DOE/PC/94217--T5

DOE/MST-9504

**A STUDY OF
MULTISTAGE/MULTIFUNCTION COLUMN
FOR FINE PARTICLE SEPARATION**

QUARTERLY TECHNICAL PROGRESS REPORT
(July 1, 1995 - September 30, 1995)

Principal Investigator: Dr. Shiao-Hung Chiang
Project Officer: Dr. Ralph W. Lai

Work Performed under DOE Contract No. DE-PG22-94PC94217

(Award: \$200,000; Duration: July 8, 1994 - July 7, 1997)

Submitted to

**U.S. Department of Energy
Pittsburgh Energy Technology Center
Pittsburgh, PA 15236-0940**

by

**Chemical and Petroleum Engineering Department
University of Pittsburgh
Pittsburgh, PA 15261**

October 20, 1995

RECEIVED
USDOE/PETC
95 OCT 26 PM 2:59
ACQUISITION & ASSISTANCE DIV.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DLC

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

1.0 INTRODUCTION

The overall objective of the proposed research program is to explore the potential application of a new invention involving a multistage column equipped with vortex-inducing loop-flow contactors (hereafter referred to as **the multistage column**) for fine coal cleaning process. The research work will identify the design parameters and their effects on the performance of the separation process. The results of this study will provide an engineering basis for further development of this technology in coal cleaning and in the general areas of fluid/particle separation.

In the last quarter, we performed image analyses of **gas bubble size** using photographs obtained from the multistage column^[1]. In this quarter, the **bubble size** measurements in the conventional column was carried out. Also, correlations for results on **gas holdup, bubble size and specific interfacial area** were developed. In Table 1.1, the project schedule shows work accomplished to date.

Table 1.1 Project Schedule

Tasks	1994			1995			1996			1997			
	7	9	12	3	6	9	12	3	6	9	12	3	6
1. Project Planning	■												
2. Equipment		■	■	■									
3. Hydrodynamic Tests				■	■	■	■						
4. Separation Tests								■	■	■	■	■	■
5. Conventional Column Tests				■	■	■	■						
6. Data Analysis				■	■	■	■	■	■	■	■	■	■
7. Reports	□	□	□	■	□	□	□	□	■	□	□	□	●

Notes: □ Quarterly Technical Progress Report; ■ Annual Report; ● Final Report.

2.0 TECHNICAL PROGRESS

2.1 Task 1: Project Planning

This task was completed in September 1994^[1].

2.2 Task 2: Equipment Design and Construction

Task 2 was completed in March 1995^[2].

2.3 Task 3: Hydrodynamic Tests

The objective of this task is to pursue a basic understanding of the hydrodynamic behavior and to characterize the flow and mixing conditions in a multistage separation column. In the last quarter, we have completed the measurements of *bubble sizes* in the three-stage column. During this quarter, we continued to perform image analyses of the bubble sizes based on the test data. The results are listed in the Appendix. The average size for the bubbles in the multistage column was found to range from 0.001m to 0.002 m. In September 1995, we began to work on correlation of data on *gas holdup*, *bubble size* and *specific interfacial area* obtained from the three-stage column and conventional column. Much of the current work has focused on developing a mathematical method to correlate the experimentally measured data in terms of operating parameters. (See Task 6 below).

2.4 Task 4: Separation Tests

This task will not be initiated until January 1996.

2.5 Task 5: Conventional Tests

Similar experiments as that of Task 3 have been carried out to study the *holdup*, *bubble size* and *specific interfacial area* in the conventional flotation column. The results are analyzed and discussed in the next section.

2.6 Task 6: Data Analysis

For engineering design and scale-up, an understanding of the hydrodynamic behavior of the multistage column is required. Gas holdup (Φ) and specific interfacial area (a) are two key parameters for evaluating the performance of the multistage column. For these purposes, gas holdup and bubble size (d_{av}) as well as specific interfacial area data were experimentally determined (Tasks 3 and 5).

These experimental data^[3-4] are analyzed in this section in terms of three key operating parameters: superficial gas velocity (V), agitation speed (N) and frother dosage (C). A second-order polynomial equation^[5] is used for the correlation:

$$Y = \beta_0 + \sum_{i=1}^k \beta_i X_i + \sum_{i=1}^k \beta_{ii} X_i^2 + \sum_{i=1}^k \sum_{j>i}^k \beta_{ij} X_i X_j \quad (2.6.1)$$

where, Y represents Φ , d_{av} or a ; X_i 's represent operating parameters, i.e., $X_1 = C$; $X_2 = N$; $X_3 = V$; and β_0 , β_i , β_{ii} , β_{ij} , are regression coefficients. The following is a summary of the correlations for these parameters.

2.6.1 Gas Holdup

Gas hold-up is one of the key parameters for evaluating the performance of the multistage column. Based on Eq. (2.6.1) and using a multi-parameter regression program^[6], a correlation for the overall gas holdup in the multistage column can be obtained as follows:

$$\begin{aligned} \Phi = & -0.122 + 7.88 \times 10^{-3} C + 3.55 \times 10^{-3} N + 6.11 V - 2.13 \times 10^{-4} C^2 - 4.37 \times 10^{-5} N^2 \\ & - 34.7 V^2 + 5.61 \times 10^{-5} C N + 9.32 \times 10^{-2} C V + 9.70 \times 10^{-3} N V \end{aligned} \quad (2.6.2)$$

Figure 2.6.1 presents a comparison of the overall gas holdup between calculated values and experimental data. The relative deviation shown in the Figure 2.6.1 is about $\pm 15\%$.

2.6.2 Bubble Size

The bubble sizes in the multistage column were investigated using photographic method. The experimental setup consisted of a camera, a strobe light, and a video camera recorder. In order to save time in counting and sizing of a large number of gas bubbles, information concerning the size and shape of gas bubbles was obtained from the photographs with the aid of a computerized image analyzer. A software package for image analysis (HARMONY)^[7] was used to examine the bubble images. The Sauter mean diameter, d_{av} , refers to the diameter of an equivalent sphere with the same volume-to-surface ratio as the gas bubble. For a distribution of bubbles, the Sauter mean diameter is defined as

$$d_{av} = \frac{\sum_{i=1}^n n_i d_i^3}{\sum_{i=1}^n n_i d_i^2} \quad (2.6.3)$$

where n_i denotes the frequency (numbers of bubbles over a specific size range) of appearance of bubbles with diameter d_i .

In order to calculate the d_{av} of the bubbles, more than 100 bubbles were counted for each run using the image analyzer. The Sauter mean diameter of bubbles in the multistage column was found to range from 0.001 m to 0.002 m which is comparable to the bubble sizes in the convention agitated column. However, in terms of bubble size, the design configuration of multistage column has a significant advantage over the conventional column. First, the multiple draft tubes are able to create an even distribution of bubbles over the entire column cross-section area, leading to almost no "dead" volume for bubble trajectories. In the conventional column, bubbles only appear in the area surrounding the shaft due to centripetal force, resulting in a low gas holdup and a poor dispersion condition. Second, even though the bubble sizes are comparable in both column configurations, the bubble sizes in multistage column are more uniform than those in the conventional column. Under this situation, the gas holdup in the multistage column are 20-50 % higher than that in the conventional column. Thus, the multistage column provides a larger interfacial area than the conventional column.

Based on Eq. (2.6.1) and using the multi-parameter regression program, the correlation for the Sauter mean diameter of bubbles in the multistage column can be obtained as follows:

$$d_{av} = 2.82 \times 10^{-3} - 1.01 \times 10^{-4} C - 3.47 \times 10^{-5} N - 1.34 \times 10^{-2} V + 2.97 \times 10^{-6} C^2 - \\ 1.84 \times 10^{-7} N^2 + 0.54 V^2 - 3.09 \times 10^{-7} C N - 8.0 \times 10^{-4} C V + 5.66 \times 10^{-4} N V \\ (2.6.4)$$

Figure 2.6.1 Comparison of Gas Holdup Between Calculated Values and Experimental Data

Figure 2.6.2 depicts a comparison of bubble size between calculated values and experimental data obtained from multistage column. The relative deviation shown in the figure is approximately $\pm 10\%$.

The bubble size data obtained from the multistage column and conventional column are listed in the Appendix.

2.6.3 Specific Interfacial Area

In the design and scale-up of the multistage column, the specific interfacial area of gas bubbles is one of the critical parameters. The specific interfacial area of gas bubbles is related to the magnitude of the gas holdup and the gas bubble Sauter mean diameter, d_{av} . Mathematically, the specific interfacial area of gas bubbles can be expressed as:

$$a = \frac{6\Phi}{d_{av}} \quad (2.6.5)$$

Based on the data of the bubble Sauter mean diameter and the corresponding overall gas holdup, the specific interfacial area of gas bubble can be calculated. Table 2.6.1 shows a comparison of the specific interfacial area data between the multistage and conventional agitated column. The results indicate that the specific interfacial areas of gas bubbles in the multistage column are significantly greater than those in the conventional agitated column under the same operating conditions. The difference is primarily due to much larger gas holdup in the multistage column. As shown in Table 2.6.1, the effects of N , V and MIBC dosage on a are also very significant.

Figure 2.6.2 Comparison of Bubble Sizes Between Calculated Values and Experimental Data

Table 2.6.1 Comparison of Specific Interfacial Area Data

MIBC, mg/L	7.0	7.0	7.0	15.0	15.0	15.0	20.0
N, Hz	14.7	30.0	30.0	21.7	21.7	45.0	21.7
V, m/s	0.04	0.04	0.04	0.03	0.05	0.03	0.02
Multistage Column, 1/m	518	595	603	968	1101	1543	940
Conventional Column, 1/m	373	490	481	614	657	996	845
Percentage of Increase, %	38	21	25	58	68	55	11

Based on Eq. (2.6.1) and using the multi-parameter regression program, the correlation for specific interfacial areas in the multistage column can be obtained as follows:

$$\begin{aligned} \alpha = & 274.6 - 19.5 C - 16.1N + 4.66 \times 10^3 V - 1.37 C^2 - 0.21 N^2 - 3.76 \times 10^5 V^2 \\ & + 2.64 C N + 1.6 \times 10^3 C V + 5.48 \times 10^2 N V \end{aligned} \quad (2.6.6)$$

Figure 2.6.3 presents a comparison of α between calculated values and experimental data obtained from the multistage column. The relative deviation shown in the figure is approximately $\pm 10\%$.

2.6.4 Summary

Experimental measurements of the overall gas holdup, gas bubble size and specific interfacial area were conducted to evaluate the roles of various operating parameters in the hydrodynamic behavior of the multistage column. Mathematical expressions developed using the multi-parameter regression method provide adequate correlations for the experimental data. In conclusion, the following points are noted:

Figure 2.6.3 Comparison of Specific Area Between Calculated Values and Experimental Data

1. The correlations for the gas holdup, bubble size and specific interfacial area under various operating range of V , N and C have been developed. A comparison of calculated values with experimental data indicates that the relative deviations of these correlations are within $\pm 10 \sim 15 \%$.
2. The gas bubble Sauter diameters in the multistage column were found to range from 0.001 m to 0.002 m, which are comparable to those in the conventional column.
3. The specific interfacial areas in the multistage column are significantly greater than those in the conventional column due to a higher gas holdup.

3.0 WORK FORECAST

In the next quarter, work for Tasks 3, 5, and 6 will be continued:

1. Conduct the investigation of mixing behavior in the multistage column:
 - a. Set up and calibrate the conductivity meter and auxiliary devices;
 - b. Carry out the measurements of mixing time under various operating conditions.
2. Initiate investigation of circulation flow characteristics around the contactor:
 - a. Define the circulation velocity and develop a measurement procedure;
 - b. Measure the circulation velocity around the contactor.

4.0 REFERENCES

1. *"A Study of Multistage/Multifunction Column for Fine Particle Separation"*, Quarterly Technical Progress Report, (July 8, 1994 - September 30, 1994), Chemical & Petroleum Engineering Department, University of Pittsburgh, Submitted to U.S. Department of Energy, PETC, January 20, 1995.
2. *"A Study of Multistage/Multifunction Column for Fine Particle Separation"*, Quarterly Technical Progress Report, (October 1, 1994 - December 31, 1994), Chemical & Petroleum Engineering Department, University of Pittsburgh, Submitted to U.S. Department of Energy, PETC, February 2, 1995.
3. *"A Study of Multistage/Multifunction Column for Fine Particle Separation"*, Quarterly Technical Progress Report, (January 1 - March 31, 1995), Chemical & Petroleum Engineering Department, University of Pittsburgh, Submitted to U.S. Department of Energy, PETC, April 20, 1995.
4. *"A Study of Multistage/Multifunction Column for Fine Particle Separation"*, Quarterly Technical Progress Report, (April 1, 1995 - June 30, 1995), Chemical & Petroleum Engineering Department, University of Pittsburgh, Submitted to U.S. Department of Energy, PETC, July 20, 1995.
5. Mason, R. L., R. F. Gunst and J. L. Hess, *<Statistical Design and Analysis of Experiments: with Applications to Engineering and Science>*, John Wiley & Sons, Inc., New York, 1989.
6. He, Da-Xin, "A Computer Program: Non-Linear Multi-Parameter Regression," (unpublished), September, 1995.
7. The *Harmony* User Manual, 2nd edition, Corporation of Canandaigua, New York, September 1993.

5.0 APPENDIX

Table 5.1 Results of Sauter Mean Diameter of Bubbles and Interfacial Area

Run	Multi-stage Column		Conventional Column	
	$d_{32} (10^{-2} \text{ m})$	$a (10^3 \text{ m}^{-1})$	$d_{32} (10^{-2} \text{ m})$	$a (10^3 \text{ m}^{-1})$
1	5.02	0.125	4.96	0.086
2	1.92	0.288	1.98	0.215
3	2.22	0.594	2.08	0.490
4	1.37	0.477	1/30	0.341
5	1.97	0.518	2.09	0.373
6	1.36	0.481	1.31	0.339
7	2.19	0.466	2.27	0.344
8	1.82	0.303	2.02	0.211
9	2.19	0.603	2.12	0.481
10	2.26	0.321	2.21	0.269
11	1.03	0.350	0.99	0.236
12	1.28	0.938	1.30	0.618
13	1.31	0.916	1.29	0.623
14	1.31	0.916	1.20	0.670
15	1.31	0.916	1.31	0.614
16	1.24	0.968	1.31	0.614
17	1.25	0.960	1.35	0.596
18	1.24	0.968	1.28	0.628
19	1.31	0.916	1.31	0.614
20	1.27	0.945	1.33	0.605
21	2.18	1.101	2.28	0.658
22	1.05	1.543	1.03	0.996
23	1.25	0.960	1.67	0.467
24	1.96	0.612	1.93	0.404
25	1.04	0.940	0.98	0.845
26	1.49	1.007	1.57	0.803
27	1.13	1.912	1.11	1.784
28	1.15	0.537	1.24	0.397
29	1.14	1.895	1.15	1.722
30	1.12	0.552	1.21	0.407
31	1.10	0.889	0.97	0.854
32	1.49	1.007	1.47	0.857
33	1.22	1.180	1.18	1.017

Table 5.2 Image Analysis of Bubble Sizes (Multistage Column : Run #11)

Area (cm ²)	Coordinates		d _b (mm)	Σd_b^2	Σd_b^3
	x(cm)	y(cm)			
0.005277	0.546232	0.893287	0.819707	0.671920	0.550778
0.005907	0.436450	0.895927	0.867255	1.424051	1.203067
0.012255	0.173566	0.841888	1.249137	2.984393	3.152147
0.003295	0.667298	0.849463	0.647753	3.403978	3.423935
0.002589	0.828093	0.834496	0.574127	3.733599	3.613179
0.008330	0.337216	0.658176	1.029858	4.794207	4.705455
0.001055	0.905802	0.790441	0.366518	4.928543	4.754692
0.003324	0.625439	0.772499	0.650570	5.351784	5.030040
0.005522	0.061030	0.751990	0.838526	6.054910	5.619630
0.004802	0.712553	0.738281	0.781957	6.666367	6.097762
0.002838	0.897593	0.712652	0.601095	7.027682	6.314947
0.001325	0.544901	0.715053	0.410745	7.196394	6.384244
0.008239	0.761473	0.641313	1.024248	8.245477	7.458765
0.004238	0.591819	0.653705	0.734531	8.785012	7.855070
0.002097	0.665756	0.631193	0.516686	9.051976	7.993007
0.009038	0.054826	0.587420	1.072730	10.20272	9.227449
0.005199	0.142281	0.563283	0.813587	10.86465	9.765982
0.001651	0.572579	0.572936	0.458430	11.07481	9.862325
0.001656	0.662916	0.575735	0.459227	11.28570	9.959171
0.002147	0.865506	0.520355	0.522783	11.55900	10.10205
0.007881	0.637175	0.467617	1.001744	12.56249	11.10729
0.003579	0.221192	0.480032	0.675031	13.01816	11.41488
0.004299	0.866646	0.435030	0.739822	13.56549	11.81981
0.002516	0.944272	0.444040	0.566000	13.88585	12.00113
0.001622	0.429717	0.433415	0.454423	14.09235	12.09497
0.005894	0.713022	0.386023	0.866270	14.84277	12.74504
0.001733	0.493339	0.408192	0.469724	15.06341	12.84868
0.001522	0.051658	0.409052	0.440253	15.25724	12.93401
0.003516	0.180600	0.367829	0.669045	15.70486	13.23349
0.002141	0.394877	0.374773	0.522084	15.97743	13.37580
0.001294	0.809679	0.372235	0.405969	16.14224	13.44270
0.005557	0.531248	0.318722	0.841139	16.84975	14.03782
0.001750	0.092793	0.329116	0.472055	17.07259	14.14301
0.005624	0.341188	0.308883	0.846196	17.78864	14.74893
0.007466	0.443433	0.296544	0.974980	18.73923	15.67573
0.002526	0.779900	0.317321	0.567076	19.06080	15.85809
0.003883	0.180914	0.276308	0.703159	19.55523	16.20576
0.004180	0.618809	0.271004	0.729534	20.08745	16.59403

Table 5.2 (Continued)

0.001538	0.269052	0.266457	0.442463	20.28323	16.68065
0.002214	0.810078	0.260739	0.530882	20.56506	16.83027
0.002583	0.042855	0.257292	0.573489	20.89395	17.01889
0.003244	0.107743	0.228166	0.642652	21.30695	17.28430
0.002386	0.552474	0.227631	0.551161	21.61073	17.45173
0.003960	0.408526	0.198641	0.710059	22.11492	17.80973
0.002342	0.217194	0.201875	0.546050	22.41309	17.97255
0.003659	0.787543	0.189039	0.682573	22.87899	18.29057
0.002302	0.626123	0.193140	0.541341	23.17204	18.44921
0.005540	0.706766	0.171182	0.839834	23.87736	19.04156
0.003763	0.865412	0.172909	0.692150	24.35644	19.37315
0.001672	0.160257	0.162656	0.461346	24.56928	19.47134
0.000200	0.057259	0.136871	0.506920	24.82624	19.60160
0.002635	0.370463	0.111748	0.579199	25.16172	19.79591
0.002457	0.120461	0.100799	0.559285	25.47451	19.97085
0.002539	0.656992	0.100398	0.568579	25.79780	20.15466
0.001760	0.824155	0.108482	0.473344	26.02185	20.26072
0.005093	0.201750	0.083945	0.805304	26.67037	20.78297
0.008565	0.706743	0.891153	1.044284	27.76089	21.92179
0.005900	0.501282	0.876425	0.866833	28.51229	22.57313
0.003470	0.158216	0.856005	0.664474	28.95382	22.86651
0.001779	0.405848	0.843140	0.475913	29.18031	22.97430
0.001970	0.227144	0.836812	0.501116	29.43143	23.10014
0.001756	0.876079	0.823853	0.472829	29.65500	23.20585
0.004395	0.100596	0.763470	0.748015	30.21452	23.62438
0.000630	0.692873	0.790766	0.283216	30.29473	23.64710
0.006150	0.255777	0.752664	0.884926	31.07783	24.34008
0.002778	0.627736	0.763511	0.594776	31.43159	24.55049
0.002656	0.518039	0.747894	0.581511	31.76974	24.74713
0.002891	0.953364	0.728563	0.606747	32.13788	24.97050
0.006338	0.425954	0.711170	0.898324	32.94487	25.69543
0.001101	0.887006	0.736223	0.374414	33.08506	25.74792
0.001756	0.574783	0.702713	0.472829	33.30862	25.85363
0.003292	0.643158	0.687380	0.647377	33.72772	26.12494
0.002962	0.136632	0.682469	0.614136	34.10488	26.35657
0.001486	0.306815	0.674721	0.434961	34.29407	26.43886
0.003619	0.739003	0.656855	0.678813	34.75486	26.75165
0.002526	0.243208	0.648937	0.567076	35.07643	26.93401
0.003311	0.810367	0.646384	0.649257	35.49797	27.20769
0.002484	0.375754	0.617076	0.562327	35.81418	27.38551
0.001844	0.179833	0.617225	0.484543	36.04896	27.49927
0.001677	0.292090	0.591829	0.462137	36.26253	27.59797
0.001564	0.485624	0.584895	0.446304	36.46172	27.68687

Table 5.2 (Continued)

0.004521	0.716539	0.566599	0.758695	37.03734	28.12358
0.011056	0.582988	0.537652	1.186473	38.44506	29.79380
0.001639	0.043592	0.574435	0.456832	38.65375	29.88914
0.002618	0.433260	0.538883	0.577302	38.98703	30.08155
0.002759	0.230700	0.533209	0.592722	39.33835	30.28978
0.002263	0.353054	0.523402	0.536819	39.62653	30.44448
0.002914	0.099767	0.498150	0.609153	39.99759	30.67052
0.002847	0.288525	0.462678	0.602108	40.36013	30.88880
0.003056	0.174711	0.443059	0.623785	40.74924	31.13152
0.001712	0.506380	0.436867	0.466861	40.96720	31.23328
0.003753	0.426507	0.424239	0.691269	41.44505	31.56360
0.007474	0.640773	0.393687	0.975480	42.39661	32.49183
0.003569	0.093523	0.383335	0.674128	42.85106	32.79819
0.002470	0.023795	0.379888	0.560808	43.16556	32.97457
0.001959	0.391044	0.354644	0.499409	43.41497	33.09912
0.002133	0.716739	0.348475	0.521149	43.68657	33.24067
0.003010	0.269538	0.299223	0.619078	44.06983	33.47793
0.002409	0.771503	0.298022	0.553808	44.37653	33.64779
0.002305	0.052735	0.280756	0.541791	44.67007	33.80682
0.002631	0.429600	0.270472	0.578778	45.00505	34.00070
0.002614	0.226305	0.233890	0.576880	45.33784	34.19268
0.004096	0.550910	0.221839	0.722145	45.85934	34.56928
0.005262	0.690778	0.206599	0.818517	46.52931	35.11766
0.002937	0.131728	0.208469	0.611550	46.90330	35.34638
0.005821	0.879032	0.191610	0.860907	47.64446	35.98445
0.002099	0.395453	0.152259	0.516921	47.91167	36.12257
0.005532	0.508763	0.119690	0.839253	48.61601	36.71369
0.002083	0.616387	0.114803	0.515032	48.88127	36.85031
0.005582	0.752973	0.094263	0.843021	49.59195	37.44943
0.003653	0.307959	0.079948	0.682038	50.05713	37.76670
0.002304	0.674245	0.065531	0.541567	50.35042	37.92554
0.000038	0.996582	0.036226	0.069829	50.35530	37.92588
0.061100	0.993943	0.006059	2.788900	58.13327	59.61785
Average Size of Bubble (mm)					1.025538

Table 5.3 Image Analysis of Bubble Size (Multistage Column: Run #25)

Area (cm ²)	Coordinates		d _b (mm)	Σd_b^2	Σd_b^3
	x(cm)	y(cm)			
0.002512	0.536788	0.910661	0.565570	0.3198696	0.18090867
0.001482	0.736669	0.916285	0.434400	0.5085726	0.26288117
0.002091	0.927517	0.911370	0.515977	0.7748044	0.40025055
0.001201	0.459884	0.912356	0.390978	0.9276682	0.46001696
0.001294	0.676040	0.903397	0.405969	1.0924789	0.52692494
0.002296	0.355981	0.881990	0.540666	1.3847981	0.68497187
0.000655	0.601098	0.890854	0.288757	1.4681786	0.70904855
0.000881	0.858775	0.884037	0.334887	1.5803278	0.74660586
0.000708	0.804790	0.882629	0.300345	1.6705348	0.77369905
0.002271	0.288739	0.856771	0.537727	1.9596849	0.92918282
0.001921	0.138416	0.851498	0.494504	2.2042195	1.05010621
0.000797	0.936054	0.861014	0.318468	2.3056414	1.08240586
0.001810	0.675416	0.848411	0.479994	2.5360353	1.19299350
0.002914	0.557244	0.838832	0.609153	2.9071031	1.41903069
0.001181	0.412416	0.823243	0.387847	3.0575287	1.47737286
0.002443	0.185651	0.800862	0.557756	3.3686206	1.65088624
0.007583	0.801033	0.774473	0.982577	4.3340785	2.59952324
0.001377	0.496291	0.783225	0.418682	4.5093730	2.67291587
0.002717	0.110653	0.762933	0.588180	4.8553287	2.87640009
0.002597	0.640486	0.757990	0.574975	5.1859254	3.06648498
0.002621	0.549218	0.742195	0.577725	5.5196911	3.25930963
0.001388	0.710989	0.750664	0.420425	5.6964485	3.33362295
0.003271	0.361597	0.721878	0.645302	6.1128627	3.60233573
0.000371	0.215661	0.729905	0.217480	6.1601604	3.61262204
0.002570	0.469438	0.680060	0.571999	6.4873435	3.79977048
0.021423	0.630820	0.627020	1.651563	9.2150042	8.30467445
0.002191	0.765198	0.668517	0.528120	9.4939150	8.45197278
0.002834	0.897151	0.663260	0.600690	9.8547434	8.66871878
0.001783	0.175070	0.664807	0.476425	10.081724	8.77685782
0.003619	0.285708	0.632650	0.678813	10.542510	9.08964560
0.001574	0.161808	0.610693	0.447667	10.742916	9.17936036
0.001718	0.486152	0.606034	0.467643	10.961606	9.28162945
0.003230	0.860375	0.595615	0.641322	11.372901	9.54540187
0.001564	0.742362	0.587503	0.446304	11.572087	9.63429967
0.025094	0.285199	0.498552	1.787464	14.767116	15.3452996
0.002338	0.124820	0.549450	0.545604	15.064800	15.5077168
0.003244	0.806686	0.540952	0.642652	15.477801	15.7731334
0.001961	0.703145	0.511405	0.499654	15.727456	15.8978742
0.001028	0.942877	0.508105	0.361832	15.858378	15.9452459
0.000804	0.643724	0.508572	0.319995	15.960775	15.9780126

Table 5.3 (Continued)

0.001752	0.875477	0.497854	0.472313	16.183854	16.0833757
0.002520	0.543742	0.483268	0.566431	16.504698	16.2651113
0.001005	0.600514	0.494298	0.357766	16.632694	16.3109039
0.001660	0.118841	0.439376	0.459757	16.844071	16.4080860
0.002060	0.409082	0.440988	0.512183	17.106403	16.5424480
0.002884	0.668971	0.425580	0.605943	17.473569	16.7649300
0.001499	0.725450	0.412328	0.436917	17.664466	16.8483361
0.000923	0.887277	0.417370	0.342801	17.781979	16.8886197
0.001176	0.836316	0.410665	0.386904	17.931674	16.9465372
0.001329	0.163478	0.395386	0.411339	18.100873	17.0161355
0.001524	0.073360	0.383302	0.440531	18.294940	17.1016280
0.002001	0.297939	0.381846	0.504751	18.549714	17.2302255
0.001139	0.625041	0.387305	0.380871	18.694777	17.2854756
0.001310	0.575414	0.383464	0.408364	18.861538	17.3535750
0.000611	0.252826	0.364222	0.278878	18.939311	17.3752642
0.001490	0.957656	0.359057	0.435521	19.128990	17.4578730
0.003799	0.363694	0.339973	0.695489	19.612694	17.7942844
0.000710	0.730003	0.339053	0.300750	19.703145	17.8214875
0.000687	0.928516	0.325295	0.295846	19.790670	17.8473816
0.001710	0.231857	0.304243	0.466601	20.008387	17.9489682
0.002030	0.456094	0.305889	0.508361	20.266817	18.0803442
0.000753	0.582694	0.313225	0.309539	20.362632	18.1100025
0.007602	0.791294	0.264789	0.983817	21.330528	19.0622354
0.001827	0.515460	0.283597	0.482274	21.563116	19.1744063
0.002445	0.921845	0.267182	0.557975	21.874452	19.3481243
0.002012	0.398574	0.258044	0.506198	22.130689	19.4778310
0.001093	0.330423	0.264394	0.373110	22.269900	19.5297719
0.000670	0.162359	0.263031	0.292114	22.355231	19.5546983
0.001838	0.695366	0.242299	0.483788	22.589281	19.6679292
0.001042	0.866960	0.245658	0.364182	22.721910	19.7162299
0.001547	0.362538	0.212639	0.443839	22.918903	19.8036631
0.002637	0.250454	0.207759	0.579410	23.254619	19.9981806
0.002131	0.099528	0.208082	0.520915	23.525972	20.1395325
0.000906	0.553952	0.209021	0.339586	23.641290	20.1786930
0.000739	0.788193	0.181791	0.306770	23.735398	20.2075625
0.003772	0.634022	0.133276	0.693031	24.215690	20.5404191
0.004293	0.300573	0.130731	0.739328	24.762295	20.9445397
0.003891	0.532444	0.129451	0.703852	25.257702	21.2932329
0.000345	0.423689	0.142867	0.209486	25.301587	21.3024261
0.018020	0.392697	0.806306	1.514737	27.596015	24.7778817
0.019975	0.139288	0.755946	1.594787	30.139362	28.8339787
0.001354	0.903811	0.793822	0.415173	30.311730	28.9055415
0.000841	0.581937	0.751369	0.327153	30.418760	28.9405565
0.001652	0.845662	0.727046	0.458695	30.629161	29.0370667

Table 5.3 (Continued)

0.001310	0.328704	0.709181	0.408364	30.795922	29.1051661
0.000820	0.429461	0.694083	0.323029	30.900270	29.1388733
0.006978	0.610558	0.646265	0.942559	31.788687	29.9762582
0.003368	0.043740	0.649307	0.654865	32.217535	30.2570963
0.000714	0.365825	0.661624	0.301560	32.308474	30.2845197
0.001128	0.300145	0.634674	0.378946	32.452073	30.3389362
0.001191	0.149823	0.624131	0.389417	32.603719	30.3979894
0.002654	0.791757	0.614458	0.581300	32.941629	30.5944167
0.002650	0.883821	0.615428	0.580881	33.279051	30.7904189
0.000885	0.421386	0.611072	0.335614	33.391688	30.8282214
0.040255	0.286311	0.497507	2.263949	38.517152	42.4320073
0.002551	0.661138	0.532298	0.569864	38.841896	42.6170676
0.002461	0.577956	0.528197	0.559720	39.155183	42.7924207
0.001032	0.124066	0.521854	0.362505	39.286593	42.8400573
0.000758	0.818150	0.521406	0.310718	39.383139	42.8700559
0.002342	0.506226	0.490679	0.546050	39.681310	43.0328723
0.000948	0.631885	0.435702	0.347393	39.801992	43.0747965
0.001634	0.752095	0.308839	0.456122	40.010039	43.1696915
0.000494	0.889031	0.409015	0.250801	40.072940	43.1854671
0.000860	0.564944	0.381091	0.330859	40.182408	43.2216853
0.000777	0.623485	0.355718	0.314617	40.281392	43.2528273
0.000754	0.155481	0.347712	0.309933	40.377450	43.2825989
0.002669	0.065374	0.320449	0.582976	40.717311	43.4807294
0.001203	0.341374	0.314789	0.391291	40.870419	43.5406393
0.003276	0.473456	0.298882	0.645869	41.287565	43.8100610
0.001765	0.899013	0.306636	0.474117	41.512352	43.9166361
0.001084	0.202141	0.306250	0.371473	41.650344	43.9678966
0.001281	0.280437	0.250574	0.403862	41.813449	44.0337683
0.000772	0.353040	0.252786	0.313452	41.911701	44.0645658
0.014917	0.616400	0.179999	1.378125	43.810929	46.6819381
0.001153	0.126775	0.228831	0.383104	43.957698	46.7381659
0.002631	0.493454	0.192446	0.578778	44.292682	46.9320474
0.001210	0.253651	0.197494	0.392535	44.446765	46.9925306
0.000559	0.785479	0.158178	0.266815	44.517956	47.0115253
0.001264	0.190231	0.143374	0.401135	44.678865	47.0760717
0.001036	0.395501	0.135609	0.363177	44.810763	47.1239738
0.000561	0.830447	0.134246	0.267272	44.882197	47.1430662
0.001681	0.688480	0.073973	0.462664	45.096255	47.2421033
0.000944	0.290252	0.055103	0.346691	45.216450	47.2837737
0.001024	0.232672	0.050215	0.361157	45.346884	47.3308811
Average Size of Bubble (mm)				1.04375156	

Table 5.4 Image Analysis of Bubble Size (Conventional Column: Run #13)

Area (cm ²)	Coordinates		d _b (mm)	Σd_b^2	Σd_b^3
	x(cm)	y(cm)			
0.016485	0.586006	0.828279	1.448757	2.0988970	3.04079175
0.000672	0.489196	0.882707	0.292531	2.1844716	3.06582504
0.012443	0.137686	0.826781	1.258661	3.7686998	5.05983158
0.001700	0.766053	0.817947	0.465292	3.9851963	5.16056566
0.001995	0.465585	0.788745	0.504026	4.2392381	5.28860925
0.011456	0.394472	0.728983	1.207756	5.6979121	7.05033117
0.042515	0.181091	0.642571	2.326618	11.111064	19.6446684
0.002505	0.495892	0.636603	0.564707	11.429958	19.8247503
0.006210	0.569167	0.577107	0.889186	12.220609	20.5277859
0.005118	0.745065	0.556063	0.807270	12.872294	21.0538713
0.004745	0.918390	0.556650	0.777266	13.476437	21.5234515
0.013764	0.388588	0.489495	1.323801	15.228886	23.8433443
0.012421	0.240094	0.451120	1.257594	16.810427	25.8322808
0.000515	0.641290	0.497211	0.256092	16.876010	25.8490760
0.000620	0.591355	0.495153	0.281055	16.955002	25.8712772
0.016596	0.094570	0.402810	1.453631	19.068045	28.9428612
0.004216	0.623149	0.401191	0.732703	19.604899	29.3362155
0.001446	0.433288	0.378916	0.429035	19.788970	29.4151884
0.003175	0.607832	0.294691	0.635786	20.193194	29.6721886
0.003586	0.042350	0.279942	0.675753	20.649836	29.9807660
0.009187	0.462104	0.251919	1.081557	21.819601	31.2459324
0.001779	0.689124	0.264573	0.475913	22.046093	31.3537232
0.001476	0.782554	0.262072	0.433558	22.234065	31.4352199
0.005294	0.226217	0.241727	0.821044	22.908180	31.9886976
0.004393	0.331861	0.212734	0.747852	23.467463	32.4069588
0.008140	0.883575	0.194010	1.018039	24.503867	33.4620590
0.002242	0.620990	0.182969	0.534316	24.789360	33.6146026
0.002616	0.172953	0.143861	0.577092	25.122395	33.8067943
0.002325	0.801316	0.135070	0.544037	25.418371	33.9678161
0.002330	0.561260	0.126200	0.544709	25.715079	34.1294357
0.008262	0.417810	0.104915	1.025674	26.767087	35.2084529
0.014752	0.654271	0.850033	1.370495	28.645344	37.7825956
0.003292	0.193995	0.832095	0.647377	29.064441	38.0539093
0.036428	0.361279	0.760459	2.153626	33.702547	48.0426548
0.008546	0.095407	0.799384	1.043116	34.790638	49.1776604
0.006627	0.735481	0.753756	0.918587	35.634439	49.9527648
0.001363	0.912659	0.768763	0.416638	35.808026	50.0250878
0.001074	0.654417	0.731384	0.369828	35.944799	50.0756701
0.013892	0.120346	0.617183	1.329956	37.713583	52.4280760
0.006495	0.812033	0.635531	0.909383	38.540561	53.1801159

Table 5.4 (Continued)

0.000978	0.723982	0.657968	0.352963	38.665144	53.2240892
0.004829	0.454319	0.614232	0.784137	39.280014	53.7062315
0.006438	0.342443	0.586034	0.905353	40.099679	54.4483173
0.000787	0.246815	0.605867	0.316548	40.199882	54.4800363
0.001536	0.028968	0.569805	0.442188	40.395412	54.5664973
0.003544	0.257071	0.517656	0.671772	40.846690	54.8696534
0.001884	0.776590	0.526342	0.489797	41.086591	54.9871564
0.002878	0.877061	0.493706	0.605339	41.453027	55.2089744
0.000454	0.476719	0.502194	0.240377	41.510808	55.2228637
0.001476	0.079865	0.487885	0.433558	41.698780	55.3043604
0.001808	0.527997	0.486506	0.479739	41.928930	55.4147721
0.000573	0.161093	0.466691	0.269995	42.001827	55.4344539
0.051246	0.417650	0.344435	2.554387	48.526720	72.1015580
0.002970	0.740386	0.414994	0.614929	48.904858	72.3340862
0.003935	0.248353	0.404452	0.707824	49.405873	72.6887163
0.003292	0.781780	0.334187	0.647377	49.824970	72.9600300
0.004971	0.188236	0.323938	0.795558	50.457882	73.4635481
0.007317	0.643578	0.292746	0.965178	51.389451	74.3626788
0.001428	0.871269	0.316967	0.426471	51.571328	74.4402441
0.000887	0.715408	0.297568	0.335977	51.684209	74.4781693
0.003502	0.728268	0.210587	0.667769	52.130124	74.7759376
0.001635	0.759450	0.147691	0.456298	52.338332	74.8709423
0.001333	0.830097	0.148766	0.411931	52.508019	74.9408417
0.001905	0.449251	0.136226	0.492528	52.750603	75.0603211
0.000594	0.561631	0.120689	0.274916	52.826182	75.0810990
0.003579	0.105040	0.099068	0.675031	53.281849	75.3886883
0.001921	0.343807	0.106352	0.494504	53.526383	75.5096117
0.002348	0.721051	0.092843	0.546719	53.825285	75.6730271
0.001381	0.413578	0.089375	0.419264	54.001067	75.7467262
0.001279	0.515630	0.084516	0.403559	54.163927	75.8124499
0.001032	0.741752	0.890507	0.362505	54.295337	75.8600865
0.003320	0.571042	0.862459	0.650195	54.718091	76.1349589
0.008318	0.401531	0.816201	1.029115	55.777169	77.2248721
0.004695	0.131365	0.779691	0.773178	56.374973	77.6870806
0.015008	0.765132	0.727376	1.382363	58.285901	80.3286784
0.001618	0.621089	0.773438	0.453886	58.491914	80.4221848
0.021762	0.329123	0.664807	1.664575	61.262725	85.0344080
0.001350	0.166705	0.692257	0.414585	61.434606	85.1056673
0.000327	0.662515	0.683200	0.204182	61.476296	85.1141797
0.002434	0.631884	0.630867	0.556663	61.786169	85.2866747
0.001507	0.570701	0.633528	0.438032	61.978041	85.3707208
0.000666	0.017163	0.629065	0.291279	62.062885	85.3954338
0.009262	0.182449	0.569143	1.085943	63.242158	86.6760576
0.001488	0.468426	0.593172	0.435241	63.431593	86.7585076

Table 5.4 (Continued)

0.005953	0.681381	0.553071	0.870622	64.189575	87.4184236
0.009702	0.562079	0.519810	1.111462	65.424923	88.7914657
0.004140	0.370316	0.519844	0.726017	65.952024	89.1741499
0.003424	0.911880	0.462723	0.660242	66.387943	89.4619617
0.006001	0.658834	0.447757	0.874115	67.152020	90.1298533
0.004663	0.471236	0.440309	0.770493	67.745679	90.5872636
0.001967	0.023533	0.431700	0.500385	67.996064	90.7125525
0.001053	0.097300	0.416259	0.366185	68.130156	90.7616547
0.004986	0.627848	0.337922	0.796782	68.765017	91.2675007
0.001099	0.068273	0.339060	0.374090	68.904960	91.3198519
0.000553	0.930910	0.335008	0.265441	68.975419	91.3385546
0.006304	0.449353	0.289732	0.895878	69.778017	92.0575846
0.001721	0.319366	0.306137	0.468164	69.997195	92.1601960
0.001607	0.537443	0.269801	0.452272	70.201745	92.2527081
0.015537	0.086068	0.198043	1.406492	72.179964	95.0350574
0.002518	0.811054	0.232503	0.566216	72.500564	95.2165865
0.000331	0.387298	0.241498	0.205372	72.542742	95.2252486
0.001953	0.250191	0.151670	0.498677	72.791421	95.3492591
0.001415	0.310634	0.146633	0.424464	72.971591	95.4257347
0.005404	0.611212	0.117326	0.829465	73.659602	95.9964158
0.001396	0.531973	0.124771	0.421582	73.837334	96.0713443
Average Size of Bubble (mm)				1.30112152	

Table 5.4 Image Analysis of Bubble Size (Conventional Column: Run #24)

Area (cm ²)	Coordinates		d _b (mm)	Σd_b^2	Σd_b^3
	x(cm)	y(cm)			
0.004733	0.307330	0.866147	0.776325	0.60268023	0.46787563
0.002629	0.687285	0.770105	0.578568	0.93742124	0.66154608
0.005746	0.307199	0.741204	0.855366	1.66907298	1.28737643
0.003772	0.077117	0.617024	0.693031	2.14936435	1.62023303
0.001465	0.875053	0.589648	0.431867	2.33587355	1.70078022
0.010016	0.362517	0.503399	1.129304	3.61120107	3.14101268
0.020207	0.775257	0.466457	1.604010	6.18404867	7.26788557
0.003945	0.507707	0.396893	0.708684	6.68628177	7.62381016
0.003699	0.340438	0.342228	0.686313	7.15730777	7.94708159
0.033496	0.855638	0.266225	2.065150	11.4221505	16.7546196
0.002891	0.603279	0.34017	0.606747	11.7902924	16.9779886
0.002068	0.512460	0.310885	0.513135	12.0535996	17.1131007
0.009723	0.257089	0.245623	1.112668	13.2916288	18.4906157
0.003573	0.421165	0.213773	0.674489	13.7465649	18.7974653
0.018191	0.279796	0.106065	1.521882	16.0626892	22.3223329
0.00278	0.852742	0.104195	0.594980	16.4166905	22.5329566
0.033777	0.309995	0.805554	2.073806	20.7173622	31.4517157
0.119946	0.754276	0.730508	3.907940	35.9893595	91.1337696
0.007093	0.475415	0.737079	0.950287	36.8924046	91.9919214
0.046791	0.556291	0.430883	2.440812	42.8499682	106.533214
0.001867	0.162213	0.397996	0.487552	43.0876756	106.649109
0.003958	0.738329	0.294178	0.709888	43.5916161	107.00685
0.054894	0.401207	0.193688	2.643735	50.5809492	125.484793
0.002937	0.840077	0.198882	0.611550	50.9549429	125.713509
0.010650	0.142018	0.173775	1.164485	52.3109684	127.29258
0.003112	0.755545	0.867488	0.629427	52.7071470	127.541946
0.002049	0.907553	0.823902	0.510753	52.9680159	127.675185
0.001306	0.285724	0.824842	0.407767	53.1342895	127.742986
0.003569	0.506760	0.812099	0.674128	53.5887379	128.049343
0.005746	0.711178	0.709199	0.855366	54.3203897	128.675173
0.072980	0.215542	0.502840	3.048286	63.6124399	157.000004
0.021331	0.865913	0.525317	1.648017	66.3283996	161.475951
0.004138	0.525035	0.526405	0.725850	66.8552572	161.858371
0.011236	0.654718	0.454947	1.196092	68.2858944	163.569545
0.002064	0.722264	0.269600	0.512659	68.5487140	163.704282
0.003653	0.364545	0.260695	0.682038	69.0138895	164.021549
0.012033	0.543420	0.237388	1.237760	70.5459402	165.917861
0.002951	0.672453	0.112340	0.612944	70.9216401	166.148144
0.001042	0.259305	0.054805	0.364182	71.0542683	166.196445
0.015219	0.233834	0.704129	1.392028	72.9920114	168.893838

Table 5.5 (Continued)

0.002348	0.593063	0.722065	0.546719	73.2909132	169.057253
0.032983	0.868021	0.650092	2.049268	77.4904133	177.663155
0.058463	0.545006	0.530413	2.728329	84.9341910	197.972228
0.001995	0.161777	0.562202	0.504026	85.1882328	198.100271
0.002122	0.296793	0.539128	0.519743	85.4583659	198.240671
0.001589	0.145803	0.438367	0.449840	85.6607218	198.331699
0.003966	0.723596	0.383653	0.710573	86.1656364	198.690478
0.012877	0.098440	0.326962	1.280459	87.8052122	200.789888
0.001649	0.558575	0.316160	0.458164	88.0151261	200.886063
0.010072	0.847134	0.220599	1.132434	89.2975328	202.338304
0.002141	0.215080	0.240278	0.522084	89.5701041	202.480609
0.002147	0.100101	0.211597	0.522783	89.8434062	202.623486
0.006863	0.214224	0.106720	0.934767	90.7171947	203.440275
0.005924	0.580235	0.101866	0.868519	91.4715203	204.095421
0.002803	0.794026	0.804412	0.597434	91.8284475	204.308661
0.002574	0.707819	0.699011	0.572425	92.1561182	204.496228
0.005674	0.535101	0.563542	0.849933	92.8785046	205.110209
0.000484	0.405359	0.580452	0.248359	92.9401867	205.125528
0.005241	0.769125	0.535349	0.816877	93.6074749	205.67062
0.002547	0.442324	0.523263	0.569436	93.9317321	205.855264
0.002562	0.320667	0.500767	0.571146	94.2579398	206.041576
0.005942	0.644782	0.475825	0.869781	95.0144592	206.699583
0.004329	0.266147	0.428191	0.742454	95.5656968	207.108851
0.001988	0.515080	0.407889	0.503057	95.8187633	207.236158
0.005128	0.363145	0.388549	0.808024	96.4716664	207.763719
0.007271	0.084155	0.335558	0.962143	97.3973853	208.654393
0.004015	0.855088	0.241445	0.715020	97.9086393	209.01995
0.006564	0.361361	0.085728	0.914197	98.744395	209.783995
0.009136	0.828687	0.853501	1.078509	99.9075768	211.038497
0.002656	0.636450	0.856945	0.581511	100.245731	211.235138
0.003632	0.507385	0.792617	0.680069	100.708225	211.549666
0.007343	0.187759	0.748784	0.966945	101.643208	212.453743
0.003410	0.636629	0.760477	0.658948	102.077421	212.739867
0.002912	0.406376	0.751793	0.608953	102.448245	212.965681
0.001139	0.866162	0.720209	0.380871	102.593307	213.020931
0.013360	0.080055	0.656138	1.304228	104.294317	215.239435
0.009903	0.327262	0.651409	1.122919	105.555263	216.655375
0.020939	0.825198	0.629028	1.632784	108.221248	221.008354
0.005702	0.646817	0.625931	0.852082	108.947293	221.627003
0.008661	0.208035	0.584278	1.050105	110.050012	222.784974
0.001597	0.311494	0.545902	0.450923	110.253343	222.876661
0.011453	0.049845	0.493877	1.207550	111.711521	224.637483
0.001294	0.426625	0.521515	0.405969	111.876332	224.704391
0.003715	0.833173	0.504468	0.687733	112.349308	225.029673

Table 5.5 (Continued)

0.009017	0.693911	0.469583	1.071478	113.497374	226.259801
0.007047	0.275639	0.460436	0.947203	114.394567	227.109625
0.000643	0.598816	0.461846	0.286213	114.476485	227.133071
0.004494	0.826944	0.389438	0.756442	115.048690	227.565911
0.013283	0.107343	0.360790	1.300483	116.739947	229.765362
0.002989	0.255903	0.335390	0.616909	117.120523	230.000143
0.006037	0.448924	0.312241	0.876761	117.889233	230.674117
0.003196	0.342864	0.299935	0.637893	118.296140	230.93368
0.039710	0.865835	0.165661	2.248551	123.352122	242.302316
0.002214	0.175016	0.245272	0.530882	123.633958	242.451937
0.013823	0.689999	0.186528	1.326654	125.393969	244.786864
0.003684	0.283534	0.188534	0.684892	125.863046	245.108131
0.003743	0.127987	0.179682	0.690387	126.339681	245.437193
0.002143	0.487822	0.178893	0.522316	126.612495	245.579689
0.005574	0.213279	0.112636	0.842442	127.322204	246.177577
0.000774	0.556663	0.105712	0.313841	127.420700	246.208490
Average Size of Bubble (mm)				1.93224876	