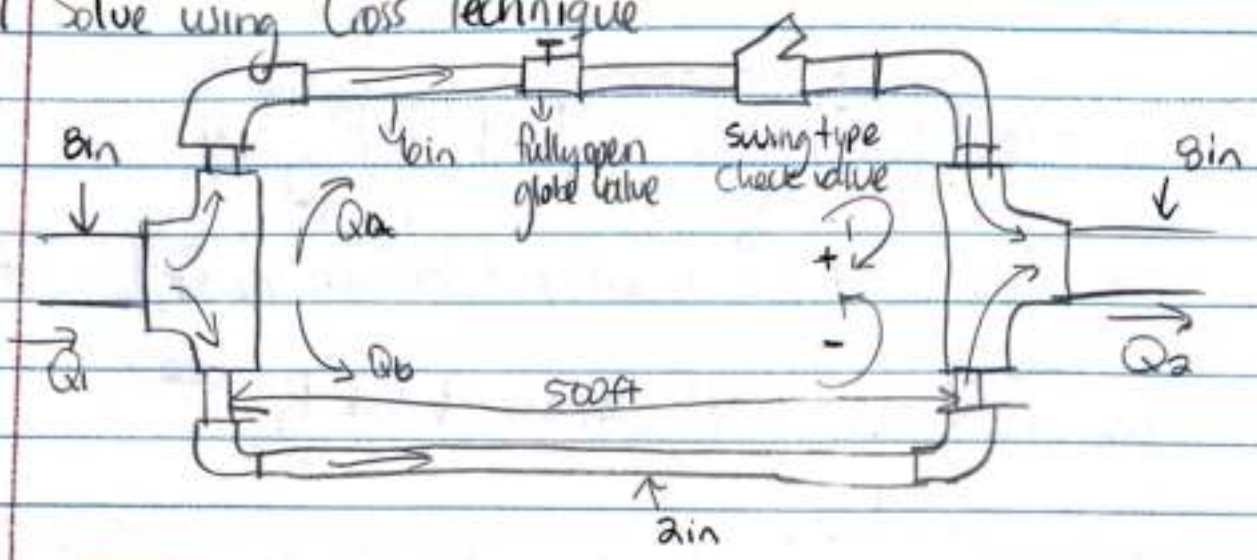
Dylan Arnold HW8 University ID: 01166349
MEG 330 Professor Ayala July 9th, 2023

8.7 Solve using Cross Technique



$Q = 1350$ gal/min
benzene $sg = 0.87$ @ 140°F
SCH40 pipes

$h = kQ^2$
assumed value Q

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

flow clockwise h + Q +
flow counterclockwise h + Q − $= \Sigma h$

$h_L = f \frac{L}{D} \frac{v^2}{2g}$

$\Delta Q = \frac{\Sigma h}{\Sigma (2kQ)}$

$R_e = \frac{VD}{\nu}$ Roughness $= \frac{D}{\varepsilon}$

$Q_1 = Q - \Delta Q$

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12.7 (cont'd) $h_a = (2)(f_a)(30)\left(\frac{V_a^2}{2g}\right) + 5.1\left(\frac{V_a^2}{2g}\right) + 1.5\left(\frac{V_a^2}{2g}\right) + f\left(\frac{L_a}{D_a}\right)\left(\frac{V_a^2}{2g}\right)$

$V_a = Q_a^2 / A_a^2$

$h_a = 60f\left(\frac{Q_a^2}{2gA_a^2}\right) + 6.6\left(\frac{Q_a^2}{2gA_a^2}\right) + f\left(\frac{L_a}{D_a}\right)\left(\frac{Q_a^2}{2gA_a^2}\right)$

$h_a = 60(0.015)\left(\frac{Q_A^2}{2(32.17)(0.2006)^2}\right) + 6.6\left(\frac{Q_A^2}{2(32.17)(0.2006)^2}\right) + f_a\left(\frac{500}{0.5054}\right)\left(\frac{Q_A^2}{2gA_A^2}\right)$

$h_a = \left(\frac{Q_A^2}{2(32.17)(0.2006)^2}\right)\left((60)(0.015) + 6.6 + f_a\left(\frac{500}{0.5054}\right)\right)$

Branch A $D/\varepsilon = \frac{.5054}{1.5\times10^{-4}} = 3369$ Branch B $D/\varepsilon = \frac{.1723}{1.5\times10^{-4}} = 1149$

$N_{R_A} = \frac{Q_A D_a}{A_A \nu} = \frac{Q_A(0.5054)}{(0.2006)[0.0493\times(10^{-4})]}$

$N_{R_A} = 5110211\, Q_A$

$h_B = 2(f_B)(30)\left(\frac{V_A^2}{2g}\right) + f\left(\frac{L_B}{D_B}\right)\left(\frac{V_A^2}{2g}\right)$

$h_B = 60f_B\left(\frac{Q_B^2}{2gA_B^2}\right) + f\left(\frac{L_B}{D_B}\right)\left(\frac{Q_B^2}{2gA_B^2}\right)$

$h_B = 2(0.019)(30)\left(\frac{Q_B^2}{2(32.17)(0.03333)^2}\right) + f_B\left(\frac{500}{0.1723}\right)\left(\frac{Q_B^2}{2(32.17)(0.0333)^2}\right)$

$h_B = \left(\frac{Q_B^2}{2(32.17)(0.03333)^2}\right)\left(1.14 + f_B\left(\frac{500}{0.1723}\right)\right)$

$Q_A + Q_B = 3.01\ ft^3/s$

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12.7 Contd. Assume 6" will have greater flow

$Q_A = 2.5\ ft^3/s \quad Q_B = 0.51\ ft^3/s$

$N_{RB} = \frac{Q_B D_B}{A_B \nu} = \frac{Q_B(0.1723)}{(0.02333)(0.0103\times10^{-4})}$

$N_{RB} = 1498261\, Q_B = 1498261(0.51) = 764113$

$N_{RA} = 511021\, Q_A = 511021(2.5) = 1277553$

$f_A = \frac{0.25}{\left[\log\left(\frac{1}{3.7(3369)} + \frac{5.74}{1277553^{0.9}}\right)\right]^2} \quad f_A = 0.0156$

$f_B = \frac{0.25}{\left[\log\left(\frac{1}{3.7(1144)} + \frac{5.74}{764113^{0.9}}\right)\right]^2} \quad f_B = 0.095$

$h_a = Q_A^2(0.386)\left(7.5 + 0.0156\left(\frac{500}{.5054}\right)\right)$
$h_a = Q_A^2(8.85) \quad h_a = 2.5^2 \times 8.85 = 55.31$

$h_B = Q_B^2(28.56)\left(1.14 + 0.095\left(\frac{500}{0.1723}\right)\right)$
$h_B = Q_B^2(1648.7) \quad h_B = 0.51^2 \times 1648.7 = 428.83$

$\Sigma h_L = h_a - h_B = 55.31 - 428.83 = -373.52$

$2k_a Q_A = (2)(8.85)(2.5) = 44.25$
$2k_B Q_B = (2)(1648.7)(0.51) = 1681.67$

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$\sum (2kQ)_i = 44.25 + 1681.67 = 1725.92$

$\sum \frac{h_i}{(2kQ_i)} = \frac{-373.52}{1725.92} = -0.216$

$Q'_A = 2.5 - (-0.216) = 2.716$
$Q'_B = 0.51 - (-0.216) = 0.726$
$= 3.442 \ ft^3/s$

Start iteration in excel

Final Q values $Q_A = 2.805 \ ft^3/s$, $Q_B = 0.205 \ ft^3/s$

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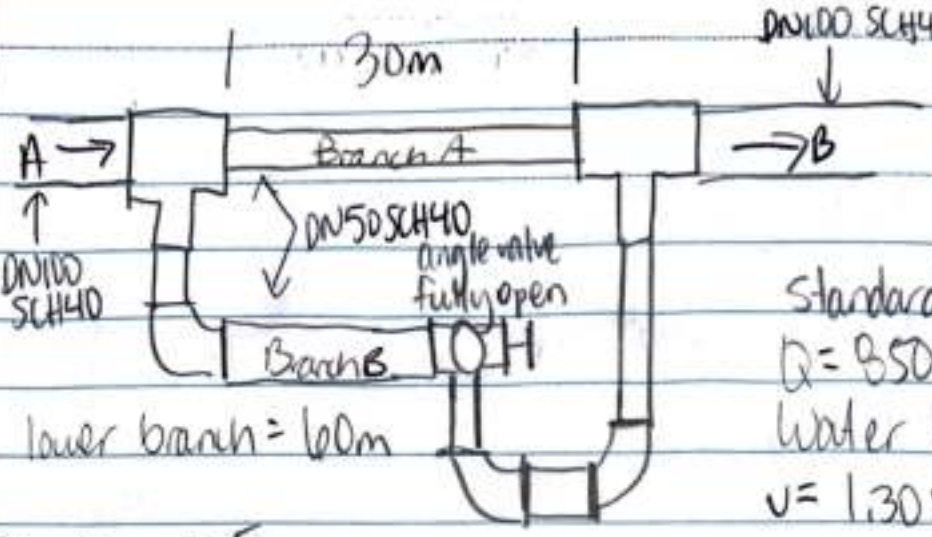
12.8



Standard elbows
$Q = 850$ L/min
Water 10°C
$\nu = 1.30 \times 10^{-6}$ m²/s

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

DN50 SCH40 $D = 52.5\text{mm} = 0.0525\text{m}$
$A = 2.168 \times 10^{-3}$ m²

DN100SCH40 = 102.3mm = .1023m
$A = 8.213 \times 10^{-3}$ m
f_t DN100 = 0.016

Angle valve = $K = 150 f_t$
Elbows = $K = 30 f_t$
DN50 $f_t = 0.019$
T flow through = $20 f_t$ →
T flow bend = $60 f_t$ ↗

$$h_a = (2)(0.016)(20)\left(\frac{V_A^2}{2g}\right) + f_A\left(\frac{L}{D}\right)\left(\frac{V_A^2}{2g}\right)$$

$$V_A = Q_A^2 / A_A^2$$

$$h_a = (0.64)\left(\frac{(Q_A^2)}{2g A_A^2}\right) + f_a\left(\frac{30\text{m}}{0.0525\text{m}}\right)\left(\frac{Q_A^2}{2(9.81)(2.168\times10^{-3})^2}\right)$$

$$D/\varepsilon = \frac{0.0525}{4.6\times10^{-5}} = 1141$$

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Q3.3 Cont'd $N_{RA} = \frac{Q_A D_A}{A_A V} = \frac{Q_A (0.0525m)}{(2.168\times10^{-3})(1.30\times10^{-6})}$

$N_{RA} = 1.75\times10^{7} Q_A$

$h_B = (2)(0.016)\left(\frac{60}{0.0525}\right)\left(\frac{V_B^2}{2g}\right) + (1.50)(0.09)\left(\frac{V_B^2}{2g}\right) + (1)(1.09)\left(\frac{V_B^2}{2g}\right) + f_B\left(\frac{L}{D}\right)\left(\frac{V_B^2}{2g}\right)$

$h_B = (1.92 + 2.95 + 1.71)\left(\frac{V_B^2}{2g}\right) + f_B\left(\frac{60m}{0.0525m}\right)\left(\frac{V_B^2}{2g}\right)$

$h_B = \left(6.48 + f_B(1142.86)\right)\left(\frac{Q_B^2}{2(9.81)(2.168\times10^{-3})^2}\right)$

$N_{RB} = \frac{Q_B D_B}{A_B V} = \frac{Q_B (0.0525m)}{(2.168\times10^{-3})(1.30\times10^{-6})}$

$N_{RB} = 1.75\times10^{7} Q_B$

$Q_{All} = 850\ L/min = 0.01417\ m^3/s$
$Q_A = 550\ L/min = 0.00917\ m^3/s$ (assume greater flow)
$Q_B = 300\ L/min = 0.005\ m^3/s$

$N_{RA} = 1.75\times10^{7}(0.00917) = 160475$
$N_{RB} = 1.75\times10^{7}(0.005) = 87500$

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12.8 Cont'd $f_A = \frac{0.25}{\left(\log\left(\frac{1}{3.7(1141)} + \frac{5.74}{160475^{0.9}}\right)\right)^2}$

$f_A = 0.021$

$f_B = \frac{0.25}{\left(\log\left(\frac{1}{3.7(1141)} + \frac{5.74}{87500^{0.9}}\right)\right)^2}$

$f_B = 0.022$

$h_A = (0.64)\left(\frac{Q_A^3}{2(9.81)(2.168\times10^{-3})^3}\right) + (0.021)\left(\frac{Q_A^2}{2(9.81)(2.168\times10^{-3})^2}\right)$

$h_A = (0.661)(10843.87)\,Q_A^2$
$h_A = 7167.8\,Q_A^2$
$h_A = 7167.8\,(0.00917)^2 = 0.603$

$h_B = (6.48 + f_B(1142.86))$
$= (6.49 + (0.022)(1142.86))$
$= (31.62)\,Q_B^2(10843.87)$
$= 342883.17(Q_B^2)$
$= 342883.17(0.005)^2 = 8.572$

$\Sigma h_L = h_A - h_B = 0.603 - 8.752 = -7.969$

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$2k_A Q_A = 2(7167.8)(0.00917)$
$= 131.46$

$2k_B Q_B = 2(342983.17)(0.005)$
$= 3428.93$

$\Sigma 2kQ_i = 131.46 + 3428.93 = 3560.29$

$\Sigma \frac{h_i}{2kQ_i} = \frac{-7.969}{3560.29} = -0.0022$

$Q'_A = 0.00917 - -0.0022 = 0.01137$

$Q_{1B} = 0.005 - -0.0022 = 0.0072$
$= 0.01957$

Start iteration in excel

Final Q values = $Q_A = 695$ lpm $(0.011588\ m^3/s)$
$Q_B = 155$ lpm $(0.002583\ m^3/s)$

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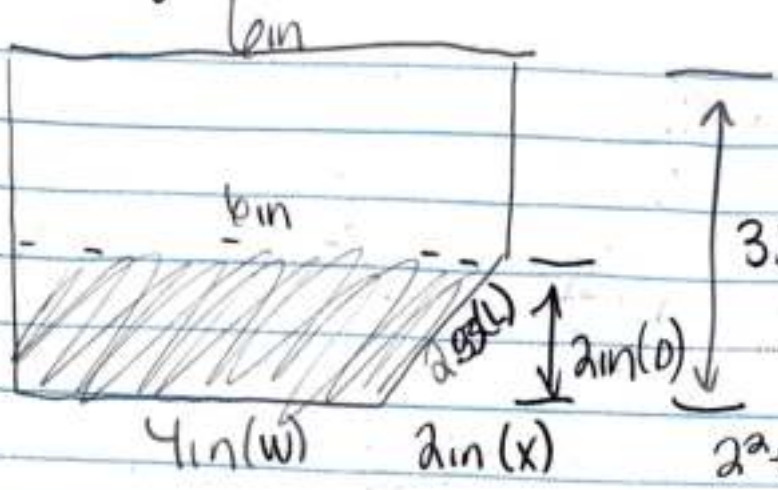
14.6



$2^2+2^2=c^2$
$=\sqrt{8}$
$=2.83$

Trapezoid open channel flow
$A = WD + XD$

$A=(4)(2)+(2)(2)=12$

$WP = W + 2L = 4 + 2(2.83) = 9.66$

$$R = \frac{A}{WP} = \frac{12}{9.66} = 1.24\text{in}$$

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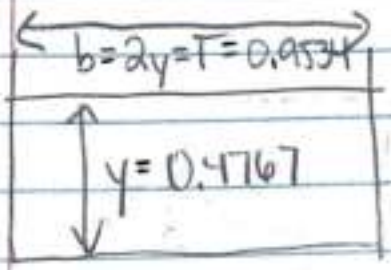
14.36 $V = 2.75 \text{ ft/s}$
$Q = 1.25 \text{ ft}^3/\text{s}$

$Q = VA \quad A = \frac{Q}{V} = \frac{1.25 \frac{\text{ft}^3}{\text{s}}}{2.75} = 1.25 \frac{\text{ft}^3}{\text{s}} \cdot \frac{1}{2.75} \frac{\text{s}}{\text{ft}}$
$A = 0.4545 \text{ ft}^2$

Rectangle area $= 2.0y^2$

$\frac{0.4545 \text{ ft}^2}{2.0} = \frac{2.0y^2}{2.0} = \sqrt{0.22725} = y$

$y = 0.4767 \text{ ft}$



$WP = 4y = 4(0.4767) = 1.9068 \text{ ft}$

$R = \frac{y}{2} = \frac{0.4767}{2} = 0.2384 \text{ ft}$

$y = 0.4767 \text{ ft} \quad b = 0.9534 \text{ ft}$

Triangle area $= y^2$

$0.4545 \text{ ft}^2 = y^2 \quad y = 0.674 \text{ ft}$
$\sqrt{0.4545 \text{ ft}^2} = y$

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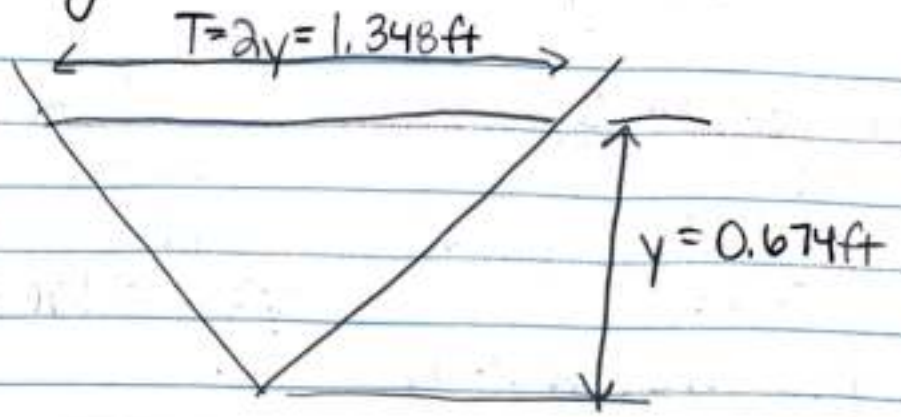
14.36 Cont'd

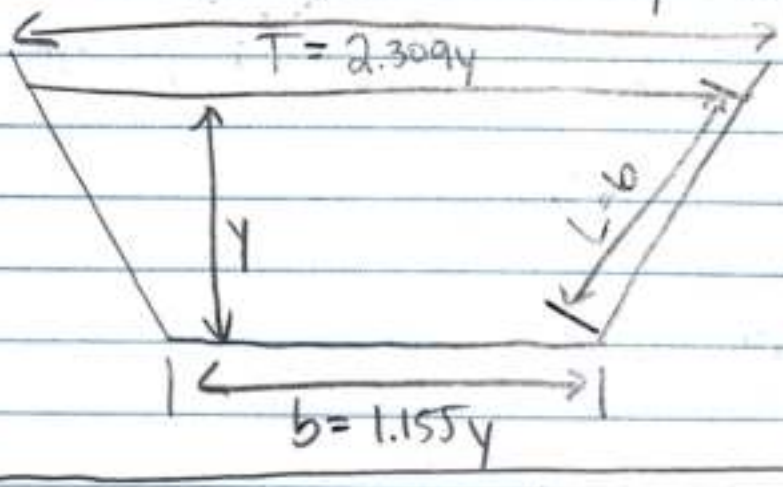


WP = 2.83y = 2.83(0.674) = 1.907ft
R = 0.354y = 0.354(0.674) = 0.239 ft
T = 1.348ft y = 0.674 ft

Trapezoid area = $1.73y^2$

$\frac{0.4545ft^2}{1.73} = \frac{1.73y^2}{1.73}$ $\sqrt{0.2627ft^2} = y$

$y = 0.5125ft$



WP = 3.46y = 3.46(0.5125ft) = 1.773ft y = 0.5125ft
R = y/2 = 0.5125/2 = 0.25625ft T = 1.183ft
b = 0.592ft L = 0.592ft

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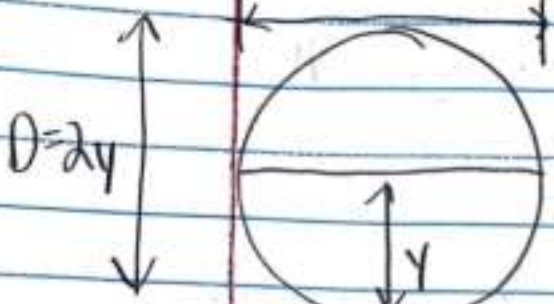
14.36 Cont'd

Semicircle area $= (1/2)\pi y^2$

$\frac{0.4545 ft^2}{\frac{1}{2}\pi} = \frac{\frac{1}{2}\pi y^2}{\frac{1}{2}\pi}$ $\quad \sqrt{0.289 ft^2} = y$

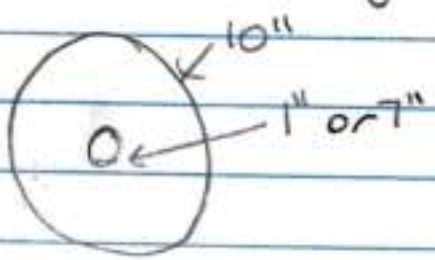
$y = 0.5376 ft$



$WP = \pi y = \pi(0.5376) = 1.689 ft$
$R = y/2 = 0.5376/2 = 0.2688 ft$
$y = 0.5376 ft \quad D = 1.0752 ft$
$T = 1.0752 ft$

15.4

10in diameter pipe
ammonia $sg = 0.83$ dynamic viscosity $= 2.5 \times 10^{-6}$ lb/ft²
$Q = 25$ gpm
what is h_2?
a) orifice 1in
b) orifice 7in
water manometer



$\gamma_{ammonia} = 62.4 \cdot 0.83 = 51.792$

$N_R = \frac{vD\rho}{\eta}$

$\rho_{ammonia} = 1.77$ slugs/ft³

10" assumption sch40 $A_1 = 0.5479 ft^2$

ID = 10.020" = 0.8350 ft = radius = 0.4175 ft

$A = \pi r^2 = 0.4175^2 \pi = 0.5476 ft^2$

$25 gpm \times \frac{1 \; ft^3/s}{449 gpm} = 0.0557 \frac{ft^3}{s}$

$Q = VA \quad V = \frac{Q}{A} \quad V = \frac{(0.0557)}{(0.5476)} = 0.1017 \; ft/s$

$A_2 = 1in = 0.083 ft / 2 = 0.04167^2 \pi = 0.005454 ft^2$

$(A_1/A_2)^2 = \frac{0.5479 ft^2}{0.005454 ft^2} = 100.46^2 = 10091.89 - 1 = 10090.89$

$\gamma_{m_{water}} = 62.4 \; lb/ft^3 \quad \gamma_{f_{ammonia}} = 51.792 \; lb/ft^3$

$[(\gamma_m/\gamma_f) - 1] = (62.4/51.792) - 1 = 0.2048$

$N_R = \frac{(0.1017)(0.8350)(1.77)}{2.5 \times 10^{-6}} = 60123 = 6 \times 10^4$

1/10 = 0.1 7/10 = 0.7

C = 0.593 figure 15.7 (a) C = 0.617 (b)

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15.4 Cont'd $V_1 = C\sqrt{\frac{2gh[(\gamma_m/\gamma_f)-1]}{(A_1/A_2)^2-1}}$

$0.1017 = 0.593\sqrt{\frac{2(32.174)(h)(0.2048)}{10090.89}}$

$(0.1715)^2 = \left(\sqrt{\frac{2(32.174)(h)(0.2048)}{10090.89}}\right)^2$

$0.0294 = \frac{2(32.174)(h)(0.2048)}{10090.89}$

$\frac{296.67}{13.178} = \frac{13.178h}{13.178}$ $\quad h = 22.5\text{ ft} = 270\text{ in}$ (a) 1 in orifice

A_3 = 7 in orfice = $0.5833\text{ft}/2 = 0.2917\text{ft}$ $\quad r^2 = 0.267\text{ft}^2$

$C = 0.617$

$(A_1/A_3)^2 - 1 = \left(\frac{0.5479\text{ft}^2}{0.267\text{ft}^2}\right)^2 = 4.211 - 1 = 3.211$

$V_1 = C\sqrt{\frac{2gh[(\gamma_m/\gamma_f)-1]}{(A_1/A_3)^2-1}}$

$0.1017 = 0.617\sqrt{\frac{2(32.174)(h)(0.2048)}{3.211}}$

$(0.1648)^2 = \left(\sqrt{\frac{13.178h}{3.211}}\right)^2$

$0.0272 = \frac{13.178h}{3.211}$ $\quad \frac{0.087}{13.178} = \frac{13.178h}{13.178}$

$h = 0.0066\text{ft}$ (b) 7in orfice
$= 0.0792\text{in}$

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15.15 Pilot static tube
standard atm p
T = 50°C
Differential manometer reads 0.24" of water
what is V_o?

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

$\gamma_g = \gamma_{water} = 62.4\ lb/ft^3$
$\gamma_{air} = @\ 50°C = 10.71\ N/m^3 \cdot \frac{1\ lb/ft^3}{157.1\ N/m^3} = 0.068\ lb/ft^3$
$h = 0.24\ in / 12 = 0.02\ ft$
$g = 32.174\ ft/s^2$

$$V_1 = \sqrt{(2)(32.174)(0.02ft)\left(\frac{62.4 - 0.068}{0.068}\right)}$$

$$\boxed{V_1 = 34.35\ ft/s}$$

Trial 1				12.7					
Circuit	Pipe	Q (ft³/s)	NR	f	k	h	2kQ	DQ	%Chg
1	a	2.5	1277607.34	0.015575641	8.85	55.3125	44.25		-9%
	b	0.51	764000.7686	0.019529811	1648.7	428.82687	1681.674		-42%
					Summations:	-373.51437	1725.924	-0.21641414	
Trial 2									
Circuit	Pipe	Q (ft³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	2.6	1328711.634	0.01555381	8.85	59.826	46.02		-6%
	b	0.41	614196.6963	0.019642309	1648.7	277.14647	1351.934		-38%
					Summations:	-217.32047	1397.954	-0.155456095	
Trial 3									
Circuit	Pipe	Q (ft³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	2.7	1379815.927	0.015533433	8.85	64.5165	47.79		-3%
	b	0.31	464392.624	0.019819362	1648.7	158.44007	1022.194		-28%
					Summations:	-93.92357	1069.984	-0.08778035	
Trial 4									
Circuit	Pipe	Q (ft³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	2.8	1430920.221	0.015514365	8.85	69.384	49.56		0%
	b	0.21	314588.5518	0.020142757	1648.7	72.70767	692.454		-2%
					Summations:	-3.32367	742.014	-0.004479255	
Trial 5									
Circuit	Pipe	Q (ft³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	2.81	1436030.65	0.015512526	8.85	69.880485	49.737		0%
	b	0.2	299608.1445	0.020190705	1648.7	65.948	659.48		3%
					Summations:	3.932485	709.217	0.005544826	
Trial 6									
Circuit	Pipe	Q (ft³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	2.805	1433475.436	0.015513444	8.85	69.63202125	49.6485		0%
	b	0.205	307068.3482	0.020166212	1648.7	69.2856175	675.967		0%
					Summations:	0.345403.75	725.6155	0.000476035	
Final flows									
Circuit	Pipe	Q (ft³/s)	Q (gpm)						
1	a	2.805	1258.97078						
	b	0.205	92.01034219						
			1350.981122						
		Original	1350						

Trial 1				12.8					
Circuit	Pipe	Q (m³/s)	NR	f	k	h	2kQ	DQ	%Chg
1	a	0.00917	160475	0.021014	7167.8	0.602732	131.4575		-24%
	b	0.005	87500	0.022189	342883.2	8.572079	3428.832		-45%
					Summations	-7.969347	3560.289	-0.002238	
Trial 2									
Circuit	Pipe	Q (m³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	0.01	175000	0.02088	7167.8	0.71678	143.356		-18%
	b	0.0042	73500	0.022632	342883.2	6.048459	2880.219		-42%
					Summations	-5.331679	3023.575	-0.001763	
Trial 3									
Circuit	Pipe	Q (m³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	0.1167	2042250	0.019247	7167.8	97.61748	1672.965		24%
	b	0.0025	43750	0.024269	342883.2	2.14302	1714.416		1127%
					Summations	95.47446	3387.38	0.028185	
Trial 4									
Circuit	Pipe	Q (m³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	0.01083	189525	0.020764	7167.8	0.840703	155.2545		-11%
	b	0.0033	57750	0.02333	342883.2	3.733998	2263.029		-36%
					Summations	-2.893294	2418.283	-0.001196	
Trial 5									
Circuit	Pipe	Q (m³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	0.01125	196875	0.020712	7167.8	0.907175	161.2755		-8%
	b	0.002917	51047.5	0.023729	342883.2	2.917555	2000.38		-32%
					Summations	-2.01038	2161.656	-0.00093	
Trial 6									
Circuit	Pipe	Q (m³/s)	NR	f	k		2kQ	DQ	%Chg
1	a	0.011583	202702.5	0.020672	7167.8	0.961674	166.0493		-6%
	b	0.002583	45202.5	0.02415	342883.2	2.287678	1771.334		-26%
					Summations	-1.326004	1937.384	-0.000684	
Final flows									
Circuit	Pipe	Q (m³/s)	Q (lpm)						
1	a	0.011583	694.98						
	b	0.002583	154.98						
			849.96						
		Original	850						