

APPENDIX A

VOLUME FRACTION MEASUREMENTS DATA

Table A-1. Experimental Data for Volume Fractions in Air-Water-Glass Beads Fluidized Bed (Superficial Gas Velocity = 3.36 cm/s, Superficial Liquid Velocity = 2.0 cm/s)

X(cm)	Y(cm)	L_y	L_x	ϵ_g	ϵ_l	ϵ_s
2.54	3.81	9.77662	6.44495	0.346492	0.370805	0.178013
2.54	5.08	9.74908	6.41129	0.320369	0.365295	0.217466
2.54	6.35	9.77159	6.40455	0.341724	0.364188	0.178173
2.54	7.62	9.77094	6.41232	0.341111	0.365464	0.180862
2.54	8.89	9.807	6.40496	0.375225	0.364255	0.118793
2.54	10.16	9.82378	6.41582	0.391067	0.366039	0.092914
2.54	11.43	9.81581	6.41253	0.383546	0.365498	0.105584
2.54	12.70	9.7923	6.42247	0.361333	0.367128	0.147056
2.54	13.97	9.82606	6.39146	0.393209	0.362034	0.084087
2.54	15.24	9.86672	6.38787	0.431466	0.361444	0.015443
2.54	16.51	9.83044	6.415	0.39734	0.365903	0.081609
2.54	17.78	9.75176	6.44711	0.322908	0.371158	0.220315
2.54	19.05	9.7507	6.46285	0.3219	0.373724	0.225324
2.54	20.32	9.72932	6.55134	0.301575	0.388035	0.279354
2.54	21.59	9.72774	6.59797	0.300068	0.395499	0.291395
2.54	22.86	9.89368	6.52912	0.456733	0.38446	-0.000528
2.54	24.13	9.73778	6.52864	0.309625	0.384382	0.260484

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_1	ϵ_s
2.54	25.40	9.83715	6.52961	0.403661	0.384539	0.093771
3.81	2.54	9.83326	6.55839	0.4	0.389167	0.106076
3.81	3.81	9.81312	6.50055	0.381009	0.379845	0.128088
3.81	5.08	9.78807	6.54584	0.357335	0.387152	0.179276
3.81	6.35	9.79503	6.53498	0.363918	0.385404	0.165398
3.81	7.62	9.80294	6.52912	0.371392	0.38446	0.150949
3.81	8.89	9.76941	6.56068	0.339657	0.389534	0.213643
3.81	10.16	9.73234	6.52573	0.30445	0.383913	0.269081
3.81	11.43	9.74289	6.53204	0.314479	0.384931	0.252557
3.81	12.70	9.74176	6.54833	0.313412	0.387552	0.257739
3.81	13.97	9.74749	6.54286	0.318853	0.386673	0.246979
3.81	15.24	9.75777	6.69599	0.328617	0.411018	0.260193
3.81	16.51	9.76195	6.70491	0.332583	0.412419	0.254911
3.81	17.78	9.73923	6.71659	0.311	0.41425	0.295517
3.81	19.05	9.74199	6.71145	0.313632	0.413446	0.289837
3.81	20.32	9.76498	6.48418	0.335454	0.377191	0.205615
3.81	21.59	9.78085	6.42184	0.350496	0.367026	0.166164
3.81	22.86	9.78899	6.43574	0.358204	0.369301	0.155336

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_1	ϵ_s
3.81	24.13	9.76395	6.39432	0.334485	0.362506	0.188911
3.81	25.40	9.78947	6.42603	0.358662	0.367711	0.152528
5.08	2.54	9.82408	6.49036	0.39135	0.378194	0.107661
5.08	3.81	9.78615	6.48326	0.355518	0.377043	0.169819
5.08	5.08	9.88878	6.56757	0.452145	0.390639	0.015367
5.08	6.35	9.84607	6.59797	0.412056	0.395499	0.092621
5.08	7.62	9.83393	6.62944	0.400633	0.400506	0.119182
5.08	8.89	9.83042	6.69566	0.397326	0.410966	0.138173
5.08	10.16	9.79052	6.70186	0.359653	0.41194	0.206262
5.08	11.43	9.75209	6.6799	0.323226	0.408486	0.266586
5.08	12.70	9.76677	6.69291	0.337154	0.410534	0.244433
5.08	13.97	9.79049	6.71387	0.359623	0.413825	0.208679
5.08	15.24	9.76115	6.71928	0.331829	0.414673	0.259077
5.08	16.51	9.76469	6.70732	0.335185	0.412798	0.250769
5.08	17.78	9.75233	6.71093	0.323454	0.413363	0.272299
5.08	19.05	9.76383	6.70679	0.334367	0.412714	0.252115
5.08	20.32	9.72829	6.70519	0.300588	0.412463	0.311755
5.08	21.59	9.73474	6.67933	0.306732	0.408396	0.295748

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_1	ϵ_s
5.08	22.86	9.73819	6.6985	0.31001	0.411412	0.293714
5.08	24.13	9.74065	7.22407	0.312352	0.490902	0.389289
5.08	25.40	9.73947	6.72557	0.311231	0.415657	0.296872
6.35	2.54	9.75012	6.70088	0.321351	0.411787	0.274054
6.35	3.81	9.7404	6.70754	0.312115	0.412831	0.291758
6.35	5.08	9.74074	6.70175	0.312443	0.411923	0.290036
6.35	6.35	9.72911	6.70913	0.301369	0.413081	0.311145
6.35	7.62	9.73278	6.72929	0.304868	0.416238	0.308897
6.35	8.89	9.74714	6.71731	0.318522	0.414364	0.28231
6.35	10.16	9.76135	6.71928	0.332017	0.414673	0.258743
6.35	11.43	9.75394	6.71846	0.32498	0.414543	0.271071
6.35	12.70	9.76207	6.7325	0.332696	0.416741	0.260133
6.35	13.97	9.78252	6.7237	0.352079	0.415365	0.224002
6.35	15.24	9.74374	6.72227	0.315287	0.41514	0.289025
6.35	16.51	9.73947	6.69872	0.311233	0.411446	0.291586
6.35	17.78	9.74029	6.68172	0.31201	0.408773	0.286852
6.35	19.05	9.74976	6.67056	0.321014	0.407014	0.268664
6.35	20.32	9.73828	6.66433	0.3101	0.40603	0.286802

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_l	ϵ_s
6.35	21.59	9.73924	6.67485	0.311013	0.407691	0.287265
6.35	22.86	9.75024	6.66551	0.321468	0.406217	0.266859
6.35	24.13	9.77028	6.70283	0.340484	0.412092	0.240477
6.35	25.40	9.78144	6.71638	0.351055	0.414217	0.22438
7.62	2.54	9.77106	6.70945	0.341222	0.413131	0.240471
7.62	3.81	9.76297	6.72278	0.333549	0.41522	0.256712
7.62	5.08	9.75953	6.72237	0.33029	0.415156	0.262415
7.62	6.35	9.76395	6.68825	0.33448	0.4098	0.248259
7.62	7.62	9.75794	6.71513	0.32878	0.414021	0.263671
7.62	8.89	9.74024	6.71167	0.311958	0.413479	0.292848
7.62	10.16	9.74695	6.70326	0.318343	0.41216	0.279862
7.62	11.43	9.77345	6.66845	0.343489	0.406682	0.228355
7.62	12.70	9.76361	6.69991	0.334156	0.411634	0.251135
7.62	13.97	9.75962	6.69588	0.330378	0.411	0.257044
7.62	15.24	9.77371	6.68601	0.343737	0.409448	0.231386
7.62	16.51	9.77674	6.6961	0.346607	0.411035	0.228282
7.62	17.78	9.74407	6.72134	0.315603	0.414995	0.288283
7.62	19.05	9.78318	6.71248	0.352702	0.413607	0.220691

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_l	ϵ_s
7.62	20.32	9.79477	6.71814	0.363671	0.414494	0.202336
7.62	21.59	9.78926	6.71387	0.35846	0.413825	0.210744
7.62	22.86	9.78633	6.70828	0.355685	0.412948	0.21457
7.62	24.13	9.77924	6.70272	0.348971	0.412075	0.225392
7.62	25.40	9.80177	6.69991	0.370293	0.411634	0.186992
8.89	2.54	9.76474	6.68217	0.335233	0.408844	0.245722
8.89	3.81	9.74171	6.6648	0.313358	0.406105	0.281113
8.89	5.08	9.74193	6.65764	0.313566	0.404973	0.279324
8.89	6.35	9.75464	6.64998	0.325644	0.403761	0.256365
8.89	7.62	9.76298	6.64665	0.333564	0.403234	0.241646
8.89	8.89	9.76084	6.66881	0.331535	0.406737	0.249642
8.89	10.16	9.75245	6.69467	0.323565	0.410811	0.2689
8.89	11.43	9.73627	6.70002	0.308186	0.411651	0.297251
8.89	12.70	9.77431	6.70143	0.344305	0.411872	0.233419
8.89	13.97	9.7704	6.69169	0.340601	0.410343	0.238074
8.89	15.24	9.75698	6.69014	0.327867	0.410098	0.26037
8.89	16.51	9.74594	6.68466	0.317379	0.409236	0.277904
8.89	17.78	9.72915	6.66845	0.301414	0.406682	0.303036

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_1	ϵ_s
8.89	19.05	9.72793	6.68319	0.300253	0.409005	0.308012
8.89	20.32	9.7376	6.66869	0.30945	0.406719	0.28882
8.89	21.59	9.72856	6.66076	0.300852	0.405466	0.302509
8.89	22.86	9.732	6.67807	0.30412	0.408198	0.300136
8.89	24.13	9.7653	7.06267	0.33576	0.467124	0.317908
8.89	25.40	9.84089	6.67079	0.407179	0.407051	0.115771
10.16	2.54	9.8358	6.68769	0.40239	0.409713	0.127611
10.16	3.81	9.82697	6.67853	0.394068	0.40827	0.140574
10.16	5.08	9.84005	6.68533	0.406388	0.409342	0.120051
10.16	6.35	9.82496	6.67462	0.392178	0.407655	0.143156
10.16	7.62	9.82696	6.68001	0.394062	0.408504	0.140877
10.16	8.89	9.82801	6.68936	0.395048	0.409976	0.140974
10.16	10.16	9.82768	6.69847	0.394739	0.411408	0.143319
10.16	11.43	9.82905	6.69258	0.396029	0.410482	0.139866
10.16	12.70	9.84746	6.7104	0.413367	0.41328	0.112604
10.16	13.97	9.81638	6.69434	0.384083	0.410759	0.161418
10.16	15.24	9.74574	6.67773	0.317191	0.408144	0.276869
10.16	16.51	9.76521	6.65884	0.33568	0.405164	0.240311

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_1	ϵ_s
10.16	17.78	9.77576	6.65456	0.34568	0.404486	0.221711
10.16	19.05	9.78256	6.64216	0.35212	0.402524	0.207819
10.16	20.32	9.77004	6.66693	0.34026	0.406441	0.233784
10.16	21.59	9.75072	6.67428	0.321922	0.4076	0.267787
10.16	22.86	9.80593	6.68013	0.374219	0.408522	0.17612
10.16	24.13	9.80593	6.70828	0.374219	0.412948	0.181672
10.16	25.40	9.80881	6.7038	0.376944	0.412244	0.175954
11.43	2.54	9.80842	6.68791	0.376575	0.409748	0.173477
11.43	3.81	9.79315	6.70881	0.362139	0.413031	0.203218
11.43	5.08	9.78909	6.69752	0.358299	0.411258	0.20781
11.43	6.35	9.79577	6.65968	0.364618	0.405296	0.189114
11.43	7.62	9.82227	6.67956	0.389639	0.408432	0.148638
11.43	8.89	9.8397	6.66112	0.406059	0.405523	0.115842
11.43	10.16	9.83804	6.65607	0.404498	0.404725	0.117613
11.43	11.43	9.83957	6.66528	0.405941	0.40618	0.116877
11.43	12.70	9.90087	6.71072	0.463462	0.41333	0.023749
11.43	13.97	9.91592	6.70033	0.477529	0.4117	-0.003262
11.43	15.24	9.92008	6.67532	0.481412	0.407764	-0.015095

Table A-1 (Continue)

X(cm)	Y(cm)	L_r	I_x	ε_g	ε_l	ε_s
11.43	16.51	9.78637	6.69708	0.355728	0.411189	0.212288
11.43	17.78	9.77687	6.66386	0.346731	0.405956	0.221689
11.43	19.05	9.77947	6.6752	0.349196	0.407746	0.219561
11.43	20.32	9.77638	6.67323	0.346262	0.407436	0.224379
11.43	21.59	9.77048	6.67933	0.340675	0.408396	0.235502
11.43	22.86	9.79093	6.68758	0.360043	0.409695	0.202753
11.43	24.13	9.79273	6.68376	0.361747	0.409094	0.198975
11.43	25.40	9.77173	6.67126	0.34186	0.407124	0.231802
12.70	2.54	9.77109	6.66563	0.341253	0.406236	0.231764
12.70	3.81	9.77922	6.6681	0.348953	0.406626	0.218588
12.70	5.08	9.77584	6.65824	0.345754	0.405069	0.222311
12.70	6.35	9.7757	5.16944	0.345625	0.513914	-0.111626
12.70	7.62	9.77456	5.20093	0.344545	0.539745	-0.101692
12.70	8.89	9.73418	5.22002	0.306196	0.555329	-0.028786
12.70	10.16	9.7652	5.20841	0.335667	0.545857	-0.084036
12.70	11.43	9.80463	5.23563	0.372994	0.56803	-0.143407
12.70	12.70	9.79513	5.22051	0.364012	0.55573	-0.131283
12.70	13.97	9.76991	5.24455	0.340135	0.575271	-0.082837

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_z	ϵ_1	ϵ_s
12.70	15.24	9.75654	5.23418	0.327454	0.566849	-0.062942
12.70	16.51	9.76833	5.22956	0.338636	0.563096	-0.083955
12.70	17.78	9.75544	5.26829	0.326409	0.594484	-0.052510
12.70	19.05	9.7673	5.24815	0.337658	0.578186	-0.077534
12.70	20.32	9.76007	5.24551	0.330802	0.57605	-0.066028
12.70	21.59	9.75738	6.70966	0.328252	0.413164	0.263534
12.70	22.86	9.75865	6.71669	0.329456	0.414266	0.262779
12.70	24.13	9.75795	5.24958	0.328785	0.579349	-0.061425
12.70	25.40	9.77369	5.22712	0.343717	0.561112	-0.093588
13.97	2.54	9.79675	5.26359	0.365547	0.590683	-0.123157
13.97	3.81	9.8002	5.28645	0.368804	0.609121	-0.123216
13.97	5.08	9.79733	5.24958	0.366088	0.579349	-0.127637
13.97	6.35	9.7987	5.30884	0.367386	0.627097	-0.115119
13.97	7.62	9.7955	5.24479	0.364366	0.575466	-0.125785
13.97	8.89	9.81248	5.22932	0.380401	0.562897	-0.158149
13.97	10.16	9.81915	5.25316	0.386695	0.582247	-0.163312
13.97	11.43	9.82414	5.2534	0.391403	0.58244	-0.171609
13.97	12.70	9.83746	5.24383	0.403949	0.574687	-0.196285

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_1	ϵ_s
13.97	13.97	9.77833	5.18047	0.348111	0.522977	-0.113226
13.97	15.24	9.77991	5.19138	0.349607	0.531927	-0.113103
13.97	16.51	9.79987	5.1494	0.368493	0.497393	-0.157345
13.97	17.78	9.82591	5.37015	0.393069	0.675938	-0.145544
13.97	19.05	9.84348	5.2993	0.409619	0.619448	-0.192454
13.97	20.32	9.84717	5.30136	0.413091	0.621094	-0.198107
13.97	21.59	9.78357	5.34223	0.353073	0.653768	-0.081435
13.97	22.86	9.81151	5.34289	0.379486	0.654291	-0.128155
13.97	24.13	9.80105	5.30997	0.369605	0.628002	-0.118776
13.97	25.40	9.78546	5.31313	0.354861	0.630531	-0.091821
15.24	2.54	9.76985	5.37143	0.340074	0.676952	-0.051166
15.24	3.81	9.75802	5.29999	0.328857	0.619997	-0.048936
15.24	5.08	9.76016	5.30635	0.330881	0.625102	-0.050944
15.24	6.35	9.7661	5.33232	0.33652	0.64587	-0.054505
15.24	7.62	9.75522	5.29839	0.326199	0.618715	-0.044615
15.24	8.89	9.74521	5.30567	0.316688	0.624557	-0.025921
15.24	10.16	9.74839	5.2802	0.319712	0.604088	-0.037641
15.24	11.43	9.76812	5.27181	0.338432	0.597322	-0.072969

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_l	ϵ_s
15.24	12.70	9.75572	5.18378	0.326676	0.525695	-0.074335
15.24	13.97	9.76474	5.22615	0.335235	0.560318	-0.078781
15.24	15.24	9.75949	5.22883	0.330247	0.562501	-0.069249
15.24	16.51	9.76524	5.20592	0.335704	0.543826	-0.084732
15.24	17.78	9.74792	5.22737	0.319264	0.561311	-0.050125
15.24	19.05	9.75297	5.26099	0.324062	0.588583	-0.050176
15.24	20.32	9.77349	5.24767	0.343531	0.577798	-0.088080
15.24	21.59	9.79729	5.20717	0.366055	0.544842	-0.138289
15.24	22.86	9.77672	5.19567	0.346593	0.535435	-0.106664
15.24	24.13	9.77255	5.19037	0.342634	0.5311	-0.100984
15.24	25.40	9.77458	5.20318	0.344563	0.541584	-0.101153
16.51	0.00	9.728	5.14334	0.300313	0.492383	-0.037883
16.51	0.00	9.72819	5.17587	0.300497	0.519197	-0.029887
16.51	0.00	9.76993	5.35422	0.340156	0.663304	-0.055547
16.51	0.00	9.81815	5.29359	0.38575	0.614856	-0.151514
16.51	0.00	9.82459	5.33674	0.391825	0.649391	-0.151577
16.51	0.00	9.85455	5.35466	0.420031	0.663649	-0.197215
16.51	0.00	9.89614	5.31245	0.459041	0.62999	-0.276904

Table A-1 (Continue)

X(cm)	Y(cm)	L_r	I_x	ϵ_g	ϵ_1	ϵ_s
16.51	0.00	9.90654	5.32322	0.468764	0.638598	-0.29149
16.51	0.00	9.9178	5.31785	0.479288	0.634307	-0.311502
16.51	0.00	9.92766	5.28368	0.488496	0.606888	-0.336388
16.51	2.54	9.9338	5.32789	0.494217	0.642332	-0.335541
16.51	3.81	9.93647	5.27041	0.49671	0.596188	-0.354291
16.51	5.08	9.94155	5.29382	0.501444	0.61504	-0.356841
16.51	6.35	9.94043	5.25625	0.500402	0.58475	-0.364395
16.51	7.62	9.92707	5.21287	0.487943	0.5495	-0.35322
16.51	8.89	9.88007	5.27087	0.443982	0.596566	-0.260574
16.51	10.16	9.87475	5.48756	0.438995	0.767932	-0.198524
16.51	11.43	9.97287	5.4036	0.530576	0.702353	-0.38145
16.51	12.70	9.78385	5.44628	0.353345	0.735813	-0.056455
17.78	13.97	9.77468	5.54246	0.344654	0.810274	-0.017912
17.78	15.24	9.7658	5.48967	0.336241	0.769567	-0.015615
17.78	16.51	9.76499	5.52141	0.33547	0.794095	-0.006632
17.78	17.78	9.77435	5.57009	0.344341	0.831429	-0.010789
17.78	19.05	9.77363	5.52216	0.343658	0.794669	-0.020989
17.78	20.32	9.78088	5.54501	0.350528	0.812235	-0.027730

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_l	ϵ_s
17.78	21.59	9.78058	5.50433	0.350245	0.780913	-0.036952
17.78	22.86	9.78997	5.50792	0.359131	0.783686	-0.051865
17.78	24.13	9.78904	5.51712	0.358256	0.790786	-0.048107
17.78	25.40	9.7882	5.43264	0.357456	0.725148	-0.067064
17.78	15.24	9.78514	5.4841	0.35456	0.765247	-0.049475
17.78	16.51	9.77552	5.71294	0.345448	0.939144	0.020683
17.78	17.78	9.77493	5.7153	0.344891	0.9409	0.022218
17.78	19.05	9.78199	5.79527	0.351581	1	0.028689
17.78	20.32	9.89325	5.79527	0.45633	1	-0.157253
17.78	21.59	9.87146	5.79527	0.435906	1	-0.120999
17.78	22.86	9.87622	5.79527	0.440374	1	-0.128929
17.78	24.13	9.88215	5.79527	0.445931	1	-0.138794
17.78	25.40	9.88704	5.79527	0.450514	1	-0.146929
19.05	2.54	9.89131	5.73957	0.454515	0.958919	-0.166785
19.05	3.81	9.89099	5.65	0.454216	0.892017	-0.187023
19.05	5.08	9.89393	5.62137	0.456974	0.870408	-0.198626
19.05	6.35	9.89643	5.5934	0.459305	0.849192	-0.209351
19.05	7.62	9.91428	5.51675	0.475998	0.790497	-0.257204

Table A-1 (Continue)

X(cm)	Y(cm)	I_y	I_x	ϵ_g	ϵ_l	ϵ_s
19.05	8.89	9.91412	5.52588	0.475854	0.797531	-0.254764
19.05	10.16	9.91766	5.74064	0.479157	0.959717	-0.210278
19.05	11.43	9.92813	5.79527	0.488933	1	-0.215127
19.05	12.70	9.94307	5.79527	0.502861	1	-0.239851
19.05	13.97	9.94139	5.79527	0.501296	1	-0.237072
19.05	15.24	9.93959	5.79527	0.499613	1	-0.234085
19.05	16.51	9.95065	5.79527	0.50992	1	-0.252382
19.05	17.78	9.94547	5.79527	0.505089	1	-0.243807
19.05	19.05	9.95927	5.79527	0.517935	1	-0.266609
19.05	20.32	9.9578	5.79527	0.516571	1	-0.264187
19.05	21.59	9.96653	5.79527	0.524682	1	-0.278585
19.05	22.86	9.96123	5.79527	0.519754	1	-0.161709
19.05	24.13	9.89787	5.79527	0.460653	1	-0.175430
19.05	25.40	9.89887	5.77354	0.461593	0.984026	-0.175308