

$$12.10 \quad Q_{in} = 6000 \text{ L/min} \times \frac{1 \text{ m}^3/\text{s}}{60000 \text{ L/min}} = 0.100 \text{ m}^3/\text{s} = 1.0 \times 10^{-1} \text{ m}^3/\text{s}$$

$$Q_{out} = 1500 \text{ L/min} = 0.025 \text{ m}^3/\text{s} \text{ (Each)} = 2.5 \times 10^{-2} \text{ m}^3/\text{s}$$

$$h = f \frac{L}{D} \frac{v^2}{2g} = f \frac{L}{D} \frac{Q^2}{2gA^2} = kQ^2; \quad k = \frac{fL}{D(2)gA^2}$$

$$\text{3-in Type K copper tubes: } D = 0.07384 \text{ m; } A = 4.282 \times 10^{-3} \text{ m}^2$$

$$k = \frac{fL}{D(2)gA^2} = \frac{fL}{(0.07384)(2)(9.81)(4.282 \times 10^{-3})^2} = (3.765 \times 10^4)fL$$

$$\text{For tubes c, f: } L = 6.0 \text{ m; } k = (2.259 \times 10^5)f$$

$$\text{For tubes d, b, e, h: } L = 15 \text{ m; } k = (5.647 \times 10^5)f$$

$$\text{For tubes a, g: } L = 18 \text{ m (Ignore minor losses): } k = (6.776 \times 10^5)f$$

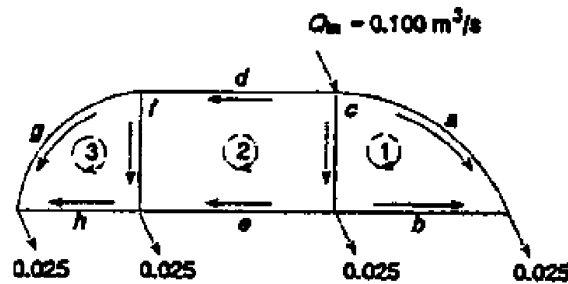
$$\text{For all tubes: Water at } 15^\circ\text{C; } \nu = 1.15 \times 10^{-6} \text{ m}^2/\text{s}$$

$$N_R = \frac{vD}{\nu} = \frac{QD}{Av} = \frac{Q(0.07384)}{(4.282 \times 10^{-3})(1.15 \times 10^{-6})} = (1.500 \times 10^7)Q$$

$$D/\epsilon = (0.07384)/(1.5 \times 10^{-6} \text{ m}) = 49227$$

Use Eq. 9.9 to compute f :

$$f = \frac{0.25}{\left[\log \left(\frac{1}{3.7D/\epsilon} + \frac{5.74}{(N_R)^{0.9}} \right) \right]^2} = \frac{0.25}{\left[\log \left(5.49 \times 10^{-6} + \frac{5.74}{(N_R)^{0.9}} \right) \right]^2}$$



For continuity at joints:

$$\textcircled{\text{I}} \quad Q_a + Q_c + Q_d = 0.100$$

$$\textcircled{\text{II}} \quad Q_a + Q_b = 0.025$$

$$\textcircled{\text{III}} \quad Q_c = 0.025 + Q_b + Q_e$$

$$\textcircled{\text{IV}} \quad Q_f + Q_e = Q_h + 0.025$$

$$\textcircled{\text{V}} \quad Q_d = Q_f + Q_g$$

$$\textcircled{\text{VI}} \quad Q_g + Q_h = 0.025$$

For Trial 1:

$$Q_a = 2.0 \times 10^{-2} \text{ (Assume)}$$

$$Q_b = 0.5 \times 10^{-2} \textcircled{\text{II}}$$

$$Q_c = 4.0 \times 10^{-2} \text{ (Assume)}$$

$$Q_d = 4.0 \times 10^{-2} \textcircled{\text{I}}$$

$$Q_e = 1.0 \times 10^{-2} \textcircled{\text{III}}$$

$$Q_f = 2.0 \times 10^{-2} \text{ (Assume)}$$

$$Q_g = 2.0 \times 10^{-2} \textcircled{\text{V}}$$

$$Q_h = 0.5 \times 10^{-2} \textcircled{\text{VI}}$$

TRIAL	CIRCUIT	PIPE	Q	REY. NO.	FR. FACT.	k	h = kQ ²	2kQ	DELTA Q	% CHANGE
1	1	a	0.0200	3.00E+05	0.0146	9900	3.960	396.00		-6.89
		b	-0.0050	7.50E+04	0.0191	10781	-0.270	107.81		27.58
		c	-0.0400	6.00E+05	0.0130	2944	-4.710	235.49		3.45
			SUM OF h AND 2kQ =					-1.019	739.31	-1.379E-03
	2	c	0.0400	6.00E+05	0.0130	2944	4.710	235.49		-16.28
		d	-0.0400	6.00E+05	0.0130	7359	-11.774	588.69		16.28
		e	0.0100	1.50E+05	0.0166	9373	0.937	187.45		-65.11
		f	-0.0200	3.00E+05	0.0146	3300	-1.320	132.02		32.58
			SUM OF h AND 2kQ =					-7.447	1143.65	-6.511E-03
	3	f	0.0200	3.00E+05	0.0146	3300	1.320	132.02		-18.64
		g	-0.0200	3.00E+05	0.0146	9900	-3.960	396.00		18.64
		h	0.0050	7.50E+04	0.0191	10781	0.270	107.81		-74.58
			SUM OF h AND 2kQ =					-2.370	635.83	-3.728E-03
2	1	a	0.0214	3.21E+05	0.0144	9788	4.473	418.42		-9.80
		b	-0.0036	5.43E+04	0.0205	11557	-0.152	83.70		56.65
		c	-0.0451	6.77E+05	0.0128	2890	-5.886	260.85		4.55
			SUM OF h AND 2kQ =					-1.565	762.97	-2.051E-03
	2	c	0.0451	6.77E+05	0.0128	2890	5.886	260.85		-2.43
		d	-0.0335	5.02E+05	0.0134	7568	-8.487	506.85		3.27
		e	0.0165	2.48E+05	0.0151	8536	2.327	281.88		-6.64
		f	-0.0172	2.58E+05	0.0150	3389	-1.005	116.70		6.37
			SUM OF h AND 2kQ =					-1.278	1166.27	-1.086E-03
	3	f	0.0172	2.58E+05	0.0150	3389	1.005	116.70		-9.21
		g	-0.0163	2.44E+05	0.0152	10269	-2.719	334.21		9.75
		h	0.0087	1.31E+05	0.0170	9624	0.733	168.00		-18.17
			SUM OF h AND 2kQ =					-0.981	618.90	-1.586E-03

TRIAL	CIRCUIT	PIPE	Q	REY. NO.	FR. FACT.	k	h = kQ ²	2kQ	DELTA Q	% CHANGE
3	1	a	0.0234	3.51E+05	0.0142	9633	5.288	451.42		-2.30
		b	-0.0016	2.35E+04	0.0248	14029	-0.035	44.04		34.28
		c	-0.0442	6.63E+05	0.0128	2899	-5.658	256.15		1.22
			SUM OF h AND 2kQ =					-0.404	751.61	-5.378E-04
	2	c	0.0442	6.63E+05	0.0128	2899	5.658	256.15		-1.49
		d	-0.0324	4.86E+05	0.0135	7608	-7.983	492.90		2.03
		e	0.0176	2.64E+05	0.0149	8438	2.616	297.15		-3.73
		f	-0.0177	2.66E+05	0.0149	3372	-1.057	119.42		3.71
			SUM OF h AND 2kQ =					-0.766	1165.61	-6.575E-04
	3	f	0.0177	2.66E+05	0.0149	3372	1.057	119.42		-1.90
		g	-0.0147	2.20E+05	0.0154	10462	-2.257	307.31		2.29
		h	0.0103	1.55E+05	0.0165	9317	0.991	192.18		-3.26
			SUM OF h AND 2kQ =					-0.208	618.91	-3.366E-04
4	1	a	0.0240	3.80E+05	0.0142	9596	5.513	460.00		-1.06
		b	-0.0010	1.65E+04	0.0278	15588	-0.017	32.17		24.63
		c	-0.0443	6.84E+05	0.0128	2898	-5.686	256.74		0.57
			SUM OF h AND 2kQ =					-0.190	748.91	-2.542E-04
	2	c	0.0443	6.84E+05	0.0128	2898	5.686	256.74		-0.44
		d	-0.0317	4.76E+05	0.0135	7633	-7.688	484.50		0.61
		e	0.0183	2.74E+05	0.0148	8383	2.797	306.24		-1.07
		f	-0.0174	2.81E+05	0.0150	3383	-1.023	117.64		1.12
			SUM OF h AND 2kQ =					-0.227	1165.11	-1.951E-04
	3	f	0.0174	2.81E+05	0.0150	3383	1.023	117.64		-0.85
		g	-0.0143	2.15E+05	0.0155	10507	-2.164	301.54		1.02
		h	0.0107	1.60E+05	0.0164	9260	1.050	197.24		-1.38
			SUM OF h AND 2kQ =					-0.091	616.42	-1.470E-04

TRIAL	CIRCUIT	PIPE	Q	REY. NO.	FR. FACT.	k	$h = kQ^2$	$2kQ$	DELTA Q	% CHANGE
5	1	a	0.0242	3.63E+05	0.0141	9579	5.620	464.04	-8.361E-05	-0.35
		b	-0.0008	1.17E+04	0.0297	16793	-0.010	26.12		10.75
		c	-0.0442	6.64E+05	0.0128	2899	-5.672	256.45		0.19
		SUM OF h AND 2kQ =						-0.062		746.62
	2	c	0.0442	6.64E+05	0.0128	2899	5.672	256.45	-8.142E-05	-0.18
		d	-0.0315	4.73E+05	0.0135	7641	-7.601	482.00		0.26
		e	0.0185	2.77E+05	0.0148	8368	2.851	308.93		-0.44
		f	-0.0173	2.60E+05	0.0150	3385	-1.017	117.37		0.47
		SUM OF h AND 2kQ =						-0.095		1164.75
	3	f	0.0173	2.60E+05	0.0150	3385	1.017	117.37	-4.759E-05	-0.27
		g	-0.0142	2.13E+05	0.0155	10527	-2.123	299.02		0.34
		h	0.0108	1.62E+05	0.0164	9236	1.077	199.44		-0.44
		SUM OF h AND 2kQ =						-0.029		615.83
6	1	a	2.431E-02	3.65E+05	0.0141	9573	5.656	465.37	-3.289E-05	-0.14
		b	-8.841E-04	1.04E+04	0.0307	17318	-0.008	24.04		4.74
		c	-4.424E-02	6.64E+05	0.0128	2899	-5.672	256.44		0.07
		SUM OF h AND 2kQ =						-0.025		745.86
	2	c	4.424E-02	6.64E+05	0.0128	2899	5.672	256.44	-2.812E-05	-0.06
		d	-3.146E-02	4.72E+05	0.0135	7644	-7.565	480.96		0.09
		e	1.854E-02	2.78E+05	0.0148	8361	2.874	310.05		-0.15
		f	-1.730E-02	2.60E+05	0.0150	3386	-1.014	117.18		0.16
		SUM OF h AND 2kQ =						-0.033		1164.63
	3	f	1.730E-02	2.60E+05	0.0150	3386	1.014	117.18	-1.855E-05	-0.11
		g	-1.416E-02	2.12E+05	0.0155	10533	-2.111	298.20		0.13
		h	1.084E-02	1.63E+05	0.0163	9228	1.085	200.15		-0.17
		SUM OF h AND 2kQ =						-0.011		615.53

12.10 (continued)

TRIAL 6 PRODUCED % CHANGE < 0.2% FOR ALL BUT PIPE b WHICH CARRIES VERY LOW FLOW.
RESULTS SUMMARIZED BELOW WITH FLOW RATES CONVERTED TO L/min.

PIPE a: Q = 1458

PIPE c: Q = 2654

PIPE e: Q = 1112

PIPE g: Q = 849

PIPE b: Q = 42

PIPE d: Q = 1888

PIPE f: Q = 1038

PIPE h: Q = 651

