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APPENDICES

Appendix A Tables of the experimental data

The following tables contain the experimental data that are flow regimes of bubble and slug, rise velocities of single slug and continuous generated slugs, void fractions within slug flow and air-lift pump operation within slug flow.

Table A1 Determination the flow regimes.

Water flow rate (ml/min)	Water velocity (cm/s)	Air flow rate (ml/min)			Air velocity (cm/s)			Predicted transition air flow rate (ml/min)	Predicted transition air velocity (cm/s)
		B	B-S	S	B	B-S	S		
0	0	50			0.29				
0	0		100			0.59			
0	0		150			0.88			
0	0		200			1.17		285.5	1.68
0	0		300			1.76			
0	0			400			2.35		
200	1.17	50			0.29				
200	1.17	100			0.59				
200	1.17		150			0.88			
200	1.17		200			1.17			
200	1.17		250			1.47			
200	1.17		300			1.76		307.7	1.81
200	1.17			400			2.35		
300	1.76	100			0.59				
300	1.76	200			1.17				
300	1.76		300			1.76			
300	1.76		320			1.88		318.8	1.87
300	1.76			500			2.93		
400	2.35	100			0.59				
400	2.35	200			1.17				
400	2.35		300			1.76			
400	2.35		330			1.94		329	1.93
400	2.35		350			2.05			
400	2.35			400			2.35		
500	2.93	100			0.59				
500	2.93		200			1.17			
500	2.93		300			1.76			
500	2.93		350			2.05		341	2.00
500	2.93		400			2.35			
500	2.93			500			2.93		
600	3.52	100			0.59				
600	3.52		200			1.17			
600	3.52		300			1.76			
600	3.52		360			2.11		352	2.07
600	3.52			400			2.35		
700	4.11	100			0.59				
700	4.11		200			1.17			
700	4.11		300			1.76			
700	4.11		360			2.11		363	2.13
700	4.11			500			2.93		

Cont.....

Table A1 (Continued)

Water flow rate (ml/min)	Water velocity (cm/s)	Air flow rate (ml/min)			Air velocity (cm/s)			Predicted transition air flow rate (ml/min)	Predicted transition air velocity (cm/s)
		B	B-S	S	B	B-S	S		
800	4.69	100			0.59				
800	4.69		200			1.17			
800	4.69		300			1.76			
800	4.69		400			2.35		374	2.19
800	4.69			500			2.93		
900	5.28	100			0.59				
900	5.28	200			1.17				
900	5.28		300			1.76			
900	5.28		400			2.35		385	2.26
900	5.28			500			2.93		
1000	5.87	100			0.59				
1000	5.87	200			1.17				
1000	5.87		300			1.76			
1000	5.87		400			2.35		397	2.33
1000	5.87		500			2.93			
1000	5.87			600			3.52		
1100	6.46	100			0.59				
1100	6.46	200			1.17				
1100	6.46	300			1.76				
1100	6.46		400			2.35		408	2.39
1100	6.46		500			2.93			
1100	6.46		600			3.52			
1100	6.46			700			4.11		
1200	7.04	100			0.59				
1200	7.04	200			1.17				
1200	7.04	300			1.76				
1200	7.04		400			2.35		418	2.45
1200	7.04		500			2.93			
1200	7.04		600			3.52			
1200	7.04			700			4.11		
1300	7.63	100			0.59				
1300	7.63	200			1.17				
1300	7.63	300			1.76				
1300	7.63		400			2.35		429	2.52
1300	7.63		500			2.93			
1300	7.63		600			3.52			
1300	7.63			700			4.11		
1400	8.22	100			0.59				
1400	8.22	200			1.17				
1400	8.22	300			1.76				
1400	8.22		400			2.35		441	2.59

Cont.....

Table A1 (Continued)

Water flow rate (ml/min)	Water velocity (cm/s)	Air flow rate (ml/min)			Air velocity (cm/s)			Predicted transition air flow rate (ml/min)	Predicted transition air velocity (cm/s)
		B	B-S	S	B	B-S	S		
1400	8.22		500			2.93			
1400	8.22		600			3.52			
1400	8.22			700			4.11		
1500	8.80	100			0.59				
1500	8.80	200			1.17				
1500	8.80	300			1.76				
1500	8.80		400			2.35		452	2.65
1500	8.80		500			2.93			
1500	8.80		600			3.52			
1500	8.80			700			4.11		
1600	9.39	100			0.59				
1600	9.39	200			1.17				
1600	9.39	300			1.76				
1600	9.39		400			2.35		463	2.72
1600	9.39		500			2.93			
1600	9.39		600			3.52			
1600	9.39			700			4.11		
1700	9.98	200			1.17				
1700	9.98	300			1.76				
1700	9.98		400			2.35		474	2.78
1700	9.98		500			2.93			
1700	9.98		600			3.52			
1700	9.98			700			4.11		
1800	10.56	200			1.17				
1800	10.56	300			1.76				
1800	10.56		400			2.35		485	2.85
1800	10.56		500			2.93			
1800	10.56		600			3.52			
1800	10.56		700			4.11			
1800	10.56			800			4.69		
1900	11.15	200			1.17				
1900	11.15	300			1.76				
1900	11.15		400			2.35			
1900	11.15		500			2.93		496	2.91
1900	11.15		600			3.52			
1900	11.15		700			4.11			
1900	11.15			800			4.69		
2000	11.74	200			1.17				
2000	11.74	300			1.76				
2000	11.74		400			2.35			
2000	11.74		500			2.93		508	2.98

Cont.....

Table A1 (Continued)

Water flow rate (ml/min)	Water velocity (cm/s)	Air flow rate (ml/min)			Air velocity (cm/s)			Predicted transition air flow rate (ml/min)	Predicted transition air velocity (cm/s)
		B	B-S	S	B	B-S	S		
2000	11.74		600			3.52			
2000	11.74		700			4.11			
2000	11.74		800			4.69			
2000	11.74			900			5.28		
2100	12.32	200			1.17				
2100	12.32	300			1.76				
2100	12.32		400			2.35			
2100	12.32		500			2.93		519	3.05
2100	12.32		600			3.52			
2100	12.32		700			4.11			
2100	12.32		800			4.69			
2100	12.32			900			5.28		
2200	12.91	300			1.76				
2200	12.91		400			2.35			
2200	12.91		500			2.93		530	3.11
2200	12.91		600			3.52			
2200	12.91		700			4.11			
2200	12.91		800			4.69			
2200	12.91			900			5.28		
2300	13.50	300			1.76				
2300	13.50		400			2.35			
2300	13.50		500			2.93		541	3.17
2300	13.50		600			3.52			
2300	13.50		700			4.11			
2300	13.50		800			4.69			
2300	13.50			900			5.28		
2400	14.08	300			1.76				
2400	14.08		400			2.35			
2400	14.08		500			2.93		552	3.24
2400	14.08		600			3.52			
2400	14.08		700			4.11			
2400	14.08		800			4.69			
2400	14.08		900			5.28			
2400	14.08			1000			5.87		
2500	14.67	300			1.76				
2500	14.67	400			2.35				
2500	14.67		500			2.93		563	3.30
2500	14.67		600			3.52			
2500	14.67		700			4.11			
2500	14.67		800			4.69			
2500	14.67		900			5.28			

Cont.....

Table A1 (Continued)

Water flow rate (ml/min)	Water velocity (cm/s)	Air flow rate (ml/min)			Air velocity (cm/s)			Predicted transition air flow rate (ml/min)	Predicted transition air velocity (cm/s)
		B	B-S	S	B	B-S	S		
2500	14.67			1000			5.87		
2600	15.26	400			2.35				
2600	15.26		500			2.93			
2600	15.26		600			3.52		574	3.37
2600	15.26		700			4.11			
2600	15.26		800			4.69			
2600	15.26		900			5.28			
2600	15.26			1000			5.87		
2700	15.85	400			2.35				
2700	15.85		500			2.93			
2700	15.85		600			3.52		586	3.44
2700	15.85		700			4.11			
2700	15.85		800			4.69			
2700	15.85		900			5.28			
2700	15.85			1000			5.87		

Note :

Cross section area, A = 2.84 cm^2

B= bubble flow

S= slug flow

B-S= bubble to slug transition

Table A2 Determination rise velocity of single slug (u_b) and slug length.

Slug No.	Start (s)	Stop (s)	Time interval (s)	Rising velocity, u_b from experiment, (cm/s)	Slug length (cm)	u_b from eq.(6) (cm/s)	Value of c in eq.(6) from experiment
1	3.66	11.32	7.66	14.32	9.00	15.11	0.33
2	1.28	8.92	7.64	14.35	14.15	15.11	0.33
3	3.36	11.05	7.69	14.27	18.11	15.11	0.33
4	3.75	11.37	7.62	14.40	3.00	15.11	0.33
5	1.88	9.82	7.94	13.82	11.27	15.11	0.32
6	3.21	10.38	7.17	15.30	4.59	15.11	0.35
7	1.13	8.78	7.65	14.34	6.25	15.11	0.33
8	0.78	7.99	7.21	14.73	7.25	15.11	0.34
9	2.93	10.39	7.46	14.71	23.24	15.11	0.34
10	3.01	10.56	7.55	14.53	26.88	15.11	0.34
11	3.65	11.51	7.86	13.96	22.96	15.11	0.32
12	2.39	10.21	7.82	14.03	26.33	15.11	0.32
13	2.26	9.86	7.60	14.43	8.51	15.11	0.33
14	1.83	9.52	7.69	14.27	19.73	15.11	0.33
15	3.21	10.8	7.59	14.45	18.00	15.11	0.33
16	3.84	11.45	7.61	14.42	5.91	15.11	0.33
17	2.09	9.59	7.50	14.63	18.22	15.11	0.34
18	2.34	9.93	7.59	14.45	11.10	15.11	0.33
19	2.39	10.12	7.73	14.19	17.68	15.11	0.33
20	2.17	9.50	7.33	14.97	21.34	15.11	0.35
21	2.50	10.24	7.74	14.17	24.66	15.11	0.33
22	2.64	10.25	7.61	14.42	8.50	15.11	0.33
23	2.59	10.35	7.76	14.14	42.14	15.11	0.33
24	2.07	9.77	7.70	14.25	9.47	15.11	0.33
25	3.61	11.87	8.26	13.28	38.25	15.11	0.31
26	3.96	11.84	7.88	13.92	37.72	15.11	0.32
27	3.59	11.51	7.92	13.85	33.52	15.11	0.32
28	2.04	9.97	7.93	13.83	28.90	15.11	0.32
29	3.75	11.85	8.10	13.54	26.40	15.11	0.31
30	2.07	9.90	7.83	14.01	29.56	15.11	0.32
31	3.52	11.5	7.98	13.75	25.30	15.11	0.32
			Average of value of c from experiment				0.33

Table A3 Determination void fractions and rise velocities of continuous generated slugs at a variety of air and water flow rate.

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Air velocity (cm/s)	Time interval (s)	Rise velocity, u_s from experiment, (cm/s)	Level of interface (cm)	Void fraction from experiment	Rise velocty, u_s (cm/s) from eq.(7)	Void fraction from eq.(9)	Error of rise velocity (%)	Error of void fraction (%)	Average error of rise velocity (%)	Average error of void fraction (%)
1	0	0.5	2.93	5.97	18.37	184.86	0.18	18.63	0.16	-1.40	11.56		
2	0	1.0	5.87	4.84	22.66	161.46	0.29	22.15	0.26	2.31	10.49		
3	0	1.5	8.80	4.11	26.72	147.96	0.36	25.67	0.34	4.07	5.05		
4	0	2.0	11.74	3.58	30.68	131.6	0.44	29.19	0.40	5.08	9.94		
5	0	2.5	14.67	3.2	34.32	123.6	0.48	32.72	0.45	4.92	7.48		
6	0	3.0	17.61	2.85	38.44	114.5	0.53	36.24	0.49	6.07	8.57		
7	0	3.5	20.54	2.67	41.06	111.7	0.54	39.76	0.52	3.26	4.81		
8	0	4.0	23.47	2.41	45.49	104.9	0.58	43.28	0.54	5.10	6.10		
9	0	4.5	26.41	2.23	49.11	99.3	0.60	46.80	0.56	4.93	6.95		
10	0	5.0	29.34	2.1	52.19	95.42	0.62	50.32	0.58	3.72	6.82		
11	0	5.5	32.28	1.98	55.35	89.83	0.65	53.84	0.60	2.80	8.57		
12	0	6.0	35.21	1.85	59.43	86.83	0.67	57.36	0.61	3.61	8.48		
13	0	6.5	38.15	1.74	63.19	82.1	0.69	60.88	0.63	3.79	10.05		
14	0	10.0	58.69	1.24	88.76	65.2	0.77	85.53	0.69	3.78	12.81		
15	0	12.0	70.42	1.04	105.33	61.7	0.79	99.62	0.71	5.73	11.96	3.85	8.64
16	200	0.5	2.93	5.72	19.20	186.6	0.17	20.04	0.15	-4.20	14.05		
17	200	1.0	5.87	4.51	24.35	166.5	0.27	23.56	0.25	3.35	7.39		
18	200	1.5	8.80	3.88	28.28	149.7	0.35	27.08	0.33	4.42	8.14		
19	200	2.0	11.74	3.32	33.07	137	0.42	30.60	0.38	8.06	8.21		

Cont.....

Table A3 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Air velocity (cm/s)	Time interval (s)	Rise velocity, u_s from experiment, (cm/s)	Level of interface (cm)	Void fraction from experiment	Rise velocty, u_s (cm/s) from eq.(7)	Void fraction from eq.(9)	Error of rise velocity (%)	Error of void fraction (%)	Average error of rise velocity (%)	Average error of void fraction (%)
20	200	2.5	14.67	3.02	36.39	128	0.46	34.12	0.43	6.63	6.99		
21	200	3.0	17.61	2.78	39.49	120.68	0.50	37.65	0.47	4.91	6.19		
22	200	3.5	20.54	2.51	43.75	117.9	0.51	41.17	0.50	6.27	2.32		
23	200	4.0	23.47	2.33	47.01	110	0.55	44.69	0.53	5.19	4.70		
24	200	4.5	26.41	2.15	50.98	101.4	0.59	48.21	0.55	5.75	8.25		
25	200	5.0	29.34	2	54.97	97.4	0.61	51.73	0.57	6.26	8.07		
26	200	5.5	32.28	1.88	58.26	98.5	0.61	55.25	0.58	5.45	3.99		
27	200	6.0	35.21	1.78	61.77	94.2	0.63	58.77	0.60	5.10	4.99		
28	200	6.5	38.15	1.68	65.46	91.1	0.64	62.29	0.61	5.08	5.25		
29	200	10.0	58.69	1.18	92.98	77.16	0.71	86.94	0.68	6.94	5.81		
30	200	12.0	70.42	0.89	122.93	69.26	0.75	101.03	0.70	21.68	8.12	6.06	6.83
31	500	0.5	2.93	4.91	22.36	192.92	0.14	22.15	0.13	0.92	2.22		
32	500	1.0	5.87	4.06	26.99	170.52	0.25	25.67	0.23	5.14	8.23		
33	500	1.5	8.80	3.62	30.36	156.08	0.32	29.19	0.30	3.98	6.00		
34	500	2.0	11.74	3.22	34.09	140.58	0.40	32.72	0.36	4.22	10.69		
35	500	2.5	14.67	2.91	37.72	131.72	0.44	36.24	0.40	4.11	9.02		
36	500	3.0	17.61	2.65	41.43	125.56	0.47	39.76	0.44	4.21	6.63		
37	500	3.5	20.54	2.43	45.11	117.04	0.51	43.28	0.47	4.24	8.47		
38	500	4.0	23.47	2.26	48.59	109.86	0.55	46.80	0.50	3.82	9.79		

Cont....

Table A3 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Air velocity (cm/s)	Time interval (s)	Rise velocity, u_s from experiment, (cm/s)	Level of interface (cm)	Void fraction from experiment	Rise velocty, u_s (cm/s) from eq.(7)	Void fraction from eq.(9)	Error of rise velocity (%)	Error of void fraction (%)	Average error of rise velocity (%)	Average error of void fraction (%)
39	500	4.5	26.41	2.13	51.56	107.56	0.56	50.32	0.52	2.45	7.13		
40	500	5.0	29.34	1.99	55.21	97.78	0.61	53.84	0.54	2.53	12.13		
41	500	5.5	32.28	1.86	58.86	93.92	0.63	57.36	0.56	2.61	12.04		
42	500	6.0	35.21	1.75	62.85	93.56	0.63	60.88	0.58	3.22	9.32		
43	500	6.5	38.15	1.62	67.61	91.26	0.64	64.41	0.59	4.98	8.68		
44	500	10.0	58.69	1.14	95.93	74.02	0.73	89.05	0.66	7.72	10.76		
45	500	12.0	70.42	0.87	125.63	70.04	0.75	103.14	0.68	21.81	9.81	5.06	8.73
46	1000	0.5	2.93	4.29	25.60	197.22	0.11	25.67	0.11	-0.30	-0.34		
47	1000	1.0	5.87	3.65	30.09	173.46	0.23	29.19	0.20	3.07	15.76		
48	1000	1.5	8.80	3.24	33.90	159.12	0.30	32.72	0.27	3.63	13.13		
49	1000	2.0	11.74	2.97	36.97	149.96	0.35	36.24	0.32	2.03	8.12		
50	1000	2.5	14.67	2.72	40.28	138.18	0.41	39.76	0.37	1.31	10.86		
51	1000	3.0	17.61	2.45	44.82	129.44	0.45	43.28	0.41	3.56	11.31		
52	1000	3.5	20.54	2.72	48.29	124.26	0.48	46.80	0.44	3.17	9.07		
53	1000	4.0	23.47	2.14	51.33	118.36	0.51	50.32	0.47	2.00	8.94		
54	1000	4.5	26.41	1.93	56.73	113.8	0.53	53.84	0.49	5.37	8.26		
55	1000	5.0	29.34	1.86	58.99	110.16	0.55	57.36	0.51	2.84	7.37		
56	1000	5.5	32.28	1.72	63.64	104.9	0.58	60.88	0.53	4.53	8.56		
57	1000	6.0	35.21	1.67	65.85	98.66	0.61	64.41	0.55	2.25	10.97		

Cont....

Table A3 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Air velocity (cm/s)	Time interval (s)	Rise velocity, u_s from experiment, (cm/s)	Level of interface (cm)	Void fraction from experiment	Rise velocty, u_s (cm/s) from eq.(7)	Void fraction from eq.(9)	Error of rise velocity (%)	Error of void fraction (%)	Average error of rise velocity (%)	Average error of void fraction (%)
58	1000	6.5	38.15	1.59	69.03	96.36	0.62	67.93	0.56	1.63	10.08		
59	1000	10.0	58.69	1.08	102.08	78.1	0.71	92.57	0.63	10.27	11.92		
60	1000	12.0	70.42	0.82	133.25	76.14	0.72	106.66	0.66	24.93	8.94	4.69	9.53
61	1500	0.5	2.93	3.7	29.65	197.9	0.11	29.19	0.10	1.55	9.94		
62	1500	1.0	5.87	3.27	33.57	177.1	0.21	32.72	0.18	2.61	19.58		
63	1500	1.5	8.80	2.97	36.92	165.08	0.27	36.24	0.24	1.87	13.04		
64	1500	2.0	11.74	2.68	41.00	151.08	0.34	39.76	0.30	3.11	16.73		
65	1500	2.5	14.67	2.47	44.43	144.9	0.38	43.28	0.34	2.65	10.77		
66	1500	3.0	17.61	2.33	47.04	138.74	0.41	46.80	0.38	0.52	8.00		
67	1500	3.5	20.54	2.15	51.13	128.82	0.46	50.32	0.41	1.60	11.69		
68	1500	4.0	23.47	2.05	53.62	126.84	0.47	53.84	0.44	-0.41	6.84		
69	1500	4.5	26.41	1.89	58.00	119.9	0.50	57.36	0.46	1.11	8.72		
70	1500	5.0	29.34	1.8	61.01	114.84	0.53	60.88	0.48	0.20	9.10		
71	1500	5.5	32.28	1.64	66.84	112.18	0.54	64.41	0.50	3.78	7.57		
72	1500	6.0	35.21	1.58	69.63	106.56	0.57	67.93	0.52	2.51	9.42		
73	1500	6.5	38.15	1.46	74.95	101.4	0.59	71.45	0.53	4.91	11.07		
74	1500	10.0	58.69	1.03	106.81	85.22	0.67	96.10	0.61	11.15	10.35		
75	1500	12.0	70.42	0.82	133.30	83.06	0.68	110.18	0.64	20.98	7.13	3.88	10.66
76	2000	0.5	2.93	3.38	32.48	202.1	0.09	32.72	0.09	-0.73	-0.21		

Cont....

Table A3 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Air velocity (cm/s)	Time interval (s)	Rise velocity, u_s from experiment, (cm/s)	Level of interface (cm)	Void fraction from experiment	Rise velocty, u_s (cm/s) from eq.(7)	Void fraction from eq.(9)	Error of rise velocity (%)	Error of void fraction (%)	Average error of rise velocity (%)	Average error of void fraction (%)
77	2000	1.0	5.87	3.02	36.32	183.48	0.18	36.24	0.16	0.22	12.75		
78	2000	1.5	8.80	2.7	40.59	168.46	0.26	39.76	0.22	2.09	16.39		
79	2000	2.0	11.74	2.53	43.31	157.74	0.31	43.28	0.27	0.07	14.79		
80	2000	2.5	14.67	2.41	45.60	151.62	0.34	46.80	0.31	-2.56	9.06		
81	2000	3.0	17.61	2.16	50.84	141.44	0.39	50.32	0.35	1.02	12.27		
82	2000	3.5	20.54	2.04	53.69	135.52	0.42	53.84	0.38	-0.28	10.73		
83	2000	4.0	23.47	1.88	58.31	128.5	0.46	57.36	0.41	1.65	11.80		
84	2000	4.5	26.41	1.73	63.35	125.44	0.47	60.88	0.43	4.04	9.00		
85	2000	5.0	29.34	1.64	67.06	119.96	0.50	64.41	0.46	4.13	9.79		
86	2000	5.5	32.28	1.57	69.79	112.86	0.54	67.93	0.48	2.74	12.74		
87	2000	6.0	35.21	1.5	73.35	110.48	0.55	71.45	0.49	2.67	11.11		
88	2000	6.5	38.15	1.36	80.80	108.78	0.56	74.97	0.51	7.78	9.29		
89	2000	10.0	58.69	0.92	119.89	89.96	0.65	99.62	0.59	20.35	10.37		
90	2000	12.0	70.42	0.77	143.45	79.36	0.70	113.70	0.62	26.16	13.54	4.62	10.89
91	2500	0.5	2.93	3.16	34.70	201.94	0.09	36.24	0.08	-4.25	11.52		
92	2500	1.0	5.87	2.78	39.54	183.22	0.18	39.76	0.15	-0.55	24.59		
93	2500	1.5	8.80	2.55	43.01	173	0.24	43.28	0.20	-0.61	15.54		
94	2500	2.0	11.74	2.32	47.37	161.78	0.29	46.80	0.25	1.23	16.07		
95	2500	2.5	14.67	2.21	49.56	154.74	0.33	50.32	0.29	-1.51	11.92		

Cont....

Table A3 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Air velocity (cm/s)	Time interval (s)	Rise velocity, u_s from experiment, (cm/s)	Level of interface (cm)	Void fraction from experiment	Rise velocty, u_s (cm/s) from eq.(7)	Void fraction from eq.(9)	Error of rise velocity (%)	Error of void fraction (%)	Average error of rise velocity (%)	Average error of void fraction (%)
96	2500	3.0	17.61	2.07	52.96	148.1	0.36	53.84	0.33	-1.65	9.94		
97	2500	3.5	20.54	1.9	57.86	140.68	0.40	57.36	0.36	0.87	10.76		
98	2500	4.0	23.47	1.79	61.23	134.1	0.43	60.88	0.39	0.57	11.40		
99	2500	4.5	26.41	1.68	65.20	131.6	0.44	64.41	0.41	1.24	7.80		
100	2500	5.0	29.34	1.57	70.14	123.36	0.48	67.93	0.43	3.26	11.86		
101	2500	5.5	32.28	1.51	72.75	121.2	0.49	71.45	0.45	1.82	9.35		
102	2500	6.0	35.21	1.43	76.77	119.1	0.50	74.97	0.47	2.40	7.41		
103	2500	6.5	38.15	1.34	81.76	113.78	0.53	78.49	0.49	4.17	9.28		
104	2500	10.0	58.69	0.87	127.03	95.18	0.62	103.14	0.57	23.17	9.68		
105	2500	12.0	70.42	0.76	144.06	86.94	0.67	117.22	0.60	22.89	10.74	3.54	11.86

Note:

Observed distance for determine rise velocity = 109.7 cm

Observed distance for determine void fraction = 200 cm

Cross section area, A = 2.84 cm^2

Rising velocity of slug in stagnant water, u_b = 15.11 cm/s

Table A4 Error bar calculation for void fraction within slug flow.

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Void fraction					Average of void fraction	Standard deviation of void fraction	Percentage of deviation (%)	Average percentage of deviation (%)
1	0	0.5	0.18	0.18	0.18	0.18	0.17	0.18	0.001754	0.998047	
2	0	1.0	0.30	0.28	0.30	0.29	0.30	0.29	0.00996	3.402774	
3	0	1.5	0.36	0.36	0.36	0.36	0.36	0.36	0.002775	0.770374	
4	0	2.0	0.43	0.46	0.44	0.44	0.44	0.44	0.009747	2.205157	
5	0	2.5	0.49	0.48	0.48	0.47	0.49	0.48	0.006471	1.34255	
6	0	3.0	0.51	0.53	0.53	0.54	0.54	0.53	0.01311	2.485329	
7	0	3.5	0.54	0.54	0.56	0.54	0.54	0.54	0.011806	2.180188	
8	0	4.0	0.58	0.57	0.59	0.57	0.58	0.58	0.008367	1.453797	
9	0	4.5	0.61	0.61	0.60	0.60	0.61	0.60	0.003791	0.628242	
10	0	5.0	0.62	0.64	0.61	0.61	0.64	0.62	0.013423	2.154909	
11	0	5.5	0.66	0.66	0.66	0.66	0.64	0.66	0.007071	1.079552	
12	0	6.0	0.67	0.67	0.67	0.67	0.66	0.66	0.007374	1.125792	
13	0	6.5	0.70	0.69	0.69	0.68	0.69	0.69	0.004809	0.69744	
14	0	10.0	0.78	0.78	0.77	0.77	0.77	0.77	0.003354	0.433347	
15	0	12.0	0.79	0.79	0.79	0.80	0.80	0.79	0.005184	0.654973	1.44
16	200	0.5	0.17	0.17	0.16	0.17	0.17	0.17	0.00326	1.951857	
17	200	1.0	0.27	0.27	0.27	0.26	0.27	0.27	0.005863	2.191783	
18	200	1.5	0.35	0.35	0.35	0.35	0.36	0.35	0.003791	1.078645	
19	200	2.0	0.41	0.42	0.42	0.41	0.42	0.42	0.005	1.204819	
20	200	2.5	0.47	0.45	0.47	0.45	0.46	0.46	0.013229	2.875817	

Cont.....

Table A4 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Void fraction					Average of void fraction	Standard deviation of void fraction	Percentage of deviation (%)	Average percentage of deviation (%)
21	200	3.0	0.50	0.48	0.51	0.51	0.50	0.50	0.011277	2.27088	
22	200	3.5	0.52	0.50	0.53	0.52	0.49	0.51	0.016808	3.292407	
23	200	4.0	0.53	0.54	0.56	0.57	0.56	0.55	0.01591	2.89271	
24	200	4.5	0.59	0.59	0.60	0.59	0.60	0.59	0.005969	1.006521	
25	200	5.0	0.62	0.62	0.62	0.60	0.62	0.61	0.007583	1.237011	
26	200	5.5	0.63	0.59	0.63	0.60	0.60	0.61	0.018371	3.024061	
27	200	6.0	0.61	0.64	0.62	0.63	0.65	0.63	0.013532	2.15141	
28	200	6.5	0.66	0.65	0.63	0.64	0.65	0.64	0.013509	2.096083	
29	200	10.0	0.71	0.71	0.72	0.71	0.72	0.71	0.007023	0.983363	
30	200	12.0	0.74	0.75	0.77	0.76	0.74	0.75	0.0139	1.844187	2.01
31	500	0.5	0.13	0.14	0.14	0.13	0.14	0.14	0.002535	1.872052	
32	500	1.0	0.25	0.24	0.24	0.26	0.25	0.25	0.010383	4.196717	
33	500	1.5	0.33	0.33	0.31	0.31	0.32	0.32	0.007733	2.419601	
34	500	2.0	0.40	0.40	0.40	0.38	0.40	0.40	0.007893	1.987669	
35	500	2.5	0.44	0.44	0.45	0.45	0.43	0.44	0.006656	1.50789	
36	500	3.0	0.47	0.48	0.48	0.48	0.45	0.47	0.011317	2.396659	
37	500	3.5	0.53	0.53	0.50	0.50	0.52	0.51	0.011568	2.24714	
38	500	4.0	0.55	0.56	0.54	0.54	0.57	0.55	0.012701	2.306406	
39	500	4.5	0.57	0.56	0.56	0.54	0.58	0.56	0.014623	2.600988	
40	500	5.0	0.61	0.61	0.62	0.61	0.61	0.61	0.004967	0.812861	

Cont....

Table A4 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Void fraction					Average of void fraction	Standard deviation of void fraction	Percentage of deviation (%)	Average percentage of deviation (%)
41	500	5.5	0.63	0.63	0.63	0.64	0.62	0.63	0.007232	1.147188	
42	500	6.0	0.61	0.63	0.65	0.64	0.64	0.63	0.014065	2.224775	
43	500	6.5	0.65	0.63	0.67	0.66	0.61	0.64	0.026355	4.094266	
44	500	10.0	0.72	0.75	0.75	0.72	0.70	0.73	0.021821	2.989647	
45	500	12.0	0.74	0.71	0.76	0.78	0.76	0.75	0.029746	3.967192	2.45
46	1000	0.5	0.12	0.11	0.12	0.11	0.11	0.11	0.005092	4.47029	
47	1000	1.0	0.22	0.24	0.25	0.22	0.24	0.23	0.012573	5.403003	
48	1000	1.5	0.29	0.29	0.32	0.31	0.31	0.30	0.010836	3.559882	
49	1000	2.0	0.37	0.33	0.34	0.36	0.36	0.35	0.017083	4.878037	
50	1000	2.5	0.40	0.42	0.41	0.41	0.41	0.41	0.006693	1.636099	
51	1000	3.0	0.46	0.44	0.45	0.44	0.48	0.45	0.016342	3.609194	
52	1000	3.5	0.50	0.45	0.49	0.47	0.48	0.48	0.019568	4.080165	
53	1000	4.0	0.51	0.52	0.49	0.51	0.51	0.51	0.013769	2.709292	
54	1000	4.5	0.51	0.54	0.52	0.55	0.54	0.53	0.016852	3.173691	
55	1000	5.0	0.58	0.54	0.59	0.50	0.54	0.55	0.033039	6.01584	
56	1000	5.5	0.55	0.60	0.58	0.58	0.56	0.58	0.020387	3.542464	
57	1000	6.0	0.62	0.60	0.61	0.59	0.63	0.61	0.01545	2.54655	
58	1000	6.5	0.63	0.60	0.61	0.62	0.64	0.62	0.017261	2.792175	
59	1000	10.0	0.68	0.70	0.75	0.71	0.71	0.71	0.024078	3.393657	
60	1000	12.0	0.74	0.73	0.69	0.74	0.70	0.72	0.022273	3.096447	3.66

Cont....

Table A4 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Void fraction					Average of void fraction	Standard deviation of void fraction	Percentage of deviation (%)	Average percentage of deviation (%)
61	1500	0.5	0.11	0.11	0.11	0.11	0.12	0.11	0.004472	4.047182	
62	1500	1.0	0.22	0.21	0.22	0.21	0.22	0.21	0.006144	2.864384	
63	1500	1.5	0.26	0.28	0.28	0.27	0.28	0.27	0.00929	3.37933	
64	1500	2.0	0.36	0.34	0.34	0.35	0.34	0.34	0.007829	2.272035	
65	1500	2.5	0.36	0.37	0.39	0.37	0.38	0.38	0.014309	3.810676	
66	1500	3.0	0.40	0.41	0.42	0.42	0.40	0.41	0.011015	2.710993	
67	1500	3.5	0.45	0.46	0.48	0.44	0.45	0.46	0.013451	2.950392	
68	1500	4.0	0.46	0.47	0.48	0.44	0.47	0.47	0.016676	3.579987	
69	1500	4.5	0.49	0.52	0.51	0.52	0.46	0.50	0.025157	5.026375	
70	1500	5.0	0.53	0.53	0.51	0.54	0.52	0.53	0.011547	2.196015	
71	1500	5.5	0.54	0.53	0.53	0.56	0.54	0.54	0.011008	2.041913	
72	1500	6.0	0.56	0.53	0.56	0.60	0.60	0.57	0.028352	4.998556	
73	1500	6.5	0.59	0.59	0.61	0.60	0.58	0.59	0.012619	2.128066	
74	1500	10.0	0.67	0.67	0.72	0.67	0.65	0.67	0.027426	4.069715	
75	1500	12.0	0.69	0.70	0.66	0.71	0.67	0.68	0.019263	2.813394	3.26
76	2000	0.5	0.10	0.09	0.09	0.09	0.09	0.09	0.006021	6.727148	
77	2000	1.0	0.19	0.18	0.18	0.19	0.18	0.18	0.004788	2.622128	
78	2000	1.5	0.24	0.26	0.26	0.27	0.25	0.26	0.011239	4.361443	
79	2000	2.0	0.31	0.32	0.30	0.32	0.30	0.31	0.011105	3.567356	
80	2000	2.5	0.36	0.32	0.35	0.34	0.35	0.34	0.017282	5.054758	

Cont....

Table A4 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Void fraction					Average of void fraction	Standard deviation of void fraction	Percentage of deviation (%)	Average percentage of deviation (%)
81	2000	3.0	0.40	0.39	0.38	0.41	0.39	0.39	0.008556	2.178131	
82	2000	3.5	0.43	0.42	0.42	0.42	0.43	0.42	0.005539	1.311198	
83	2000	4.0	0.48	0.44	0.45	0.46	0.47	0.46	0.015827	3.459495	
84	2000	4.5	0.46	0.47	0.48	0.48	0.48	0.47	0.011278	2.385427	
85	2000	5.0	0.53	0.47	0.52	0.50	0.48	0.50	0.024946	4.987294	
86	2000	5.5	0.55	0.54	0.53	0.51	0.55	0.54	0.020269	3.783614	
87	2000	6.0	0.52	0.55	0.56	0.56	0.56	0.55	0.015726	2.871763	
88	2000	6.5	0.57	0.56	0.55	0.56	0.54	0.56	0.011019	1.981532	
89	2000	10.0	0.64	0.66	0.65	0.63	0.68	0.65	0.01747	2.686862	
90	2000	12.0	0.72	0.67	0.74	0.69	0.70	0.70	0.024338	3.460997	3.43
91	2500	0.5	0.09	0.09	0.09	0.10	0.08	0.09	0.004177	4.626046	
92	2500	1.0	0.18	0.19	0.18	0.19	0.19	0.18	0.004379	2.381146	
93	2500	1.5	0.24	0.23	0.21	0.24	0.25	0.24	0.015075	6.414814	
94	2500	2.0	0.29	0.29	0.29	0.29	0.29	0.29	0.002859	0.982204	
95	2500	2.5	0.34	0.32	0.31	0.34	0.33	0.33	0.012523	3.837873	
96	2500	3.0	0.37	0.36	0.33	0.37	0.36	0.36	0.019439	5.407234	
97	2500	3.5	0.41	0.39	0.37	0.41	0.40	0.40	0.015773	3.977155	
98	2500	4.0	0.42	0.45	0.43	0.43	0.43	0.43	0.009766	2.27381	
99	2500	4.5	0.44	0.45	0.43	0.46	0.43	0.44	0.015379	3.479311	
100	2500	5.0	0.50	0.49	0.48	0.47	0.48	0.48	0.011622	2.405252	

Cont....

Table A4 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Void fraction					Average of void fraction	Standard deviation of void fraction	Percentage of deviation (%)	Average percentage of deviation (%)
101	2500	5.5	0.49	0.50	0.47	0.51	0.51	0.49	0.016355	3.310815	
102	2500	6.0	0.51	0.53	0.49	0.51	0.48	0.50	0.019154	3.796627	
103	2500	6.5	0.53	0.55	0.51	0.52	0.55	0.53	0.017358	3.26831	
104	2500	10.0	0.63	0.61	0.63	0.64	0.62	0.62	0.012033	1.928102	
105	2500	12.0	0.66	0.63	0.67	0.68	0.69	0.67	0.023392	3.516054	3.44

Table A5 Error bar calculation for rise velocities of continuous generated slugs.

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Rise velocity of continuous generated slugs (cm/s)					Average of rise velocity (cm/s)	Stadard deviation of rise velocity (cm/s)	Percentage of deviation (%)	Average percentage of deviation (%)
1	0	0.5	18.59	18.13	18.22	18.59	18.31	18.37	0.21	1.16	
2	0	1.0	22.43	23.49	22.43	22.53	22.43	22.66	0.46	2.05	
3	0	1.5	27.02	26.50	26.82	26.82	26.43	26.72	0.25	0.92	
4	0	2.0	30.73	30.56	30.56	30.81	30.73	30.68	0.12	0.38	
5	0	2.5	34.39	34.17	34.39	34.50	34.17	34.32	0.14	0.42	
6	0	3.0	38.63	38.49	38.36	38.49	38.22	38.44	0.15	0.40	
7	0	3.5	41.24	40.93	41.24	40.93	40.93	41.06	0.17	0.41	
8	0	4.0	45.33	45.14	46.29	44.78	45.90	45.49	0.60	1.33	
9	0	4.5	48.97	48.54	48.97	49.19	49.86	49.11	0.48	0.99	
10	0	5.0	52.24	52.49	52.74	51.75	51.75	52.19	0.44	0.85	
11	0	5.5	55.97	55.40	55.13	55.13	55.13	55.35	0.37	0.66	
12	0	6.0	59.95	59.95	58.66	59.95	58.66	59.43	0.70	1.18	
13	0	6.5	63.41	63.05	62.69	63.05	63.78	63.19	0.42	0.66	
14	0	10.0	89.19	87.76	89.19	89.92	87.76	88.76	0.96	1.08	
15	0	12.0	104.48	106.50	101.57	105.48	108.61	105.33	2.60	2.47	1.00
16	200	0.5	19.55	18.53	19.95	19.01	18.95	19.20	0.55	2.89	
17	200	1.0	23.90	24.99	24.43	24.22	24.22	24.35	0.40	1.66	
18	200	1.5	27.56	28.27	28.57	28.79	28.20	28.28	0.47	1.65	
19	200	2.0	33.55	32.75	33.55	33.34	32.17	33.07	0.60	1.82	
20	200	2.5	36.20	37.19	35.73	35.50	37.31	36.39	0.83	2.28	

Cont.....

Table A5 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Rise velocity of continuous generated slugs (cm/s)					Average of rise velocity (cm/s)	Stadard deviation of rise velocity (cm/s)	Percentage of deviation (%)	Average percentage of deviation (%)
21	200	3.0	39.18	39.32	40.18	39.60	39.18	39.49	0.42	1.07	
22	200	3.5	43.36	44.78	43.36	43.53	43.71	43.75	0.59	1.36	
23	200	4.0	46.29	47.08	46.88	47.70	47.08	47.01	0.50	1.07	
24	200	4.5	51.26	51.26	51.50	50.09	50.79	50.98	0.56	1.10	
25	200	5.0	54.58	55.13	55.69	54.04	55.40	54.97	0.66	1.20	
26	200	5.5	56.84	60.94	57.43	58.66	57.43	58.26	1.64	2.81	
27	200	6.0	61.98	61.63	61.28	61.63	62.33	61.77	0.40	0.64	
28	200	6.5	65.69	64.91	66.48	65.69	64.53	65.46	0.76	1.16	
29	200	10.0	92.18	93.76	93.76	93.76	91.42	92.98	1.11	1.19	
30	200	12.0	126.09	126.09	123.26	113.09	126.09	122.93	5.63	4.58	1.77
31	500	0.5	22.71	22.71	21.85	22.43	22.07	22.36	0.39	1.72	
32	500	1.0	27.09	27.02	26.95	27.09	26.82	26.99	0.11	0.41	
33	500	1.5	30.56	29.97	30.30	30.73	30.22	30.36	0.29	0.97	
34	500	2.0	34.28	33.45	34.61	34.39	33.75	34.09	0.48	1.41	
35	500	2.5	37.70	37.44	37.83	37.96	37.70	37.72	0.19	0.51	
36	500	3.0	42.03	41.24	41.09	41.71	41.09	41.43	0.42	1.02	
37	500	3.5	45.33	44.41	45.71	44.41	45.71	45.11	0.66	1.46	
38	500	4.0	47.49	48.97	49.19	48.54	48.76	48.59	0.66	1.36	
39	500	4.5	51.26	52.49	51.26	51.75	51.02	51.56	0.58	1.13	
40	500	5.0	53.25	54.58	56.55	55.97	55.69	55.21	1.31	2.37	

Cont....

Table A5 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Rise velocity of continuous generated slugs (cm/s)					Average of rise velocity (cm/s)	Stadard deviation of rise velocity (cm/s)	Percentage of deviation (%)	Average percentage of deviation (%)
41	500	5.5	58.04	58.66	58.04	59.62	59.95	58.86	0.88	1.50	
42	500	6.0	61.98	64.53	61.98	63.78	61.98	62.85	1.22	1.94	
43	500	6.5	64.91	68.99	65.30	69.87	68.99	67.61	2.32	3.44	
44	500	10.0	94.57	97.08	95.39	98.83	93.76	95.93	2.04	2.12	
45	500	12.0	130.60	120.55	127.56	127.56	121.89	125.63	4.24	3.37	1.65
46	1000	0.5	25.69	25.39	25.75	25.57	25.57	25.60	0.14	0.54	
47	1000	1.0	29.49	30.05	30.56	30.14	30.22	30.09	0.39	1.29	
48	1000	1.5	33.55	33.34	34.17	34.39	34.07	33.90	0.44	1.30	
49	1000	2.0	37.70	35.85	37.19	36.69	37.44	36.97	0.73	1.97	
50	1000	2.5	40.63	39.89	39.46	40.63	40.78	40.28	0.57	1.43	
51	1000	3.0	45.14	44.78	45.71	44.06	44.41	44.82	0.64	1.43	
52	1000	3.5	47.70	48.33	48.33	48.33	48.76	48.29	0.38	0.78	
53	1000	4.0	52.74	50.32	50.09	51.75	51.75	51.33	1.11	2.15	
54	1000	4.5	57.43	55.13	57.43	56.84	56.84	56.73	0.95	1.67	
55	1000	5.0	59.95	58.04	58.98	58.04	59.95	58.99	0.95	1.61	
56	1000	5.5	61.98	63.78	64.53	64.15	63.78	63.64	0.98	1.54	
57	1000	6.0	65.30	65.69	66.89	66.48	64.91	65.85	0.82	1.25	
58	1000	6.5	71.70	67.30	69.87	67.30	68.99	69.03	1.86	2.69	
59	1000	10.0	97.95	108.61	100.64	103.49	99.73	102.08	4.16	4.08	
60	1000	12.0	126.09	135.43	132.17	137.13	135.43	133.25	4.39	3.29	1.80

Cont.....

Table A5 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Rise velocity of continuous generated slugs (cm/s)					Average of rise velocity (cm/s)	Stadard deviation of rise velocity (cm/s)	Percentage of deviation (%)	Average percentage of deviation (%)
61	1500	0.5	30.73	30.05	29.18	28.87	29.41	29.65	0.74	2.51	
62	1500	1.0	33.34	33.34	33.55	33.86	33.75	33.57	0.23	0.70	
63	1500	1.5	37.06	36.32	37.31	37.31	36.57	36.92	0.45	1.22	
64	1500	2.0	41.55	41.09	40.78	40.78	40.78	41.00	0.34	0.82	
65	1500	2.5	45.14	43.02	44.41	44.41	45.14	44.43	0.87	1.95	
66	1500	3.0	47.08	47.49	46.68	47.08	46.88	47.04	0.30	0.64	
67	1500	3.5	52.24	50.55	51.75	50.55	50.55	51.13	0.81	1.58	
68	1500	4.0	53.77	53.77	53.51	52.74	54.31	53.62	0.57	1.07	
69	1500	4.5	61.98	55.69	56.55	58.04	57.74	58.00	2.42	4.17	
70	1500	5.0	62.69	63.05	58.35	58.98	61.98	61.01	2.18	3.58	
71	1500	5.5	65.30	68.14	68.56	64.91	67.30	66.84	1.66	2.48	
72	1500	6.0	68.99	68.99	72.17	69.87	68.14	69.63	1.55	2.22	
73	1500	6.5	76.18	75.66	76.18	73.13	73.62	74.95	1.46	1.95	
74	1500	10.0	104.48	103.49	106.50	106.50	113.09	106.81	3.75	3.51	
75	1500	12.0	130.60	129.06	140.64	129.06	137.13	133.30	5.29	3.97	2.16
76	2000	0.5	33.86	31.43	32.26	31.98	32.84	32.48	0.92	2.85	
77	2000	1.0	35.05	37.44	36.69	36.32	36.09	36.32	0.88	2.41	
78	2000	1.5	41.71	41.09	39.46	40.93	39.75	40.59	0.95	2.34	
79	2000	2.0	43.02	44.59	42.52	42.36	44.06	43.31	0.98	2.26	
80	2000	2.5	46.68	45.71	45.33	45.14	45.14	45.60	0.65	1.42	

Cont....

Table A5 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Rise velocity of continuous generated slugs (cm/s)					Average of rise velocity (cm/s)	Stadard deviation of rise velocity (cm/s)	Percentage of deviation (%)	Average percentage of deviation (%)
81	2000	3.0	50.55	51.02	51.02	51.02	50.55	50.84	0.26	0.51	
82	2000	3.5	55.13	54.04	54.04	53.25	51.99	53.69	1.16	2.16	
83	2000	4.0	58.66	58.66	56.84	57.43	59.95	58.31	1.21	2.07	
84	2000	4.5	64.53	62.33	63.78	62.69	63.41	63.35	0.87	1.38	
85	2000	5.0	68.56	67.30	66.08	66.48	66.89	67.06	0.95	1.42	
86	2000	5.5	69.87	69.43	68.99	70.32	70.32	69.79	0.58	0.83	
87	2000	6.0	72.17	71.70	73.13	74.63	75.14	73.35	1.50	2.04	
88	2000	6.5	78.92	83.11	80.66	80.66	80.66	80.80	1.49	1.85	
89	2000	10.0	113.09	123.26	123.26	121.89	117.96	119.89	4.38	3.65	
90	2000	12.0	150.27	142.47	133.78	142.47	148.24	143.45	6.42	4.48	2.11
91	2500	0.5	34.94	34.94	34.39	34.17	35.05	34.70	0.39	1.12	
92	2500	1.0	41.24	39.60	39.32	38.76	38.76	39.54	1.02	2.58	
93	2500	1.5	43.53	43.88	41.71	44.23	41.71	43.01	1.21	2.82	
94	2500	2.0	48.33	47.08	47.90	46.88	46.68	47.37	0.71	1.49	
95	2500	2.5	51.02	49.41	49.19	48.97	49.19	49.56	0.83	1.68	
96	2500	3.0	53.00	51.75	54.04	53.51	52.49	52.96	0.89	1.68	
97	2500	3.5	57.14	57.74	58.35	58.04	58.04	57.86	0.46	0.80	
98	2500	4.0	58.66	63.41	63.78	61.63	58.66	61.23	2.48	4.05	
99	2500	4.5	62.33	66.08	63.41	66.89	67.30	65.20	2.21	3.39	
100	2500	5.0	74.12	66.89	71.70	69.43	68.56	70.14	2.82	4.02	

Cont....

Table A5 (Continued)

Slugs No.	Water flow rate (ml/min)	Air flow rate (L/min)	Rise velocity of continuous generated slugs (cm/s)					Average of rise velocity (cm/s)	Stadard deviation of rise velocity (cm/s)	Percentage of deviation (%)	Average percentage of deviation (%)
101	2500	5.5	72.65	73.62	73.13	72.65	71.70	72.75	0.71	0.98	
102	2500	6.0	79.49	78.92	75.66	74.63	75.14	76.77	2.27	2.95	
103	2500	6.5	81.26	82.48	80.07	83.74	81.26	81.76	1.40	1.71	
104	2500	10.0	117.96	124.66	123.26	137.13	132.17	127.03	7.59	5.98	
105	2500	12.0	144.34	144.34	150.27	138.86	142.47	144.06	4.13	2.87	2.54

Table A6 Determination air-lift pump operation.

Initial		Ending		Required air flow rate from experiment (ml/min)	Required air velocity from experiment (cm/s)	Void fraction	Predicted required air velocity from eq.(7) (cm/s)	Predicted required air flow rate from eq.(7) (ml/min)	Error of air velocity (%)	Renold number
H (cm)	h (cm)	H (cm)	h (cm)							
276	276	289	276	100	0.59	0.05	0.72	122.65	-18.47	136.8
274	274	289	273	150	0.88	0.05	0.87	147.86	1.44	164.9
263	263	289	262	200	1.17	0.09	1.56	265.80	-24.76	296.4
247	247	289	247	400	2.35	0.15	2.67	454.18	-11.93	506.4
240	240	289	239	450	2.64	0.17	3.23	550.66	-18.28	614
232	232	289	231	600	3.52	0.20	3.96	674.48	-11.04	752.1
227	227	289	226	650	3.81	0.22	4.41	752.10	-13.58	838.6
213	213	289	212	800	4.69	0.27	5.88	1001.36	-20.11	1117
203	203	289	202	1000	5.87	0.30	7.03	1197.13	-16.47	1335
198	198	289	197	1100	6.46	0.32	7.79	1327.68	-17.15	1480
185	185	289	184	1300	7.63	0.36	9.63	1641.31	-20.79	1830
174	174	289	174	1600	9.39	0.40	11.55	1967.41	-18.67	2194
166	166	289	165	1800	10.56	0.43	13.28	2262.66	-20.45	2523
156	156	289	155	2100	12.32	0.46	15.67	2670.09	-21.35	2977
148	148	289	147	2500	14.67	0.49	18.17	3095.80	-19.25	3452
140	140	289	139	2700	15.85	0.52	20.89	3559.55	-24.15	3969
129	129	289	128	3200	18.78	0.56	25.15	4285.00	-25.32	4778
120	120	289	119	3500	20.54	0.59	30.16	5138.58	-31.89	5730
112	112	289	111	4000	23.47	0.62	35.91	6118.88	-34.63	6823

Cont....

Table A6 (Continued)

Initial		Ending		Required air flow rate from experiment (ml/min)	Required air velocity from experiment (cm/s)	Void fraction	Predicted required air velocity from eq.(7) (cm/s)	Predicted required air flow rate from eq.(7) (ml/min)	Error of air velocity (%)	Renold number
H (cm)	h (cm)	H (cm)	h (cm)							
102	102	289	101	4800	28.17	0.65	44.62	7602.59	-36.86	8477
90.5	90.5	289	89	5550	32.57	0.69	61.39	10461.54	-46.95	11665
80	80	289	78.5	6500	38.15	0.73	86.93	14813.60	-56.12	16518
						Average error of air velocities (%)			-23.03	
						Absolute average error of air velocities (%)			23.17	

Note:

H = height of water in main column

h = height of water in reservoir column

Cross section area, A = 2.84 cm^2

Rising velocity of slug in stagnant water, u_b = 15.11 cm/s

Appendix B Calibration of Rotameters

The followings contain calibration tables and graphs of air and water rotameters, which were used for experiments.

Table B1 Calibration of the first air rotameter.

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
500	12.0	14.5	2.5	74.08	456	-9		
500	11.5	16	4.5	137.14	443	-11		
500	11.5	19	7.5	228.05	444	-11		
500	11.5	16	4.5	118.33	513	3		
500	11.5	15	3.5	100.93	468	-6		
500							465	-7
1000	11.5	15.5	4	52.57	1027	3		
1000	11.5	16	4.5	60.48	1004	0		
1000	11.5	16.5	5	69.75	968	-3		
1000	11.5	16.5	5	65.83	1025	3		
1000	11.5	17.5	6	80.87	1002	0		
1000							1005	1
1500	11.5	15.5	4	35.94	1503	0		
1500	11.5	17	5.5	49.28	1507	0		
1500	11.5	17.5	6	54.13	1496	0		
1500	11.5	16	4.5	40.2	1511	1		
1500	11.5	16	4.5	39.09	1554	4		
1500							1514	1
2000	11.5	19	7.5	52.53	1927	-4		
2000	11.5	17	5.5	35.5	2092	5		

Cont....

Table B1 (Continued)

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
2000	11.5	17	5.5	39.77	1867	-7		
2000	11.5	17	5.5	34.99	2122	6		
2000	11.5	18.5	7	47.45	1992	0		
2000							2000	0
2500	11.5	17	5.5	29.83	2489	0		
2500	11.5	16.5	5	27.43	2461	-2		
2500	11.5	17	5.5	29.74	2497	0		
2500	11.5	16.5	5	26.93	2506	0		
2500	11.5	16.5	5	27.5	2455	-2		
2500							2482	-1
3000	11.5	19	7.5	33.16	3053	2		
3000	11.5	16.5	5	23.18	2912	-3		
3000	11.5	16.5	5	23.35	2891	-4		
3000	11.5	16.5	5	22.09	3056	2		
3000	11.5	16.5	5	23.06	2927	-2		
3000							2968	-1
3500	11.5	16.5	5	20.22	3338	-5		
3500	11.5	16.5	5	19.64	3437	-2		
3500	11.5	16.5	5	20.03	3370	-4		
3500	11.5	16.5	5	19.92	3389	-3		
3500	11.5	17	5.5	22.15	3352	-4		

Cont....

Table B1 (Continued)

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
3500							3377	-4
4000	11.5	16.5	5	17.1	3947	-1		
4000	11.5	16.5	5	17.62	3831	-4		
4000	11.5	16.5	5	16.5	4091	2		
4000	11.5	20	8.5	30.07	3816	-5		
4000	11.5	16.5	5	16.96	3980	-1		
4000							3933	-2
4500	11.5	16.5	5	15.37	4392	-2		
4500	11.5	16.5	5	15.38	4389	-2		
4500	11.5	16.5	5	15.14	4458	-1		
4500	11.5	16.5	5	15.33	4403	-2		
4500	11.5	16.5	5	15.25	4426	-2		
4500							4414	-2
5000	11.5	16.5	5	13.39	5041	1		
5000	11.5	16.5	5	13.64	4949	-1		
5000	11.5	16.5	5	13.9	4856	-3		
5000	11.5	19.5	8	21.96	4918	-2		
5000	11.5	16.5	5	13.82	4884	-2		
5000							4930	-1
5500	11.5	17	5.5	13.73	5408	-2		
5500	11.5	17.5	6	15.04	5386	-2		

Cont....

Table B1 (Continued)

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
5500	11.5	16.5	5	12.43	5430	-1		
5500	11.5	16.5	5	11.73	5754	5		
5500	11.5	16.5	5	12.34	5470	-1		
5500							5490	0
6000	11.5	16.5	5	11.78	5730	-4		
6000	11.5	16.5	5	11.19	6032	1		
6000	11.5	20	8.5	19.62	5849	-3		
6000	11.5	16.5	5	11.82	5711	-5		
6000	11.5	16.5	5	11.46	5890	-2		
6000							5842	-3
6500	11.5	16.5	5	10.4	6490	0		
6500	11.5	16.5	5	10.83	6233	-4		
6500	11.5	16.5	5	10.74	6285	-3		
6500	11.5	16.5	5	10.21	6611	2		
6500	11.5	16.5	5	10.04	6723	3		
6500							6468	0

Note:

Cross-section area of calibrator = 225 cm^2

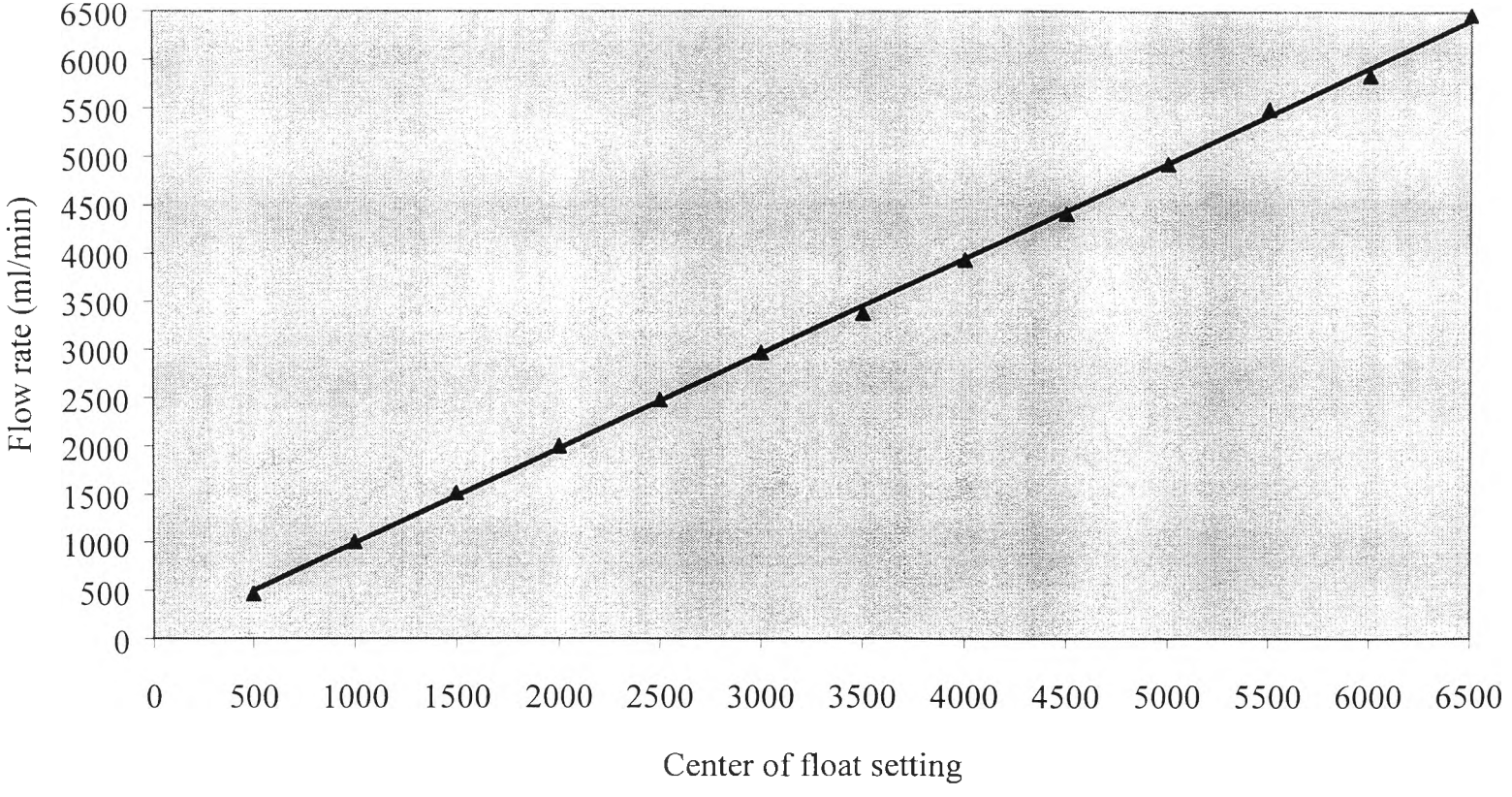

Figure B1 Calibration for the first air rotameter @ 1 bar (Float: glass).

Table B2 Calibration of the second air rotameter.

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
10	12	17	5	6.91	9.8	-2.3		
10	12	17	5	7.21	9.4	-6.4		
10	12	19	7	10.29	9.2	-8.2		
10	12	17	5	7.07	9.5	-4.5		
10	12	17	5	6.93	9.7	-2.6		
10							9.5	-4.8
12	12	17	5	5.75	11.7	-2.2		
12	12	17	5	5.91	11.4	-4.8		
12	12	17	5	5.85	11.5	-3.8		
12	12	17	5	5.69	11.9	-1.1		
12	12	17	5	6.04	11.2	-6.9		
12							11.5	-3.8
20	12	18	6	4.09	19.8	-1.0		
20	12	18	6	4.14	19.6	-2.2		
20	12	18	6	4.07	19.9	-0.5		
20	12	18	6	3.99	20.3	1.5		
20	12	18	6	3.95	20.5	2.5		
20							20.0	0.1

Note: Cross-section area of calibrator = 225 cm^2

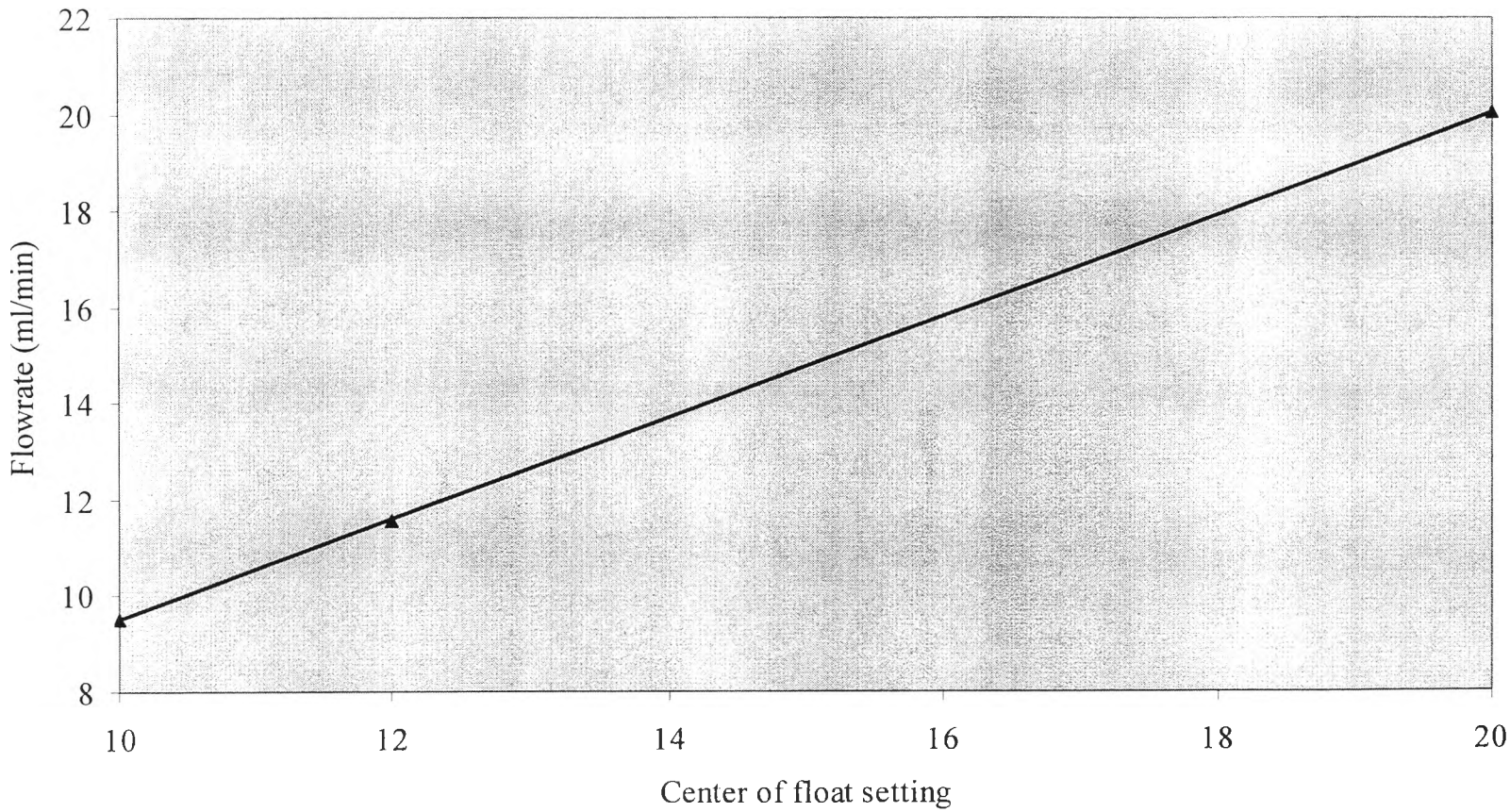

Figure B2 Calibration for the second air rotameter @ 1 bar (Float: stainless steal).

Table B3 Calibration of water rotameter.

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
200	30.5	40.5	10	7.91	215	8		
200	40.5	50.5	10	7.03	242	21		
200	30.5	40.5	10	7.22	236	18		
200	30.5	40.5	10	7.39	231	15		
200	30.5	40.5	10	7.19	237	18		
200							232	16
500	30.5	50.5	20	5.95	573	15		
500	30.5	50.5	20	5.98	570	14		
500	30.5	50.5	20	6.05	563	13		
500	30.5	50.5	20	6.17	552	10		
500	30.5	50.5	20	6.23	547	9		
500							561	12
1000	30.5	60.5	30	5.1	1002	0		
1000	40.5	60.5	20	3.37	1011	1		
1000	30.5	60.5	30	4.93	1037	4		
1000	40.5	60.5	20	3.37	1011	1		
1000	30.5	60.5	30	5.01	1020	2		
1000							1016	2
1500	30.5	60.5	30	3.37	1517	1		

Cont....

Table B3 (Continued)

Flow rate from rotameter (ml/min)	Start level (cm)	Stop level (cm)	Level interval (cm)	Time interval (s)	Calibrated flow rate (ml/min)	Error of Rotameter (%)	Average of flow rates (ml/min)	Average error of flow rates (%)
1500	30.5	60.5	30	3.29	1554	4		
1500	30.5	60.5	30	3.29	1554	4		
1500	30.5	60.5	30	3.46	1477	-2		
1500	30.5	60.5	30	3.35	1526	2		
1500							1526	2
2000	50.5	70.5	20	1.69	2017	1		
2000	30.5	60.5	30	2.42	2112	6		
2000	30.5	60.5	30	2.59	1974	-1		
2000	30.5	60.5	30	2.48	2061	3		
2000	30.5	60.5	30	2.53	2021	1		
2000							2037	2
2500	30.5	70.5	40	2.48	2748	10		
2500	30.5	50.5	20	1.31	2602	4		
2500	30.5	50.5	20	1.3	2622	5		
2500	30.5	50.5	20	1.24	2748	10		
2500	30.5	50.5	20	1.3	2622	5		
2500							2668	7

Note:

Cross-section area of calibrator = 2.84 cm^2

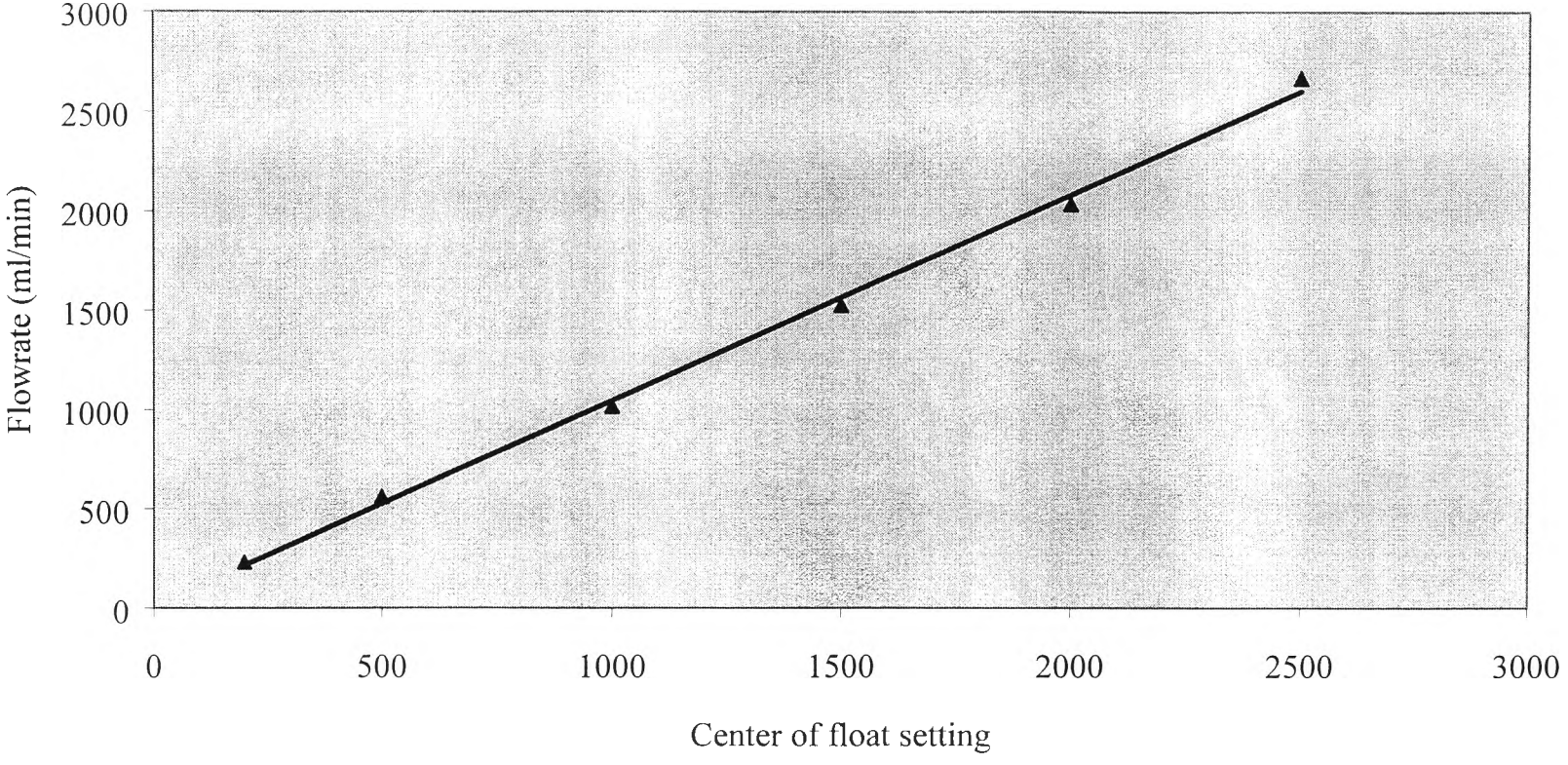

Figure B3 Calibration for water rotameter (Float: stainless steal).

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