APPENDIX C: Tanks-in-Series Model Calculations

Model Parameters Based on Slurry Level Detectors

LIN VEL (FT/S)	AVG L/D	CSTRS IN SERIES	RES TIME (S)	TOT RES TM (S)	CSTR/L/D	
0.25	9.66	2.40	20.21	48.51	0.25	CSTR AVG
0.25	9.66	2.40	20.77	49.85	0.25	2.77
0.25	9.66	2.40	20.27	48.65	0.25	0.37
0.25	9.63	3.10	14.41	44.67	0.32	CSTR/L/D AVG
0.25	9.63	3.20	13.99	44.78	0.33	0.29
0.25	9.63	3.20	14.10	45.12	0.33	0.04
0.25	9.60	3.10	14.53	45.04	0.32	RES TIM AVG
0.25	9.60	2.40	20.49	49.18	0.25	17.41
0.25	9.60	2.40	20.07	48.17	0.25	2.97
0.25	9.60	3.10	15.24	47.24	0.32	TOT RES TIM AVG
						47.12
						1.92
0.50	10.56	3.40	7.07	24.02	0.32	CSTR AVG
0.50	10.56	3.30	7.74	25.54	0.31	3.59
0.50	10.56	3.30	7.65	25.25	0.31	0.38
0.50	10.56	3.40	7.31	24.84	0.32	CSTR/L/D AVG
0.50	10.53	4.10	6.24	25.56	0.39	0.34
0.50	10.53	4.20	6.54	27.46	0.40	0.04
0.50	10.53	4.20	6.38	26.78	0.40	RES TIM AVG
0.50	10.53	4.10	6.29	25.78	0.39	7.18
0.50	10.52	3.40	7.36	25.02	0.32	0.59
0.50	10.52	3.50	7.35	25.74	0.33	TOT RES TIM AVG
0.50	10.52	3.20	8.03	25.70	0.30	25.52
0.50	10.52	3.20	7.72	24.71	0.30	0.84
0.50	10.52	3.33	7.62	25.29	0.32	
0.60	10.75	3.22	7.36	23.70	0.30	CSTR AVG
0.60	10.75	3.28	7.35	24.12	0.31	4.09
0.60	10.75	3.35	7.72	25.87	0.31	0.73
0.60	10.61	3.63	5.66	20.83	0.35	CSTR/L/D AVG
0.60	10.61	3.53	6.02	21.25	0.33	0.39
0.60	10.61	3.49	6.05	21.11	0.33	0.07
0.60	10.61	3.54	5.99	21.20	0.33	RES TIM AVG
0.60	10.60	4.44	4.62	20.52	0.42	5.61
0.60	10.60	4.23	5.06	21.39	0.40	1.14
0.60	10.60	4.60	4.36	20.06	0.43	TOT RES TIM AVG
0.60	10.60	4.22	5.08	21.42	0.40	22.23
0.60	10.52	5.40	4.27	23.06	0.51	1.62
0.60	10.52	5.15	4.61	23.73	0.49	
0.60	10.52	5.16	4.46	22.99	0.49	
0.50	7.43	3.20	5.39	17.25	0.43	CSTR AVG
0.50	7.43	2.40	7.96	19.10	0.32	2.89
0.50	7.43	2.50	7.29	18.23	0.34	0.56
0.50	7.43	2.70	6.50	17.55	0.36	CSTR/L/D AVG
0.50	7.40	4.40	4.17	18.35	0.59	0.39
0.50	7.40	3.10	5.92	18.35	0.42	0.08
0.50	7.40	3.10	5.67	17.58	0.42	RES TIM AVG
0.50	7.40	3.20	5.10	16.32	0.43	6.45
0.50	7.39	2.90	5.70	16.53	0.39	1.33
0.50	7.39	2.30	8.76	20.15	0.31	TOT RES TIM AVG
0.50	7.39	2.30	8.21	18.88	0.31	17.97

0.50	7.39	2.60	6.69	17.40	0.35	1.05

0.25	6.62	1.40	24.42	34.19	0.21	CSTR AVG
0.25	6.62	1.35	32.89	41.11	0.19	1.59
0.25	6.62	1.20	39.70	47.64	0.18	0.45
0.25	6.62	1.30	30.01	39.01	0.20	CSTR/L/D AVG
0.25	6.54	1.30	30.18	39.24	0.20	0.24
0.25	6.54	1.20	40.41	48.49	0.18	0.07
0.25	6.54	1.20	43.32	51.99	0.18	RES TIM AVG
0.25	6.54	1.30	33.03	42.93	0.20	27.29
0.25	6.52	2.30	12.04	27.69	0.35	10.99
0.25	6.52	2.20	13.91	30.59	0.34	TOT RES TIM AVG
0.25	6.52	2.20	13.57	29.86	0.34	33.62
0.25	6.52	2.20	13.96	30.71	0.34	7.78

0.18	6.24	1.20	48.79	58.55	0.19	CSTR AVG
0.18	6.24	1.10	66.26	72.88	0.18	1.23
0.18	6.24	1.10	74.27	81.69	0.18	0.10
0.18	6.24	1.20	58.22	69.87	0.19	CSTR/L/D AVG
0.18	6.23	1.50	26.94	40.41	0.24	0.20
0.18	6.23	1.30	36.02	46.82	0.21	0.02
0.18	6.23	1.20	44.99	53.99	0.19	RES TIM AVG
0.18	6.23	1.30	45.25	58.82	0.21	50.50
0.18	6.22	1.20	47.16	56.59	0.19	12.07
0.18	6.22	1.20	50.37	60.45	0.19	TOT RES TIM AVG
0.18	6.22	1.20	56.69	68.03	0.19	61.21
0.18	6.22	1.30	51.10	66.44	0.21	10.92

APPENDIX D: Axial Dispersion: Equation (16) Derivation

APPENDIX D

Solution of equation (16):

$$\theta_L \frac{\partial^2 C}{\partial Z^2} = \frac{\partial C}{\partial t} \qquad t > t_o \qquad 0 <= Z <= L \tag{1}$$

Rewrite as:

$$C_t - \theta_L C_{zz} = 0 \tag{2}$$

$$C(z,t_o) = \delta(z) \tag{3}$$

$$C_z(0,t) = 0 \tag{4}$$

$$C_z(L,t) = 0 \tag{5}$$

Use the method of separation of variables:

$$C = Z(z)\ T(t) \tag{6}$$

$$C_z = Z'(z)\ T(t) \tag{7}$$

$$C_{zz} = Z''(z)\ T(t) \tag{8}$$

$$C_t = Z(z)\ T'(t) \tag{9}$$

Substitute (6) through (9) into (2):

$$Z(z)\ T'(t) - \theta_L Z''(z)\ T(t) = 0 \tag{10}$$

Divide by equation (6) to get:

$$\frac{T'(t)}{T(t)} - \theta_L \frac{Z''(z)}{Z(z)} = 0 \tag{11}$$

$$\frac{T'(t)}{T(t)} = \lambda \qquad \frac{Z''(z)}{Z(z)} = \frac{\lambda}{\theta_L} \tag{12}$$

$$T'(t) - \lambda T(t) = 0 \qquad Z''(z) - \frac{\lambda}{\theta_L} Z(z) = 0 \tag{13,14}$$

Solve for T(t):

$$T(t) = \exp(\lambda t) \tag{15}$$

$$T'(t) = \lambda \exp(\lambda t) \tag{16}$$

$$\frac{T'(t)}{T(t)} = \lambda \tag{17}$$

Solve for Z(z):

$$Z(z) = +\cos \sqrt{-\frac{\lambda}{\theta_L}}\ z \qquad Z(z) = -\cos \sqrt{-\frac{\lambda}{\theta_L}}\ z \tag{18,19}$$

$$Z'(z) = -\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ \sin\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ z \qquad Z'(z) = \sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ \sin\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ z \tag{20,21}$$

$$Z''(z) = \frac{\lambda}{\mathcal{D}_L}\ \cos\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ z \qquad Z''(z) = \frac{-\lambda}{\mathcal{D}_L}\ \cos\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ z \tag{22,23}$$

$$\frac{Z''(z)}{Z(z)} = \frac{\lambda}{\mathcal{D}_L} \qquad \text{for both solutions} \tag{24}$$

Apply boundary conditions:

$$C = Z(z)\ T(t) \tag{25}$$

$$C = +-\ \cos\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ z\ \ \exp\ (\ \lambda\ t) \tag{26}$$

$$C_z = Z'(z)\ T(t) \tag{27}$$

$$C_z = -\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ \sin\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ z\ \ \exp\ (\ \lambda\ t) \tag{28}$$

$$C_z(0,t) = -\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ \sin 0\ \ \exp\ (\ \lambda\ t) = 0 \tag{29}$$

$$C_z(L,t) = -\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ \sin\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ L\ \ \exp\ (\ \lambda\ t) = 0 \tag{30}$$

$$\sin\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ L = 0 \tag{31}$$

$$\sqrt{\frac{-\lambda}{\mathcal{D}_L}}\ L = n\pi \tag{32}$$

$$\sqrt{\frac{-\lambda}{\mathcal{D}_L}} = \frac{n\pi}{L} \tag{33}$$

$$\lambda = -\frac{n^2\pi^2}{L^2}\ \mathcal{D}_L \tag{34}$$

Substituting for λ into 26 gives

$$C = +-\ \cos\ [\ \frac{n\pi}{L}\ z]\ \ \exp\ (\ \frac{-n^2\pi^2}{L^2}\ \mathcal{D}_L\ \ t\ ) \tag{35}$$

APPENDIX E: Axial Dispersion: Equation (20) Derivation

APPENDIX E: Derivation of Equation 20

For the gas phase dispersion:

$$\mathcal{D}_G \frac{\partial^2 C_G}{\partial Z^2} - \frac{U_G}{\epsilon_G} \frac{\partial C_G}{\partial Z} + K_L a \,(HC_L - C_G) = \frac{\partial C_G}{\partial t} \quad (1)$$

For the liquid phase dispersion:

$$\mathcal{D}_L \frac{\partial^2 C_L}{\partial Z^2} - K_L a \frac{\epsilon_G}{\epsilon_L} (HC_L - C_G) = \frac{\partial C_L}{\partial t} \quad (2)$$

Multiply (1) by ϵ_G and (2) by ϵ_L:

$$\epsilon_G \mathcal{D}_G \frac{\partial^2 C_G}{\partial Z^2} - U_G \frac{\partial C_G}{\partial Z} + K_L a \,\epsilon_G (HC_L - C_G) = \epsilon_G \frac{\partial C_G}{\partial t} \quad (3)$$

$$\epsilon_L \mathcal{D}_L \frac{\partial^2 C_L}{\partial Z^2} - K_L a \,\epsilon_G (HC_L - C_G) = \epsilon_L \frac{\partial C_L}{\partial t} \quad (4)$$

The total concentration is:

$$\epsilon_G * C_G + \epsilon_L * C_L \quad (5)$$

$$\frac{\partial}{\partial t} (\epsilon_G C_G + \epsilon_L C_L) = \epsilon_G \frac{\partial C_G}{\partial t} + \epsilon_L \frac{\partial C_L}{\partial t} \quad (6)$$

Assume mass transfer is small; then $C_G = H^*C_L$. Also assume that H (Henry's Law constant) is not a function of time or location within the reactor. Then:

$$\frac{1}{H}\frac{\partial C_G}{\partial Z} = \frac{\partial C_L}{\partial Z} \qquad (7)$$

$$\frac{1}{H}\frac{\partial C_G}{\partial t} = \frac{\partial C_L}{\partial t} \qquad (8)$$

Substitute (7) and (8) into (4) and add (3) and (4) together:

$$\left(\epsilon_G \mathcal{D}_G + \frac{\epsilon_L}{H}\mathcal{D}_L\right)\frac{\partial^2 C_G}{\partial Z^2} - U_G\frac{\partial C_G}{\partial Z} = \left(\epsilon_G + \frac{\epsilon_L}{H}\right)\frac{\partial C_G}{\partial t} \qquad (9)$$

Rearrange (9) to get:

$$\frac{\mathcal{D}_G\epsilon_G + \mathcal{D}_L\frac{\epsilon_L}{H}}{\epsilon_G + \frac{\epsilon_L}{H}}\frac{\partial^2 C_G}{\partial Z^2} - \frac{U_G}{\epsilon_G + \frac{\epsilon_L}{H}}\frac{\partial C_G}{\partial Z} = \frac{\partial C_G}{\partial t} \qquad (10)$$

or:

$$\mathcal{D}_{EFF}\frac{\partial^2 C_G}{\partial Z^2} - U_{EFF}\frac{\partial C_G}{\partial Z} = \frac{\partial C_G}{\partial t} \qquad (11)$$

where:

$$\mathcal{D}_{EFF} = \frac{\mathcal{D}_G + \frac{\epsilon_L}{\epsilon_G H}\mathcal{D}_L}{1 + \frac{\epsilon_L}{\epsilon_G H}} \qquad (12)$$

and

$$U_{EFF} = \frac{U_G}{\epsilon_G + \epsilon_L/H} \qquad (13)$$

Rearranging (13) to solve for H gives:

$$H = \frac{U_{EFF}\,\epsilon_G}{U_G - U_{EFF}\,\epsilon_G} \qquad (14)$$

APPENDIX F: Derivation of Equations (23) - (28)

APPENDIX F

Derivation of Equations (23) through (28):

From Brenner:

$$C(x,t) = 2 \exp[P(2x-t^*)] \sum_{k=1}^{\infty} \frac{P\,\lambda_k}{(\lambda_k^2 + P^2 + P)(\lambda_k^2 + P^2)} [\lambda_k \cos 2\lambda_k x$$

$$- P \sin 2\lambda_k x] * \exp(-\lambda_k^2 t^*/P) \qquad (1)$$

This equation is the solution for a step change problem with the same boundary conditions as for our reactor. To find the response of a delta function, differentiate Brenner's solution, C(x,t), with respect to t. This will give the correct solution for the concentration, C(x,t), as applied to the delta function problem.

$$C^* = -\frac{dC}{dt} = 2P \exp[P(2x-t^*)] \sum_{k=1}^{\infty} \frac{P\,\lambda_k}{(\lambda_k^2 + P^2 + P)(\lambda_k^2 + P^2)} [\lambda_k \cos 2\lambda_k x$$

$$+ P \sin 2\lambda_k x] * \exp(-\lambda_k^2 t^*/P) + 2 \exp[P(2x-t^*)]$$

$$\sum_{k=1}^{\infty} \frac{\lambda_k^2}{P} \frac{P\,\lambda_k}{(\lambda_k^2 + P^2 + P)(\lambda_k^2 + P^2)} [\lambda_k \cos 2\lambda_k x$$

$$+ P \sin 2\lambda_k x] * \exp(-\lambda_k^2 t^*/P) \qquad (2)$$

Simplify:

$$C^* = \frac{2}{P} \exp[P(2x-t^*)] \sum_{k=1}^{\infty} P^2 \frac{P\,\lambda_k}{(\lambda_k^2 + P^2 + P)(\lambda_k^2 + P^2)} [\lambda_k \cos 2\lambda_k x$$

$$+ P \sin 2\lambda_k x] * \exp(-\lambda_k^2 t^*/P) +$$

$$\lambda_k^2 \frac{P\,\lambda_k}{(\lambda_k^2 + P^2 + P)(\lambda_k^2 + P^2)} [\lambda_k \cos 2\lambda_k x$$

$$+ P \sin 2\lambda_k x] * \exp(-\lambda_k^2 t^*/P) \qquad (3)$$

Combine the two summation terms, cancel a P term, and cancel $(P^2 + \lambda_k^2)$ from the numerator and denominator.

$$C^* = 2 \exp[P(2x-t^*)] \sum_{k=1}^{\infty} \frac{\lambda_k}{(\lambda_k^2 + P^2 + P)} [\lambda_k \cos 2\lambda_k x$$

$$+ P \sin 2\lambda_k x] * \exp(-\lambda_k^2 t^*/P) \qquad (4)$$

Substitute the following definitions:

$$P = \frac{Pe}{4} = \frac{UL}{4D} \qquad (5)$$

$$x = z/L \qquad (6)$$

$$\alpha_n = 2\lambda_k \tag{7}$$

To give:

$$C^* = 2 \exp\left[\frac{Pe}{4}\left(\frac{2z}{L}-t^*\right)\right] \sum_{n=1}^{\infty} \frac{\alpha_n/2}{(\alpha_n^2/4 + Pe^2/16 + Pe/4)} \left[\alpha_n/2 \cos \alpha_n z/L + Pe/4 \sin \alpha_n z/L\right] * \exp(-\alpha_n^2 t^*/Pe) \tag{8}$$

Multiply numerator and denominator by 16/16 and factor a 1/2 out of the summation.

$$C^* = \exp\left[\frac{Pe}{4}\left(\frac{2z}{L}-t^*\right)\right] \sum_{n=1}^{\infty} \frac{8\alpha_n}{4(\alpha_n^2 + Pe) + Pe^2} \left[\alpha_n \cos \alpha_n z/L + Pe/2 \sin \alpha_n z/L\right] * \exp(-\alpha_n^2 t^*/Pe) \tag{9}$$

Combine exponential terms:

$$C^* = \sum_{n=1}^{\infty} \frac{8\alpha_n}{4(\alpha_n^2 - Pe) + Pe^2} \left[\alpha_n \cos \alpha_n z/L + Pe/2 \sin \alpha_n z/L\right] * \exp\left(\frac{Pe}{2}\frac{z}{L} - \frac{Pe\, t^*}{4} - \frac{\alpha_n^2 t^*}{Pe}\right) \tag{10}$$

Define

$$f_n = \frac{8\alpha_n}{4(\alpha_n^2 + Pe^2) + Pe^2} \left[\alpha_n \cos \alpha_n z/L + Pe/2 \sin \alpha_n z/L\right] \exp\left(\frac{Pe\, z}{2L}\right) \tag{11}$$

Then:

$$C^* = \sum_{n=1}^{\infty} f_n \exp\left(-\left(\frac{Pe}{4} + \frac{\alpha_n^2}{Pe}\right) t^*\right) \tag{12}$$

Define $A_n = \alpha_n^2 + Pe^2/4$

$$C^* = \sum_{n=1}^{\infty} f_n \exp\left(-\frac{A_n t^*}{Pe}\right) \tag{13}$$

Brenner's t is a dimensionless t defined as

$$t^* = t\, U/L \tag{14}$$

Substitute for t and the definition of the Peclet number ($UL/\mathcal{D}$).

$$C^* = \sum_{n=1}^{\infty} f_n \exp\left(-\frac{A_n t \mathcal{D}}{L^2}\right) \tag{15}$$

Brenner states that λ_k is the solution to

$$\lambda_k \tan \lambda_k - P = 0 \tag{16}$$

$$\lambda_k \cot \lambda_k + P = 0 \tag{17}$$

Substituting the definition for $\alpha_n = 2\lambda_k$

$$\frac{\alpha_n}{2} \tan \frac{\alpha_n}{2} - \frac{Pe}{4} = 0 \tag{18}$$

$$\frac{\alpha_n}{2} \cot \frac{\alpha_n}{2} + \frac{Pe}{4} = 0 \tag{19}$$

Brenner defines his normalization factor as

$$\overline{C} = \int_0^1 C(x,t)\, dx \tag{20}$$

This is appropriate for a step change where the net quantity before the change or a long time after it, is not a function of time. For our system, a pulse function, the normalization factor is :

$$\overline{C} = \int_0^\infty C(x_o, t^*)\, dt^* \tag{21}$$

where x_o is any fixed value of x for which dC/dx is zero. For our problem, L satisfies this condition. t is Brenner's dimensionless time which is defined in equation (14). By substitution of (14) into (21), the following normalization factor is obtained.

$$\overline{C} = \frac{U}{L}\int_0^\infty C(L,t)\, dt \tag{22}$$

APPENDIX G: Dispersion Model: Individual Detectors Best Fit Parameters

Individual Detectors - Best Fit Parameters

	Detector	Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
1	2	0.00663	69.77	0.120	2.39	25.00	18.08	yes
	3	0.00580	49.90	0.080	1.03	20.42	18.08	no
	4	0.00719	60.93	0.100	3.66	20.42	18.08	yes
	5	0.00781	59.63	0.080	2.86	20.42	18.08	no
	6	0.00791	56.89	0.080	2.82	20.42	18.08	no
	7	0.00552	49.34	0.080	0.56	19.17	18.08	no
	8	0.00683	51.13	0.070	0.63	19.17	18.08	no
	9	0.00622	52.56	0.070	0.79	19.17	18.08	no
	10	0.00646	50.60	0.060	0.38	19.17	18.08	no
	11	0.00756	36.29	0.060	0.03	12.67	18.08	no
	12	0.01662	74.65	0.300	12.89	12.67	18.08	yes
	13	0.00905	47.12	0.160	9.45	12.67	18.08	yes
	14	0.00704	38.82	0.040	0.90	12.67	18.08	no
	15	0.00758	49.90	0.170	9.35	7.17	18.08	yes
	16	0.00517	43.29	0.050	0.14	7.17	18.08	no
	17	0.00477	37.15	0.050	1.28	3.67	18.08	no
	18	0.01166	22.53	0.140	8.19	3.67	18.08	yes
	19	0.01389	25.83	0.200	22.34	3.67	18.08	yes
	20	0.00734	27.86	0.120	4.07	3.67	18.08	yes
2	2	0.00645	69.18	0.130	2.85	25.00	18.08	yes
	3	0.00547	51.66	0.110	2.40	20.42	18.08	yes
	4	0.00706	56.60	0.080	3.00	20.42	18.08	no
	5	0.00687	56.21	0.080	3.02	20.42	18.08	no
	6	0.00621	55.72	0.090	3.57	20.42	18.08	yes
	7	0.00946	46.31	0.140	2.46	19.17	18.08	yes
	8	0.00678	51.67	0.070	0.13	19.17	18.08	no
	9	0.00627	51.05	0.070	0.06	19.17	18.08	no
	10	0.00581	50.75	0.070	1.60	19.17	18.08	no
	11	0.00721	35.71	0.060	1.53	12.67	18.08	no
	12	0.01863	78.86	0.330	13.19	12.67	18.08	yes
	13	0.00964	44.42	0.180	11.35	12.67	18.08	yes
	14	0.00768	36.82	0.060	1.14	12.67	18.08	no
	15	0.00751	43.04	0.150	10.44	7.17	18.08	yes
	16	0.00555	41.28	0.060	0.37	7.17	18.08	no
	17	0.00410	35.65	0.050	2.47	3.67	18.08	no
	18	0.01163	21.00	0.180	12.57	3.67	18.08	yes
	19	0.01131	26.39	0.210	23.69	3.67	18.08	yes
	20	0.00476	31.26	0.060	1.24	3.67	18.08	no

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
3	2	0.00725	72.73	0.160	3.55	25.00	18.00	yes
	3	0.00594	51.80	0.130	2.90	20.42	18.00	yes
	4	0.00598	57.13	0.110	3.82	20.42	18.00	yes
	5	0.00694	56.74	0.100	3.11	20.42	18.00	yes
	6	0.00697	54.72	0.100	4.05	20.42	18.00	yes
	7	0.00650	51.80	0.100	1.33	19.17	18.00	yes
	8	0.00715	54.46	0.090	0.73	19.17	18.00	yes
	9	0.00608	54.35	0.090	0.81	19.17	18.00	yes
	10	0.00567	50.94	0.060	0.93	19.17	18.00	no
	11	0.00620	36.21	0.070	1.97	12.67	18.00	no
	12	0.01658	71.29	0.350	20.97	12.67	18.00	yes
	13	0.00943	44.11	0.190	12.81	12.67	18.00	yes
	14	0.00661	37.54	0.070	2.90	12.67	18.00	no
	15	0.00876	40.39	0.150	10.25	7.17	18.00	yes
	16	0.00510	42.22	0.060	0.93	7.17	18.00	no
	17	0.00375	34.84	0.100	3.17	3.67	18.00	yes
	18	0.01063	20.76	0.190	12.20	3.67	18.00	yes
	19	0.01065	26.85	0.200	20.42	3.67	18.00	yes
	20	0.00562	27.73	0.110	1.61	3.67	18.00	yes
4	2	0.00573	33.17	0.080	0.06	25.00	19.83	no
	3	0.00865	21.57	0.060	0.34	17.17	19.83	no
	4	0.01117	24.19	0.100	2.82	17.17	19.83	yes
	5	0.01163	25.83	0.130	4.33	17.17	19.83	yes
	6	0.01012	24.50	0.090	2.82	17.17	19.83	yes
	7	0.00832	25.46	0.060	0.41	20.67	19.83	no
	8	0.00814	26.90	0.060	0.27	20.67	19.83	no
	9	0.00834	26.67	0.060	0.14	20.67	19.83	no
	10	0.00786	25.94	0.060	0.41	20.67	19.83	no
	11	0.00763	22.36	0.060	0.62	12.67	19.83	no
	12	0.01123	26.80	0.160	4.16	12.67	19.83	yes
	13	0.01117	26.06	0.160	4.24	12.67	19.83	yes
	14	0.01024	24.19	0.110	3.63	12.67	19.83	yes
	15	0.00885	24.59	0.190	6.23	7.17	19.83	yes
	16	0.00623	24.14	0.060	1.25	7.17	19.83	no
	17	0.00504	21.53	0.060	0.93	3.67	19.83	no
	18	0.00887	15.94	0.160	5.08	3.67	19.83	yes
	19	0.01131	17.95	0.180	10.19	3.67	19.83	yes
	20	0.00714	17.21	0.100	1.44	3.67	19.83	yes

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
5	2	0.00719	33.57	0.080	0.58	25.00	19.75	no
	3	0.00840	21.41	0.060	0.58	17.17	19.75	no
	4	0.01024	23.82	0.080	1.63	17.17	19.75	no
	5	0.01111	24.59	0.090	2.46	17.17	19.75	yes
	6	0.01078	24.32	0.080	2.45	17.17	19.75	no
	7	0.00791	26.11	0.090	0.73	20.67	19.75	yes
	8	0.00682	27.94	0.080	0.72	20.67	19.75	no
	9	0.00730	27.56	0.070	0.03	20.67	19.75	no
	10	0.00824	26.41	0.070	0.83	20.67	19.75	no
	11	0.00942	21.39	0.100	0.37	12.67	19.75	yes
	12	0.01272	26.16	0.150	4.51	12.67	19.75	yes
	13	0.01274	26.53	0.160	4.50	12.67	19.75	yes
	14	0.00987	24.56	0.100	2.36	12.67	19.75	yes
	15	0.01055	24.79	0.160	5.73	7.17	19.75	yes
	16	0.00857	22.30	0.080	0.73	7.17	19.75	no
	17	0.00562	21.24	0.040	0.58	3.67	19.75	no
	18	0.00974	15.97	0.100	3.43	3.67	19.75	yes
	19	0.01313	17.81	0.170	6.81	3.67	19.75	yes
	20	0.00920	17.64	0.100	3.54	3.67	19.75	yes
6	2	0.00377	32.82	0.090	1.33	25.00	19.75	yes
	3	0.00375	23.25	0.210	2.53	17.17	19.75	yes
	4	0.00537	25.87	0.210	3.95	17.17	19.75	yes
	5	0.00510	25.56	0.210	3.65	17.17	19.75	yes
	6	0.00453	25.29	0.200	3.58	17.17	19.75	yes
	7	0.00394	28.87	0.160	1.04	20.67	19.75	yes
	8	0.00356	29.26	0.110	1.67	20.67	19.75	yes
	9	0.00412	28.85	0.130	1.59	20.67	19.75	yes
	10	0.00423	28.42	0.140	1.16	20.67	19.75	yes
	11	0.00364	26.27	0.260	2.67	12.67	19.75	yes
	12	0.00517	29.73	0.290	5.52	12.67	19.75	yes
	13	0.00485	28.69	0.290	6.51	12.67	19.75	yes
	14	0.00382	27.87	0.260	4.15	12.67	19.75	yes
	15	0.00390	29.96	0.410	8.13	7.17	19.75	yes
	16	0.00329	30.85	0.390	3.32	7.17	19.75	yes
	17	0.00334	23.70	0.530	5.14	3.67	19.75	yes
	18	0.00436	17.98	0.570	8.74	3.67	19.75	yes
	19	0.00512	17.94	0.570	8.36	3.67	19.75	yes
	20	0.00442	20.37	0.540	5.33	3.67	19.75	yes

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
7	2	0.00623	27.57	0.050	0.68	25.00	20.17	no
	3	0.00896	18.72	0.060	0.59	17.17	20.17	no
	4	0.01153	21.44	0.120	2.27	17.17	20.17	yes
	5	0.01186	22.12	0.130	3.90	17.17	20.17	yes
	6	0.01135	20.87	0.080	2.05	17.17	20.17	no
	7	0.00820	21.75	0.050	0.25	20.67	20.17	no
	8	0.00868	22.81	0.070	0.88	20.67	20.17	no
	9	–	–	1.000	250.49	20.67	20.17	yes
	10	0.00835	22.03	0.050	0.16	20.67	20.17	no
	11	0.00982	18.69	0.100	0.82	12.67	20.17	yes
	12	0.01224	22.76	0.150	3.50	12.67	20.17	yes
	13	–	–	0.590	59.52	12.67	20.17	yes
	14	0.01065	21.61	0.100	2.68	12.67	20.17	yes
	15	0.01253	18.78	0.180	3.90	7.17	20.17	yes
	16	0.00729	21.72	0.100	0.88	7.17	20.17	yes
	17	0.00686	18.83	0.120	0.74	3.67	20.17	yes
	18	0.01027	13.57	0.140	2.58	3.67	20.17	yes
	19	0.01121	15.96	0.210	9.33	3.67	20.17	yes
	20	0.00872	16.13	0.140	2.90	3.67	20.17	yes
8	2	0.00614	27.91	0.070	0.33	25.00	19.92	no
	3	0.01029	18.28	0.080	0.68	17.17	19.92	no
	4	0.01188	20.21	0.100	2.35	17.17	19.92	yes
	5	0.01224	21.48	0.100	2.05	17.17	19.92	yes
	6	0.01160	20.78	0.080	1.82	17.17	19.92	no
	7	0.00813	21.60	0.090	0.39	20.67	19.92	yes
	8	0.00828	21.90	0.060	0.26	20.67	19.92	no
	9	0.00802	21.34	0.090	0.47	20.67	19.92	yes
	10	0.00830	21.97	0.050	0.31	20.67	19.92	no
	11	0.00992	18.67	0.100	0.77	12.67	19.92	yes
	12	0.01300	22.62	0.190	4.79	12.67	19.92	yes
	13	–	–	1.000	258.41	12.67	19.92	yes
	14	0.01232	21.33	0.100	2.35	12.67	19.92	yes
	15	0.01166	19.52	0.260	4.43	7.17	19.92	yes
	16	0.00612	22.85	0.070	0.55	7.17	19.92	no
	17	0.00582	19.31	0.090	0.80	3.67	19.92	yes
	18	0.00692	16.49	0.130	3.45	3.67	19.92	yes
	19	0.00675	16.23	0.110	0.78	3.67	19.92	yes
	20	0.00734	17.35	0.100	2.09	3.67	19.92	yes

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
9	2	0.00533	28.73	0.090	0.95	25.00	19.92	yes
	3	0.00934	16.80	0.070	0.62	17.17	19.92	no
	4	0.01071	20.96	0.110	2.13	17.17	19.92	yes
	5	0.00995	20.97	0.110	1.79	17.17	19.92	yes
	6	0.01050	20.68	0.080	1.90	17.17	19.92	no
	7	0.00704	21.66	0.090	0.44	20.67	19.92	yes
	8	0.00731	22.40	0.060	0.13	20.67	19.92	no
	9	0.00724	21.61	0.090	0.44	20.67	19.92	yes
	10	0.00745	22.57	0.070	0.59	20.67	19.92	no
	11	0.00889	19.17	0.090	0.61	12.67	19.92	yes
	12	0.01183	22.40	0.150	3.28	12.67	19.92	yes
	13	–	–	0.760	12.43	12.67	19.92	yes
	14	0.00995	21.31	0.110	3.08	12.67	19.92	yes
	15	0.00800	22.40	1.000	578.93	7.17	19.92	yes
	16	0.00685	22.00	0.070	0.70	7.17	19.92	no
	17	0.00727	20.04	0.080	1.19	3.67	19.92	no
	18	–	–	0.730	140.01	3.67	19.92	yes
	19	0.01039	17.58	0.170	6.70	3.67	19.92	yes
	20	0.00828	17.28	0.090	2.95	3.67	19.92	yes
10	2	0.00639	28.44	0.100	0.53	25.00	19.75	yes
	3	0.00925	19.22	0.090	1.45	17.17	19.75	yes
	4	0.01137	21.51	0.130	2.46	17.17	19.75	yes
	5	0.01040	20.67	0.120	2.08	17.17	19.75	yes
	6	0.01012	20.43	0.060	0.59	17.17	19.75	no
	7	0.00734	22.96	0.090	0.25	20.67	19.75	yes
	8	0.00837	24.14	0.100	0.24	20.67	19.75	yes
	9	0.00857	23.31	0.090	0.01	20.67	19.75	yes
	10	0.00799	23.17	0.080	0.17	20.67	19.75	no
	11	0.00882	20.35	0.090	1.10	12.67	19.75	yes
	12	–	–	0.690	55.27	12.67	19.75	yes
	13	–	–	0.400	15.50	12.67	19.75	yes
	14	0.00931	21.11	0.100	1.29	12.67	19.75	yes
	15	–	–	0.710	107.65	7.17	19.75	yes
	16	0.00868	21.09	0.130	1.60	7.17	19.75	yes
	17	0.00616	21.30	0.080	1.60	3.67	19.75	no
	18	–	–	0.740	123.70	3.67	19.75	yes
	19	–	–	0.830	156.84	3.67	19.75	yes
	20	0.00780	15.69	0.120	1.09	3.67	19.75	yes

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
b1	2	0.01383	30.67	0.190	2.77	25.00	13.92	yes
	3	0.01306	15.75	0.060	0.58	11.67	13.92	no
	4	0.01996	19.05	0.170	6.70	11.67	13.92	yes
	5	0.02181	18.86	0.190	7.39	11.67	13.92	yes
	6	0.01429	16.68	0.060	1.01	11.67	13.92	no
	7	0.01443	18.46	0.050	0.44	14.67	13.92	no
	8	0.01761	21.12	0.130	4.39	14.67	13.92	yes
	9	0.01669	19.68	0.090	3.74	14.67	13.92	yes
	10	0.01560	18.96	0.060	1.09	14.67	13.92	no
	11	0.01208	16.10	0.080	1.16	8.67	13.92	no
	12	0.01891	20.23	0.230	9.71	8.67	13.92	yes
	13	0.02380	23.47	0.200	1.14	8.67	13.92	yes
	14	0.01204	17.69	0.100	3.38	8.67	13.92	yes
	15	0.01294	18.21	0.150	6.29	6.00	13.92	yes
	16	0.01235	16.44	0.130	0.72	6.00	13.92	yes
	17	0.01050	13.96	0.100	1.78	3.67	13.92	yes
	18	0.01414	10.43	0.160	0.67	3.67	13.92	yes
	19	0.01301	11.06	0.130	0.97	3.67	13.92	yes
	20	0.01077	13.19	0.080	0.97	3.67	13.92	no
b2	2	0.01560	30.22	0.170	3.21	25.00	13.92	yes
	3	0.01347	15.33	0.050	0.61	11.67	13.92	no
	4	0.01868	17.88	0.140	5.19	11.67	13.92	yes
	5	0.02119	19.86	0.190	7.56	11.67	13.92	yes
	6	0.01375	16.68	0.040	0.50	11.67	13.92	no
	7	0.01476	18.09	0.060	0.00	14.67	13.92	no
	8	0.01548	20.75	0.110	3.57	14.67	13.92	yes
	9	0.01615	19.87	0.100	3.18	14.67	13.92	yes
	10	0.01450	18.61	0.050	1.01	14.67	13.92	no
	11	0.01440	15.84	0.090	1.35	8.67	13.92	yes
	12	0.01780	19.90	0.200	8.19	8.67	13.92	yes
	13	0.01534	19.10	0.180	7.55	8.67	13.92	yes
	14	–	–	–	–	8.67	13.92	yes
	15	0.01525	16.17	0.150	5.37	6.00	13.92	yes
	16	0.00943	17.53	0.100	1.67	6.00	13.92	yes
	17	0.01227	13.68	0.110	2.33	3.67	13.92	yes
	18	0.01523	10.61	0.130	0.43	3.67	13.92	yes
	19	0.01241	12.51	0.090	0.60	3.67	13.92	yes
	20	0.01156	13.10	0.120	1.42	3.67	13.92	yes

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
b3	2	0.01448	29.74	0.170	2.69	25.00	13.83	yes
	3	0.01625	15.45	0.070	0.91	11.67	13.83	no
	4	0.02064	17.50	0.140	5.54	11.67	13.83	yes
	5	0.02441	19.35	0.200	7.78	11.67	13.83	yes
	6	0.01783	16.08	0.060	0.70	11.67	13.83	no
	7	0.01687	18.09	0.060	0.33	14.67	13.83	no
	8	0.01962	20.96	0.140	4.99	14.67	13.83	yes
	9	0.01850	20.09	0.100	3.43	14.67	13.83	yes
	10	0.01690	18.74	0.070	1.34	14.67	13.83	no
	11	0.01278	16.38	0.070	0.74	8.67	13.83	no
	12	0.01875	20.62	0.220	8.40	8.67	13.83	yes
	13	0.01740	19.10	0.200	7.46	8.67	13.83	yes
	14	0.01521	17.12	0.100	2.68	8.67	13.83	yes
	15	0.01464	18.31	0.160	5.75	6.00	13.83	yes
	16	0.01338	15.67	0.140	1.06	6.00	13.83	yes
	17	0.01070	15.16	0.070	1.31	3.57	13.83	no
	18	0.01521	11.24	0.130	0.50	3.67	13.83	yes
	19	0.01707	10.45	0.130	0.80	3.67	13.83	yes
	20	0.01118	14.06	0.060	1.01	3.67	13.83	no
b4	2	–	–	0.330	11.80	25.00	12.42	yes
	3	–	–	0.330	12.03	20.42	12.42	yes
	4	–	–	0.320	12.49	20.42	12.42	yes
	5	–	–	0.320	11.91	20.42	12.42	yes
	6	–	–	0.310	11.80	20.42	12.42	yes
	7	0.01721	34.80	0.100	3.90	13.00	12.42	yes
	8	–	–	–	–	13.00	12.42	yes
	9	0.01838	46.93	0.140	6.45	13.00	12.42	yes
	10	0.01742	39.04	0.120	3.89	13.00	12.42	yes
	11	0.01111	24.25	0.070	1.23	8.67	12.42	no
	12	–	–	–	–	8.67	12.42	yes
	13	0.01861	32.97	0.230	17.31	8.67	12.42	yes
	14	–	–	–	–	8.67	12.42	yes
	15	0.01679	24.92	0.140	7.92	6.00	12.42	yes
	16	0.01023	27.76	0.060	2.49	6.00	12.42	no
	17	0.00760	21.93	0.050	0.39	3.67	12.42	no
	18	0.01819	13.93	0.120	0.89	3.67	12.42	yes
	19	0.01677	16.12	0.090	1.20	3.67	12.42	yes
	20	0.00920	21.02	0.070	1.41	3.67	12.42	no

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
b5	2	–	–	–	–	–	–	yes
	3	–	–	0.350	14.82	20.42	12.25	yes
	4	–	–	0.370	14.91	20.42	12.25	yes
	5	–	–	0.370	14.42	20.42	12.25	yes
	6	–	–	0.390	16.23	20.42	12.25	yes
	7	0.02101	38.17	0.100	2.03	13.00	12.25	yes
	8	0.02187	44.49	0.130	5.98	13.00	12.25	yes
	9	0.01657	48.11	0.130	4.99	13.00	12.25	yes
	10	0.01853	41.71	0.110	1.18	13.00	12.25	yes
	11	0.01320	23.26	0.080	1.91	8.67	12.25	no
	12	0.01898	35.01	0.270	21.57	8.67	12.25	yes
	13	0.01811	33.14	0.260	22.41	8.67	12.25	yes
	14	0.01255	25.44	0.070	3.86	8.67	12.25	no
	15	0.01572	26.98	0.160	13.72	6.00	12.25	yes
	16	0.01131	24.08	0.080	3.01	6.00	12.25	no
	17	0.01031	20.55	0.100	2.34	3.67	12.25	yes
	18	0.01714	13.35	0.120	1.17	3.67	12.25	yes
	19	0.01859	14.68	0.090	2.28	3.67	12.25	yes
	20	0.01036	20.28	0.050	0.97	3.67	12.25	no
b6	2	–	–	0.340	12.54	25.00	12.25	yes
	3	–	–	0.300	10.46	20.42	12.25	yes
	4	–	–	0.300	12.65	20.42	12.25	yes
	5	–	–	0.310	11.77	20.42	12.25	yes
	6	–	–	0.310	12.52	20.42	12.25	yes
	7	0.01728	35.58	0.140	5.41	13.00	12.25	yes
	8	0.01950	42.81	0.180	10.27	13.00	12.25	yes
	9	0.01921	42.43	0.170	10.36	13.00	12.25	yes
	10	0.01661	36.57	0.110	4.06	13.00	12.25	yes
	11	–	–	0.560	17.13	8.67	12.25	yes
	12	0.01792	28.50	0.210	15.91	8.67	12.25	yes
	13	0.01695	31.22	0.220	17.43	8.67	12.25	yes
	14	0.01271	26.37	0.080	5.28	8.67	12.25	no
	15	0.01459	26.92	0.160	10.20	6.00	12.25	yes
	16	0.01054	27.04	0.100	8.31	6.00	12.25	yes
	17	0.00918	20.59	0.060	0.52	3.67	12.25	no
	18	0.01792	14.90	0.210	15.37	3.67	12.25	yes
	19	0.01446	15.08	0.140	1.52	3.67	12.25	yes
	20	0.01020	19.67	0.090	2.93	3.67	12.25	yes

Individual Detectors - Best Fit Parameters

Detector		Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
b7	2	–	–	0.350	19.25	25.00	11.67	yes
	3	–	–	0.370	21.23	20.42	11.67	yes
	4	–	–	0.410	24.66	20.42	11.67	yes
	5	–	–	0.390	22.32	20.42	11.67	yes
	6	–	–	0.420	23.66	20.42	11.67	yes
	7	0.02037	59.45	0.090	2.72	12.33	11.67	yes
	8	–	–	0.350	9.21	12.33	11.67	yes
	9	0.01852	77.20	0.110	5.19	12.33	11.67	yes
	10	0.01592	70.47	0.080	1.52	12.33	11.67	no
	11	–	–	0.560	27.93	8.67	11.67	yes
	12	0.01790	41.16	0.210	23.24	8.67	11.67	yes
	13	0.01550	44.20	0.220	28.34	8.67	11.67	yes
	14	0.01107	34.15	0.060	4.81	8.67	11.67	no
	15	0.01665	33.70	0.140	17.34	6.00	11.67	yes
	16	0.01012	32.52	0.070	0.34	6.00	11.67	no
	17	0.00997	26.79	0.060	3.39	3.67	11.67	no
	18	0.02122	18.07	0.180	15.72	3.67	11.67	yes
	19	0.01905	17.80	0.140	2.07	3.67	11.67	yes
	20	0.01040	26.00	0.060	1.45	3.67	11.67	no
b8	2	–	–	0.420	26.27	25.00	11.67	yes
	3	–	–	0.390	24.27	20.42	11.67	yes
	4	–	–	0.400	24.39	20.42	11.67	yes
	5	–	–	0.430	26.10	20.42	11.67	yes
	6	–	–	0.420	26.16	20.42	11.67	yes
	7	0.02317	57.07	0.070	2.69	12.33	11.67	no
	8	–	–	0.360	6.11	12.33	11.67	yes
	9	0.02238	67.17	0.110	4.98	12.33	11.67	yes
	10	0.01706	69.06	0.090	0.21	12.33	11.67	yes
	11	–	–	0.570	24.05	8.67	11.67	yes
	12	–	–	0.450	2.55	8.67	11.67	yes
	13	0.01595	42.95	0.210	27.47	8.67	11.67	yes
	14	0.01136	33.46	0.040	3.46	8.67	11.67	no
	15	–	–	0.490	12.26	6.00	11.67	yes
	16	0.01247	30.62	0.080	1.15	6.00	11.67	no
	17	0.00863	27.86	0.080	4.66	3.67	11.67	no
	18	0.02438	16.55	0.150	14.37	3.67	11.67	yes
	19	0.02040	18.41	0.100	1.99	3.67	11.67	yes
	20	0.00970	27.15	0.060	2.51	3.67	11.67	no

Individual Detectors - Best Fit Parameters

Detector	Dispersion D/(L*L) (1/sec)	Slurry Mean Residence Time (sec)	Norm of Residuals	Difference in Centroids (sec)	Position z (ft)	Total Height L (ft)	Reject if Norm > 0.09
b9 2	–	–	0.410	26.92	25.00	11.67	yes
3	–	–	0.400	24.69	20.42	11.67	yes
4	–	–	0.410	27.89	20.42	11.67	yes
5	–	–	0.420	28.49	20.42	11.67	yes
6	–	–	0.430	28.73	20.42	11.67	yes
7	0.02630	64.01	0.090	1.15	12.33	11.67	yes
8	0.02764	68.19	0.120	2.36	12.33	11.67	yes
9	0.02307	74.56	0.110	0.16	12.33	11.67	yes
10	0.01536	74.28	0.110	2.63	12.33	11.67	yes
11	–	–	0.600	33.73	8.67	11.67	yes
12	–	–	0.430	13.94	8.67	11.67	yes
13	0.01445	41.94	0.200	27.34	8.67	11.67	yes
14	0.01100	34.35	0.060	5.13	8.67	11.67	no
15	0.01938	31.68	0.150	16.45	6.00	11.67	yes
16	0.01141	33.47	0.080	0.52	6.00	11.67	no
17	0.00924	25.49	0.080	2.18	3.67	11.67	no
18	0.02520	16.32	0.240	16.71	3.67	11.67	yes
19	0.01675	19.20	0.140	1.99	3.67	11.67	yes
20	0.00837	27.53	0.070	2.88	3.67	11.67	no

APPENDIX H: Calculation of the Number of CSTR's for a Commercial Scale Application of LPMEOH

APPENDIX H

Calculation of the Number of CSTR's for a Commerical Scale Application of LPMEOH

1. Calculate $\mathcal{D}_L$

$$\mathcal{D}_L = 0.667\ (gD^4Ug)^{1/3}$$

D = 12.8 ft
Ug = 0.7 ft/sec
g = 32.2 ft/sec^2

$$\mathcal{D}_L = 0.667\ [(32.2)(12.8)^4(0.7)]^{1/3}$$

$$\mathcal{D}_L = 56.16\ ft^2/sec$$

2. Calculate $\mathcal{D}_G$

$$\mathcal{D}_G = 4.421\ D^{1.5}Ug^{1.8}$$

$$= 4.421\ (12.8)^{1.5}(0.7)^{1.8}$$

$$\mathcal{D}_G = 106.52\ ft^2/sec$$

3. Calculate U_{EFF}

$$U_{EFF} = \frac{Ug}{\varepsilon_G + \frac{\varepsilon_L}{H}}$$

Calculate a molar average Henry's law constant assuming outlet composition.

Use $\bar{H} = 5.62$

$\varepsilon_G = 0.40$
$\varepsilon_{SL} = 0.05$

$$\varepsilon_L = (1 - \varepsilon_G)(1 - \varepsilon_{SL})$$
$$\varepsilon_L = (0.60)(0.95) = 0.57$$

$$U_{EFF} = \frac{0.7}{0.4 + \frac{0.57}{5.62}}$$

$$U_{EFF} = 1.40\ ft/sec$$

4. Calculate $\mathcal{D}_{EFF}$

$$\mathcal{D}_{EFF} = \frac{\mathcal{D}_G + \eta\mathcal{D}_L}{(1 + \eta)}$$

$$\eta = \frac{U_G - \varepsilon_G U_{EFF}}{\varepsilon_G U_{EFF}}$$

$$\eta = \frac{0.7 - 0.4(1.40)}{0.40(1.40)} = 0.25$$

$$\mathcal{D}_{EFF} = \frac{106.52 + 0.250(56.16)}{(1 + 0.25)}$$

$$\mathcal{D}_{EFF} = \underline{96.45}\ ft^2/sec$$

5. Calculate Peclet number

$$Pe_{EFF} = \frac{U_{EFF} L}{\mathcal{D}_{EFF}}$$

$$Pe_{EFF} = \frac{(1.40)(42.8)}{(96.45)}$$

$$Pe_{EFF} = \underline{0.622}$$

6. Calculate number of CSTRs

$$n = [2Pe^{-1} - 2Pe^{-2}(1 - \exp(-Pe))]^{-1}$$

$$n = \underline{1.22} \text{ tanks}$$

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