frac{4\left(1.114\,ft^3/s\right)(0.1667\,ft)}{\pi\,(0.1667\,ft)^2 \cdot (7.41\cdot 10^{-6}\,ft^2/s)} = 1.15\cdot 10^6$$

$$D/\varepsilon = \frac{(0.1667\,ft)}{(1.5\cdot 10^{-4}\,ft)} = 1111\,ft$$

12-7 cont

5. ALGEBRAICALLY SUM HEAD LOSSES TAKING DIRECTION INTO ACCOUNT

$$\Sigma h_1 = h_A + h_B = \overrightarrow{46.23 \text{ ft}} + (\overleftarrow{-2305.42 \text{ ft}})$$

$$= -2259.19$$

6. CALCULATE 2kQ FOR EACH PIPE

$$A = 2 \cdot 12.89 \cdot 1.894 \text{ ft}^3/\text{s} = 48.83$$

$$B = 2 \cdot 1857.72 \cdot 1.114 \text{ ft}^3/\text{s} = 4139$$

7. SUM ALL 2kQ VALUES FOR EACH CIRCUIT, ASSUMING ALL POSITIVE VALUES

$$\Sigma 2kQ = 48.83 + 4139 = 4187.83$$

8. FOR EACH CIRCUIT, CALCULATE A ΔQ

$$\Delta Q = \frac{\Sigma h}{\Sigma 2kQ} = \frac{(-2259.19)}{(4187.85)} = -0.539$$

9. FOR EACH PIPE, CALCULATE A NEW ESTIMATED VALUE OF Q

$$Q' = Q - \Delta Q$$

$$Q'_A = 1.894 - (-0.539) = 2.433$$

$$Q'_B = -1.114 - (-0.539) = -0.575$$

• Q_B IS NEGATIVE B/C IT FLOWS TO THE RIGHT ←

10. REPEAT 4-8 UNTIL ΔQ BECOMES NEGLIBLY SMALL

• STEP 10 COMPLETED IN EXCEL, SEE TABLE.

FINAL SOLUTION:

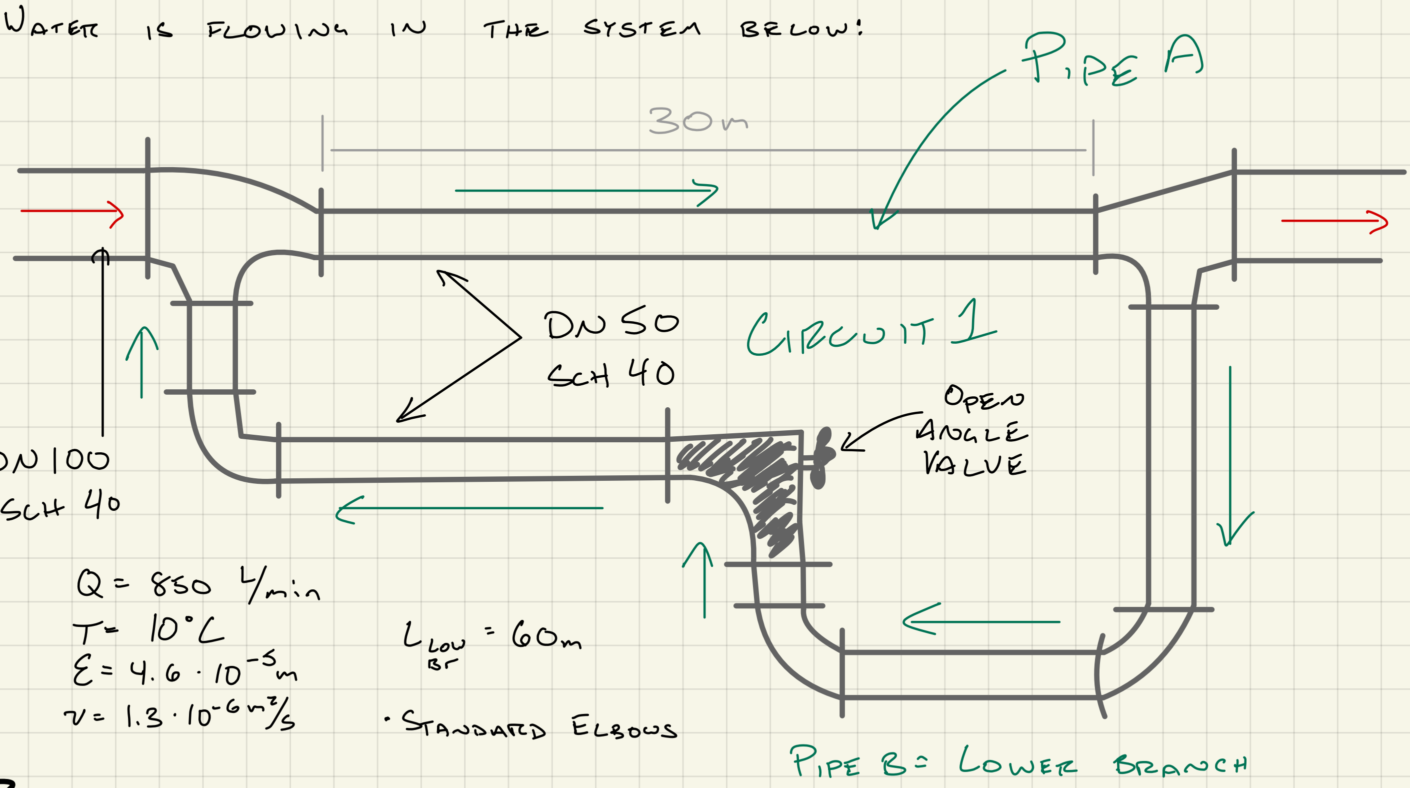
$$Q_A = 2.787 \text{ ft}^3/\text{s} \left(\frac{7.48052 \text{ gal} \cdot 60 \text{ s}}{1 \text{ ft}^3 \cdot 1 \text{ min}} \right) = \boxed{1250.89 \text{ gal/min}}$$

$$Q_B = 0.221 \text{ ft}^3/\text{s} \left(\frac{7.48052 \text{ gal} \cdot 60 \text{ s}}{1 \text{ ft}^3 \cdot 1 \text{ min}} \right) = \boxed{99.19 \text{ gal/min}}$$

Initial:																
Circuit	**Pipe**	**Q (gal/min)**	**Q (ft^3/s)**	**D (ft)**	**e (ft)**	**L (ft)**	**Le**	**D/e**	**V**	**Re**	**f**	**k**	**kQ^2**	**2kQ**		**Error %**
1	A	850	1.894	0.500	1.50E-04	500	500	3.33E+03	9.645	6.51E+05	0.016	12.97	46.52	49.13		-28.505
	B	-500	-1.114	0.167	1.50E-04	500	0	1.11E+03	-51.062	1.15E+06	0.020	1909.81	-2370.09	4255.08	**Delta Q**	48.459
												Σ:	-2323.57	4304.21	-0.540	
Iteration 1:																
1	A		2.434	0.500	1.50E-04	500	500	3.33E+03	12.394	8.36E+05	0.016	12.80	75.79	62.29		-10.114
	B		-0.574	0.167	1.50E-04	500	0	1.11E+03	-26.318	5.92E+05	0.020	1938.21	-638.97	2225.72	**Delta Q**	42.869
												Σ:	-563.17	2288.01	-0.246	
Iteration 2																
1	A		2.680	0.500	1.50E-04	500	500	3.33E+03	13.648	9.21E+05	0.016	12.74	91.48	68.28		-3.315
	B		-0.328	0.167	1.50E-04	500	0	1.11E+03	-15.036	3.38E+05	0.020	1977.79	-212.81	1297.53	**Delta Q**	27.081
												Σ:	-121.33	1365.81	-0.089	
Iteration 3:																
1	A		2.769	0.500	1.50E-04	500	500	3.33E+03	14.100	9.51E+05	0.016	12.72	97.50	70.44		-0.611
	B		-0.239	0.167	1.50E-04	500	0	1.11E+03	-10.964	2.47E+05	0.021	2009.18	-114.95	961.17	**Delta Q**	7.071
												Σ:	-17.45	1031.60	-0.017	
Iteration 4:																
1	A		2.786	0.500	1.50E-04	500	500	3.33E+03	14.187	9.57E+05	0.016	12.72	98.67	70.85		-0.038
	B		-0.222	0.167	1.50E-04	500	0	1.11E+03	-10.189	2.29E+05	0.021	2017.63	-99.69	896.96	**Delta Q**	0.472
												Σ:	-1.02	967.80	-0.001	
Iteration 5:																
1	A		2.787	0.500	1.50E-04	500	500	3.33E+03	14.192	9.58E+05	0.016	12.72	98.75	70.87		-0.001
	B		-0.221	0.167	1.50E-04	500	0	1.11E+03	-10.140	2.28E+05	0.021	2018.19	-98.78	892.97	**Delta Q**	0.015
												Σ:	-0.03	963.85	0.000	
γ Benzene:	54.55	lb/ft^3														
v:	7.41E-06	ft^2/s														
g:	32.2	ft/s^2														

12-3 **GIVEN:**

WATER IS FLOWING IN THE SYSTEM BELOW:



$Q = 850\ L/min$

$T = 10°C$

$\varepsilon = 4.6 \cdot 10^{-5} m$

$\nu = 1.3 \cdot 10^{-6} m^2/s$

$L_{LOW\ BR} = 60m$

· STANDARD ELBOWS

REQUIRED:

a) FIND Q IN EACH BRANCH.

b) FIND $P_A - P_B$

- INCLUDE MINOR LOSSES IN LOWER BRANCH
- SOLVE W/ HARDY CROSS METHOD

SOLUTION:

1. $h = kQ^2$ FOR EACH BRANCH:

$$k = \frac{8(L + Le)f}{\pi^2 g D^5}$$

$$h_A = \frac{8(30m + 0m) f_A}{\pi^2 (9.81 m/s^2)(0.0525)^5} \cdot Q_A^2 = (6.22 \cdot 10^6) f_A \cdot Q_A^2$$

$Le_{elb} = 30m$ $\qquad Le_{ANGLE\ VALVE} = 150m$

$$h_B = \frac{8(60m + 3 \cdot 30m + 150m) f_B}{\pi^2 (9.81 m/s^2)(0.0525)^5} \cdot Q_B^2 = (6.22 \cdot 10^7) f_B \cdot Q_B^2$$

2. GUESS Q VALUE FOR EACH BRANCH THAT ADDS UP TO Q AT JUNCTION:

$Q_{in} = 850\ L/min$ $\qquad Q_A = 650\ L/min = 0.0108\ m^3/s$

$Q_B = 200\ L/min = 0.00333\ m^3/s$

12.8 cont

3. SPLIT NETWORK INTO CIRCUITS

- THIS NETWORK ONLY HAS 1 LOOP, CIRCUIT 1

4. CALCULATE $h = kQ^2$ w/ ASSUMED Q_A, Q_B VALUES:

h_A:

$$f_A = \frac{0.25}{\left(\log\left(\frac{1}{3.7 \cdot D/\varepsilon} + \frac{5.47}{Re^{0.9}}\right)\right)^2}$$

$$= \frac{0.25}{\left(\log\left(\frac{1}{3.7 \cdot 1141} + \frac{5.47}{(2.01 \cdot 10^5)^{0.9}}\right)\right)^2}$$

$$= 0.0206$$

$$Re = \frac{4QD}{\pi D^2 \nu} = \frac{4(0.0108)(0.0525)}{\pi(0.0525)^2(1.3 \cdot 10^{-6})} = 2.01 \cdot 10^5$$

$$\frac{D}{\varepsilon} = \frac{0.0525}{4.6 \cdot 10^{-5}} = 1141$$

$$h_A = (6.22 \cdot 10^6) f_A \cdot Q_A^2 = (6.22 \cdot 10^6)(0.0206)(0.0108)^2$$

$$= \boxed{14.945}$$

h_B:

$$f_B = \frac{0.25}{\left(\log\left(\frac{1}{3.7 \cdot 1141} + \frac{5.47}{(6.21 \cdot 10^4)^{0.9}}\right)\right)^2}$$

$$= 0.023$$

$$Re = \frac{4(0.00333)(0.0525)}{\pi(0.0525)^2(1.3 \cdot 10^{-6})} = 6.21 \cdot 10^4$$

$$\frac{D}{\varepsilon} = 1141$$

$$h_B = (6.22 \cdot 10^7) f_B \cdot Q_B^2 = (6.22 \cdot 10^7) \cdot (0.023) \cdot (0.00333)^2$$

$$= \boxed{15.864}$$

5. SUM UP h VALUES, TAKING FLOW DIRECTION WITHIN THE CIRCUIT INTO ACCOUNT.

$$\Sigma h = h_A + h_B = (14.945) + (-15.864) = \boxed{-0.9187}$$

6. CALCULATE 2kQ FOR EACH PIPE.

PIPE A: $2k_A Q_A = 2 \cdot (6.22 \cdot 10^6)(0.0206)(0.0108) = \boxed{2768}$

PIPE B: $2k_B Q_B = 2 \cdot (6.22 \cdot 10^7)(0.023)(0.00333) = \boxed{9528}$

12-8 cont

7. SUM ALL 2kQ VALUES, ASSUMING ALL ARE POSITIVE

$$\Sigma 2kQ = 2k_A Q_A + 2k_B Q_B = (2768) + (9528)$$

$$= \boxed{12{,}296}$$

8. FOR EACH CIRCUIT, CALCULATE ΔQ

$$\Delta Q = \frac{\Sigma h}{\Sigma 2kQ} = \frac{(-0.9187)}{(12{,}296)} = \boxed{-7.5 \cdot 10^{5}}$$

9. CALCULATE NEW Q VALUE FOR EACH PIPE

$$Q' = Q - \Delta Q$$

$$Q'_A = (0.0108) - (-7.5 \cdot 10^{-5}) = \boxed{0.010875}$$

$$Q'_B = (0.00333) - (-7.5 \cdot 10^{-5}) = \boxed{0.003405}$$

10. REPEAT 4-8 UNTIL ΔQ BECOMES NEGLIGABLY SMALL

- MY GUESSES FOR FLOW RATE WERE QUITE CLOSE, BUT I MADE AN EXCEL SHEET ANYWAY FOR PRACTICE. SEE TABLE FOR ITERATIONS.

FINAL ITERATION FLOW RATES:

$$Q_A = 0.01091 \ m^3/s = \boxed{655 \ L/min}$$

$$Q_B = 0.00326 \ m^3/s = \boxed{196 \ L/min}$$

- USE BERNOULLI'S EQUATION TO FIND PRESSURE LOSS B/T INLET PIPE (1) AND OUTLET PIPE (2)

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

$$\frac{P_1 - P_2}{\gamma} = h_L \quad \therefore \quad \Delta P = h_L \cdot \gamma$$

- $h_{LA} = h_{LB}$, SO I WILL USE h_{LA} AS IT HAS NO MINOR LOSSES

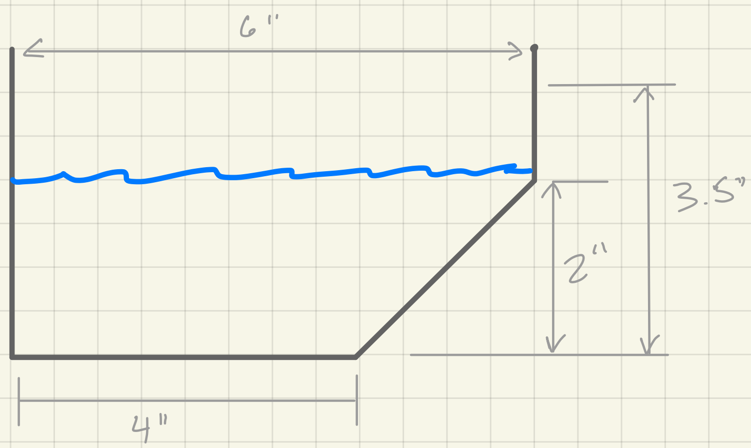
$$\Delta P = f_A \left(\frac{L_A}{D} \cdot \frac{v_A^2}{2g} \right) \gamma_{WAT}$$

$$= (0.0206) \left(\frac{30}{0.0525} \cdot \frac{16 \cdot (0.01091)^2}{\pi^2 (0.0525)^4 \cdot 2(9.81)} \right) (9.81) = \boxed{149.5 \ kPa}$$

Initial:																
Circuit	**Pipe**	**Q (L/min)**	**Q (m^3/s)**	**D (m)**	**e (m)**	**L (m)**	**Le**	**D/e**	**V**	**Re**	**f**	**k**	**kQ^2**	**2kQ**		**Error %**
1	A	650	0.01083	0.0525	4.60E-05	30	0	1.14E+03	5.004	2.02E+05	0.021	1.28E+05	15.08	2784.10		-0.663
	B	-200	-0.00333	0.0525	4.60E-05	60	240	1.14E+03	-1.540	6.22E+04	0.023	1.44E+06	-15.97	9581.11	**Delta Q**	2.154
												Σ:	-0.89	12365.21	-7.18E-05	
Iteration 1:																
1	A		0.01091	0.0525	4.60E-05	30	0	1.14E+03	5.038	2.03E+05	0.021	1.28E+05	15.27	2801.35		-0.042
	B		-0.00326	0.0525	4.60E-05	60	240	1.14E+03	-1.507	6.08E+04	0.023	1.44E+06	-15.33	9401.10	**Delta Q**	0.142
												Σ:	-0.06	12202.45	-4.62E-06	
Iteration 2:																
1	A		0.01091	0.0525	4.60E-05	30	0	1.14E+03	5.040	2.04E+05	0.021	1.28E+05	15.29	2802.46		-0.002
	B		-0.00326	0.0525	4.60E-05	60	240	1.14E+03	-1.505	6.08E+04	0.023	1.44E+06	-15.29	9389.52	**Delta Q**	0.008
												Σ:	0.00	12191.98	-2.67E-07	
Iteration 3:																
1	A		0.01091	0.0525	4.60E-05	30	0	1.14E+03	5.040	2.04E+05	0.021	1.28E+05	15.29	2802.53		0.000
	B		-0.00326	0.0525	4.60E-05	60	240	1.14E+03	-1.504	6.08E+04	0.023	1.44E+06	-15.29	9388.85	**Delta Q**	0.000
												Σ:	0.00	12191.37	-1.54E-08	
γ Water:	9.81	kN/m^3														
v:	1.30E-06	m^2/s														
g:	9.81	m/s^2														

14-6 **GIVEN:**

THE FOLLOWING FIGURE REPRESENTS THE CROSS SECTION OF A RAIN GUTTER ON A HOUSE:



REQUIRED:

CALCULATE THE HYDRAULIC RADIUS FOR THE SECTION IF WATER IS 2" DEEP.

SOLUTION:

$$R = \frac{A}{WP}$$

A:

- SPLIT INTO IDENTIFIABLE SHAPES, SUM THE AREA

LOWER RECTANGLE: $4'' \cdot 2'' = 8\ si$ $\therefore$ $A = \boxed{10\ si}$

TRIANGLE: $\frac{2'' \cdot 2''}{2} = 2\ si$

WP:

- SUM WETTED LENGTHS TOGETHER, USE PYTHAGOREAN THEORY FOR ANGLED WALL

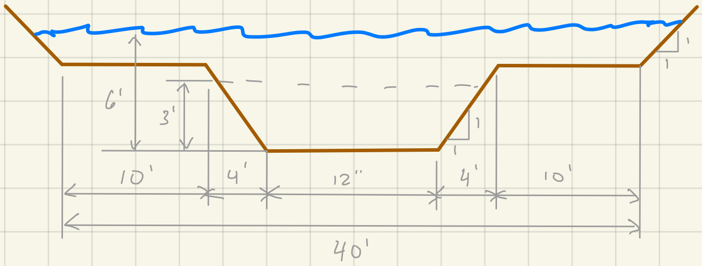
$$C = \sqrt{a^2+b^2} = \sqrt{2^2+2^2} = 2.83''$$

$$2'' + 4'' + 2.83'' = \boxed{8.83''}$$

$$R = \frac{10\ si}{8.83''} = \boxed{1.13''}$$

14-15 **GIVEN:**

BELOW IS AN APPROXIMATION OF A NATURAL STREAM CHANNEL w/ LEVEES ON BOTH SIDES:



$n = 0.04$

AVG SLOPE $= 0.00015$

REQUIRED:

CALCULATE NORMAL DISCHARGE RATE AT WATER DEPTHS OF 3' AND 6'

SOLUTION:

- USE MANNING'S EQUATION w/ MASS FLOW RATE EQUIVALANCY:

$$Q = \left(\frac{1.49}{n}\right) A R^{2/3} S^{1/2}$$

- n AND S ARE GIVEN; FIND A AND R

A @ 6':

TOP TRAPAZOID: $(b + zy)y = (40\,ft + (1ft \cdot 2ft)) \cdot 2ft = 84\,sf$

BOT TRAPAZOID: $(12\,ft + (1 \cdot 4ft)) \cdot 4ft = 64\,sf$

$A = 84\,sf + 64\,sf = \boxed{148\,sf}$

A @ 3':

TRAPAZOID: $(12\,ft + (1 \cdot 3ft))3\,ft = \boxed{45\,sf}$

R @ 6':

WP: $2\left(\sqrt{2^2+2^2}\right) + 2(10ft) + 2\left(\sqrt{4^2+4^2}\right) + 12ft = \boxed{48.97\,ft}$

$$R = \frac{A}{WP} \approx \frac{148\,sf}{48.97ft} = \boxed{3.022\,ft}$$

R @ 3':

WP: $2\left(\sqrt{3^2+3^2}\right) + 12ft = 20.49\,ft$

$$R = \frac{45\,sf}{20.49ft} = \boxed{2.196\,ft}$$

14-15 cont

• SOLVE FOR Q:

$$Q = \left(\frac{1.49}{n}\right) A R^{2/3} S^{1/2}$$

Q @ 6':

$$Q_{6'} = \left(\frac{1.49}{0.04}\right)(148\,sf)(3.022)^{2/3}(0.00015)^{1/2}$$

$$= \boxed{141.1\ ft^3/s}$$

$$Q_{3'} = \left(\frac{1.49}{0.04}\right)(45\,sf)(2.196)^{2/3}(0.00015)^{1/2}$$

$$= \boxed{34.7\ ft^3/s}$$

15-4

GIVEN:

A SHARP EDGED ORIFICE PLATE IS PLACED IN A 10" PIPE CARRYING AMMONIA.

$Sg_{AMMONIA} = 0.83$ $\quad \eta = 2.5 \cdot 10^{-6}\ lb/ft^2$ $\quad Q = 25\ gal/min = 0.0557\ ft^3/s$

REQUIRED:

CALCULATE THE DEFLECTION OF A WATER MANOMETER IF THE ORIFICE:

a) IS 1" b) IS 7"

SOLUTION:

• EQUATION FOR VELOCITY, PULLED FROM LECTURE:

$$V_1 = C\sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_{FL}} - 1\right)}{\left(\frac{A_1}{A_2}\right)^2 - 1}} \quad \therefore \quad h = \frac{V^2}{C^2}\,\frac{\left(\frac{A_1}{A_2}\right)^2 - 1}{2g\left(\frac{\gamma_m}{\gamma_{FL}} - 1\right)} \quad \text{———} \quad (1)$$

• WHERE $A_1 = A_{tube}$, $A_2 = A_{ORIFICE}$, $C =$ ORIFICE COEFF, $\gamma_m =$ SW OF MAN
$\gamma_{FL} =$ SW OF WORKING FLUID, $h =$ DISPLACEMENT IN MANOMETER

• FOR THE ABOVE EQUATION, ALL BUT h AND C ARE KNOWN OR CAN BE CALCULATED W/ GIVEN INFO.

• C CAN BE FOUND USING THE DISCHARGE COEFFICIENT GRAPH FOUND ON PAGE 403, FIGURE 15.7. IT REQUIRES A REYNOLDS NUMBER AND A RATIO B/T THE PIPE AND THE ORIFICE, BOTH OF WHICH CAN BE CALCULATED

15-4 CONT

C:

$$N_R = \frac{VD}{\nu}$$

$$= \frac{(0.1022\ ft/s)(0.8333\ ft)}{1.55 \cdot 10^{-6}\ ft^2/s}$$

$$= \boxed{5.49 \cdot 10^4}$$

$$\frac{d_1}{D} = \frac{0.08333\ ft}{0.8333\ ft} = \boxed{0.1}$$

$$\frac{d_7}{D} = \frac{0.5833\ ft}{0.8333\ ft} = \boxed{0.7}$$

$$Q = AV \quad \therefore \quad V = \frac{Q}{A} \qquad A = \pi\left(\frac{D}{2}\right)^2$$

$$V_1 = \frac{4Q}{\pi D^2} = \frac{4(0.0557\ ft^3/s)}{\pi(0.833\ ft)^2} = \boxed{0.1022\ ft/s}$$

$$\nu = \frac{\mu}{\rho} \qquad Sg = \frac{\gamma}{\gamma_{water}} \qquad \rho = \frac{\gamma}{g}$$

$$\gamma_{Amm} = Sg_{Amm} \cdot \gamma_{water} = (0.83)(62.4\ lb/ft^3) = \boxed{51.792\ lb/ft^3}$$

$$\rho = \frac{51.792\ lb/ft^3}{32.2\ ft/s^2} = 1.608\ slugs/ft^3$$

$$\nu = \frac{2.5 \cdot 10^{-6}\ lb/ft^2}{1.608\ slugs/ft^3} = \boxed{1.55 \cdot 10^{-6}\ ft^2/s}$$

$$\boxed{C_1 = 0.595 \qquad C_7 = 0.618}$$

• FIGURE 15.7

• CALCULATE (1) FOR EACH ORIFICE SIZE (1" AND 7")

- CALCULATE AREA FOR PIPE AND BOTH ORIFICE SIZES (A_1, A_{01} A_{07})

$$A_1 = \pi\left(\frac{0.8333\ ft}{2}\right)^2 = \boxed{0.545\ ft^2}$$

$$A_{01} = \pi\left(\frac{0.08333\ ft}{2}\right)^2 = \boxed{0.00545\ ft^2} \qquad A_{07} = \pi\left(\frac{0.5833\ ft}{2}\right)^2 = \boxed{0.267\ ft^2}$$

$$h_1 = \frac{(0.1022\ ft/s)^2}{(0.595)^2} \cdot \left(\frac{\left(\frac{0.545\ ft^2}{0.00545\ ft^2}\right)^2 - 1}{2(32.2\ ft/s^2)\left(\frac{62.4\ lb/ft^2}{51.792\ lb/ft^2} - 1\right)} \right) = \boxed{22.4\ ft}$$

$$h_7 = \frac{(0.1022\ ft/s)^2}{(0.618)^2} \cdot \left(\frac{\left(\frac{0.545\ ft^2}{0.267\ ft^2}\right)^2 - 1}{2(32.2\ ft/s^2)\left(\frac{62.4\ lb/ft^2}{51.792\ lb/ft^2} - 1\right)} \right) = \boxed{0.00656\ ft}$$

15-15 **GIVEN:**

A PITOT-STATIC TUBE IS INSERTED INTO A DUCT CARRYING AIR @ STANDARD ATMOSPHERIC PRESSURE AND A TEMPERATURE OF 50°C. A DIFFERENTIAL MANOMETER READS 0.24" OF WATER.

$$0.24''\left(\frac{0.0254\text{ m}}{1''}\right) = 0.0061\text{ m}$$

REQUIRED:

FIND THE VELOCITY OF THE FLOW OF AIR.

SOLUTION:

FOR PITOT-STATIC TUBES USING A DIFFERENTIAL MANOMETER:

$$V_1 = \sqrt{2gh(\gamma_g - \gamma)/\gamma}$$

- $\gamma_g = \gamma$ OF GAUGE FLUID, WATER HERE
- $\gamma = \gamma$ OF WORKING FLUID, AIR IN THIS CASE

$\gamma_g = \gamma_w = 9810\ \text{N/m}^3$ • ASSUMING MANOMETER IS @ ROOM TEMP (~10°C)

$\gamma = \gamma_{air} = 10.71\ \text{N/m}^3$ • AT GIVEN 50°C

$$V_1 = \sqrt{2(9.81\ \text{m/s}^2)(0.0061\text{ m})\frac{(9810\ \text{N/m}^3 - 10.71\ \text{N/m}^3)}{(10.71\ \text{N/m}^3)}}$$

$$= \boxed{10.46\ \text{m/s}}$$