THE EFFECT OF ONP CHEMISTRY AND FIBER TYPE ON GAS BUBBLE SIZE IN A QUIESCENT BUBBLE COLUMN

Project F00903

Report 5

to the

MEMBER COMPANIES OF THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

February 12, 1998

INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

Atlanta, Georgia

THE EFFECT OF ONP CHEMISTRY AND FIBER TYPE ON GAS BUBBLE SIZE IN A QUIESCENT BUBBLE COLUMN

Project F00903

Report 5

A Progress Report

to the

MEMBER COMPANIES OF THE INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

By

T.J. Heindel and A.E. Emery

February 12, 1998

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Experiments were performed to determine the bubble size in a quiescent bubble column with four different experimental systems: (1) ONP systems with various chemistries and chemistry concentrations; (2) NBSK systems with various consistencies but no added chemistry; (3) a copy paper system with no added chemistry; and (4) an ONP system with no added chemistry but a higher gas flow rate.

For the specific chemistries addressed here and added to an air/water system or an air/water/1% ONP system, clear trends were difficult to ascertain due to the variations in the fiber network structure for the different test conditions. However, in general, the nonionic surfactant produced smaller average bubble diameters, but variations in the general trends were observed.

The northern bleached softwood kraft studies were conducted at an air flow rate of 2 slpm, which produced severe backmixing. This resulted in the sparger air injection technique yielding a higher gas holdup and a bimodal bubble size distribution, with the majority of the bubbles in the size range less than 10 mm in diameter and a peak in the 2-3 mm range. The bubbles in this range all have the same average bubble size (~3 mm) for all NBSK fiber consistencies addressed here, but the relative frequency decreases with increasing consistency. Few bubbles are greater than 10 mm in diameter, but there are those that are typically larger than 25 mm. The number of bubbles that fall in this category increases with increasing NBSK consistency. These larger bubbles play an important role by acting as mobile mixers, which keeps the smaller bubbles uniform and the fiber suspension well-mixed and homogeneous. Also, the average bubble size increases with NBSK fiber consistency.

The 1% copy paper and 1% ONP systems with an air injection rate of 2 slpm produced similar results to those obtained with 1% NBSK. The most significant difference was that the ONP system produced the smallest average bubble size.

2. INTRODUCTION

Information related to bubble size in gas/liquid/fiber suspensions is important to many aspects of pulp and paper processing. These complex multiphase systems are found in gaseous bleaching, direct steam heating, air removal from fiber flows, and flotation deinking. This research program utilizes flash x-ray radiography (FXR) to visualize gas flows in fiber suspensions at consistencies typically encountered in flotation deinking (i.e., ~0.8-1.2%). Report 3 of PAC Project F00903 [1] presented preliminary work in this area, where the FXR procedure was described in detail and bubble size measurements obtained in a quiescent bubble column of 0-1.5% ONP were quantified. General conclusions from this initial study were

(i) FXR is a useful tool to visualize gas flows in fiber suspensions;

(ii) air bubble rise characteristics and bubble size are dependent on ONP fiber consistency;

(iii) conclusions obtained in a simple air/water system are not applicable at fiber consistencies common to flotation deinking.

This report continues this work and summarizes results obtained with different system chemistries and fiber types. The report will first review the various experimental procedures employed in this study. Then bubble flow observations and bubble size measurements will be presented. The results section will first address different system chemistries in an ONP suspension, and then, without any added chemistry, results for northern bleached softwood kraft, copy paper, and ONP suspensions will be summarized. Throughout the results section, comparisons between the various systems addressed in this phase of the study will be made. This report will end with a brief summary of the general conclusions from this study and outline the direction for future bubble size studies in fiber suspensions.

3. EXPERIMENTAL METHODS

The experimental methods initially employed in this project to visualize and record bubble size distributions in a pulp suspension have been detailed in Report 3 of this project [1]. These details will be summarized in this section for completeness, and any additions or modifications to the original procedures will be clarified. This section will begin by outlining the equipment used in this study, followed by a description of the various fiber types. Then chemistry modifications used in selected experiments will be addressed. Details of the flash x-ray radiography and image analysis procedures will then be presented. This section will conclude with a brief summary of the different experimental conditions addressed in this report.

3.1 Equipment

Figure 1 is a schematic representation of the experimental setup used in this study. The x-ray unit was a 300 keV HP 43733A flash x-ray system (currently supported by Physics International), which generates a 30 nanosecond x-ray pulse. The x-ray tube head was mounted in a locking vertical slide to allow x-ray exposures at various heights. A 3.25 mm aluminum filter was mounted directly in front of the x-ray source aperture to filter soft x-rays that promote scattering effects and result in fuzzy images [2]. The resulting hardened x-ray beam produced sharper images with less scattering.

The entire system is housed in a 3.5 m × 4.5 m room lined with lead foil for safety considerations. A planar bubble column, with interior dimensions 20 cm wide by 2 cm deep, was constructed with face panes of 6.35 mm clear acrylic stock. The column was 1 m tall with lead numbers affixed to both sides to indicate the column height, which was recorded on film when x-rays were taken. Compressed and filtered building air was injected into the base of the column by one of two methods referred to throughout this report as *gasket* or *sparger*, respectively.

The *gasket* air injection method consisted of a single, centrally located hole drilled in a 3.18 mm thick n-butyl rubber gasket. The hole was formed with a 0.34 mm diameter drill bit and was self-sealing when the air pressure was removed. The rubber gasket separated the bubble column from a conical air diffuser and allowed for the possibility of using different air injection patterns and/or hole sizes. This injection technique is indicated in the following figures by a single arrow at the column base identified as "air inlet."

The *sparger* air injection method utilized a bronze pneumatic filter, designed to remove 40 μm particles, but in this experiment, it was attached to the end of an air line and placed on the bottom of the column. The air line was positioned near the column wall such that it did not interrupt the bulk air flow patterns. Note that the x-rays utilizing this technique typically have a dark line running down the left-hand side of the x-ray, indicating the air-filled Tygon tubing that leads to the sparger.

Air flow through the gasket or sparger was regulated with a Dixon air regulator and filter, and was measured with a Sierra Instruments mass flow meter that covers an air flow rate range less than 1 slpm (standard liter per minute). A second Sierra Instruments mass flow meter that can measure flow rates as high as 40 slpm is available in a parallel flow circuit, and was used at the higher air flow rates. The entire bubble column was mounted on a support stand with locking wheels to allow horizontal placement from the x-ray source.

The bubble column was charged by filling it with the desired water/fiber slurry from the top until a fluid height of 80 cm was reached. This allowed for fluid expansion in the column once air was introduced into the system. The column was drained when not in use through a valved opening located on the column side near its base. After filling, wood fiber suspensions slowly separate over a period of hours if the system is not agitated. Therefore, a high air flow rate was maintained to keep the system well mixed. After an experiment was set up and the x-ray film was properly located, the air flow rate was adjusted to the desired level. At the lower fiber consistencies, a waiting period of approximately 10 minutes allowed the flow to reach quasi-steady-state conditions, whereupon an x-ray was taken. For the higher consistencies ($\geq 1\%$), the fibers settled much quicker, and the slurry was agitated with a stir bar prior to the x-ray discharge to promote a uniform fiber suspension.

3.2 Fiber Type

Experiments were performed initially in an air/water system (without fiber), comprised of compressed and filtered building air and deionized water, to form base-line conditions for the various experimental parameters. Then identical experiments were performed where only the fiber consistency was altered. The air/water/fiber systems were composed of deionized water and unprinted paper of various types. The unprinted paper was reslushed following TAPPI Method T 205 om-88 [3]; however, deionized water was used, and disintegration was performed at 1.2-1.3% consistency. Pulp slurries of 0.1, 0.5, and 1.0% consistency were prepared by diluting samples of the reslushed stock with deionized water. Slurries with consistencies greater than 1.2% were prepared by filtering water from the reslushed stock until the desired consistency was obtained (i.e., 1.5%).

The various fiber types used in these experiments were unprinted old newsprint (ONP), unprinted northern bleached softwood kraft (NBSK), and unprinted Union Camp Yorktown xerographic paper (copy paper). In addition to preparing samples of these fibers at the desired consistencies, a representative sample of each fiber type was analyzed to determine weight-weighted fiber length (Kajaani FS-100 fiber length analyzer) and ash content (TAPPI Method T413 om-93 [4]). These results are summarized in Table 1. As expected, the ONP has the shortest average fiber length, and the copy paper has the highest ash content.

Table 1: Fiber length and ash content of the fiber types used in this study.

	Average Fiber Length (mm)	Ash Content (%)
ONP	1.4	0.7
NBSK	2.8	0.3
Copy Paper	2.0	6.6

3.3 Chemistry Modifications

Report 3 of this research program [1] presented bubble size results for ONP suspensions with no added system chemistry. The ONP bubble size experiments presented in this report have been completed with modified system chemistries. A series of ONP deinking surfactants available through Buckman Laboratories were used in this program. They include (1) BRD 2360, a fatty acid; (2) BRD 2342, a nonionic surfactant; and (3) BRD 2363, a fatty acid/nonionic surfactant blend. Experiments were performed with more than one concentration of each surfactant, based on dry fiber weight. Specific concentrations are tabulated in Table 2. For each chemical and concentration addressed in this study, bubble size measurements were made in air/water and air/water/1% ONP fiber systems. The chemical concentration in the air/water system was based on the dry fiber weight in the 1% ONP system. Therefore, identical amounts of each surfactant were added to the air/water and air/water/1% ONP systems.

Table 2: Chemical concentrations used in this ONP study of bubble size.

	BRD 2360	BRD 2342	BRD 2363
Density (g/ml)	0.9	1.02	1.0
1.7 ml/kg (3 lbs/ton)	X	X	X
3.3 ml/kg (6 lbs/ton)	X	X	X
6.7 ml/kg (12 lbs/ton)	X		

In the tests where the system chemistry was modified, water hardness was adjusted to 120-150 ppm Ca^{2+} with $CaCl_2$, and pH was adjusted to approximately 10 with NaOH. The system was stirred in a bucket with a mechanical mixer for 10 minutes before being transferred to the bubble column.

The NBSK and copy paper experiments performed in this study were completed in deionized water with no added system chemistry.

3.4 FXR Procedures

The background to flash x-ray radiography (FXR) was presented in Report 3 of this project [1]. The specific FXR procedures utilized in this study are presented below.

A single 20 cm × 25.2 cm x-ray negative was exposed during the discharge of the x-ray unit. The x-ray film was AGFA D8 Structurix film and was mounted in a film cassette between two Dupont Quanta Rapid Back PF intensifying screens. This was performed in a lightproof room where the x-ray negatives were also manually developed.

Each x-ray negative was exposed by attaching the film cassette to the back of the bubble column in the orientation and in one of four positions identified in Fig. 1, and then discharging the x-ray unit. A lead letter/number identification was taped to each cassette to permanently identify the image when exposed to radiation. The x-ray source was located in front of, and perpendicular to, the planar bubble column. All radiographs were taken at a source to film distance of 1.65 m and an object to film distance of 1.6 cm, ensuring negligible image magnification and distortion [2, 5]. The bubble column and x-ray tube were aligned using a laser pointer mounted on top of the x-ray tube such that the x-ray aperture was coincident with the center of the x-ray film.

The exposed film was removed from the film holder in the lightproof, darkened room and secured to a metal hanger for processing. Film processing consisted of developing, washing/stop-bath, fixing, washing, and drying procedures. The exposed film was first immersed in a developer solution (Kodak industrial manual developer and replenisher) for approximately 4 minutes. The film is next immersed for 30 seconds in a Kodak stop-bath to deactivate the developer chemicals remaining on the film surface. After the stop-bath, the film is placed in a fixing solution (Kodak rapid fixer with hardener) for 5 minutes. The film is then washed in a circulating water bath for at least 15 minutes to remove the fixing chemicals and soluble salts. Finally, the film was dipped in a photoflo solution to prevent water spots, mounted in a film dryer, and dried for 1 hour.

3.5 Image Analysis

Once the FXR images acquired in this study were developed, they were analyzed using image analysis software. The x-ray was placed on a light table and a 7.6 cm × 7.6 cm region of interest was isolated to perform image analysis. Since the x-rays were black and white, the image was digitized using Optimas 5.2 with the 8-bit mono setting (as opposed to the 16-bit RGB default setting) and saved as a Tiff file. The resulting electronic image was then enhanced (to increase the contrast between the bubbles and the background) using NIH Image v1.60b7 for the Macintosh.

The image was then electronically returned to Optimas 5.2 to record the bubble areas. This process was repeated until all regions with bubbles on the x-ray were analyzed. Care was taken not to record a bubble more than once if regions overlapped.

The recorded bubble areas were automatically saved to an Excel spreadsheet to determine the equivalent bubble diameter and Sauter mean diameter. The equivalent bubble diameter is defined as the diameter of a circle whose area is identical to that of the bubble. The Sauter mean diameter is a volume-weighted diameter defined by $d_{32} = \Sigma d^3/\Sigma d^2$, where the summation takes place over the entire bubble population, and d is the equivalent bubble diameter.

3.6 Experimental Conditions Addressed in this Report

Table 3 outlines the experimental conditions explored in this report. This table also includes some of the conditions addressed in Report 3 because comparisons between the present data and the data reported in Report 3 will be made. A series of four x-rays, one at each position, were obtained for each consistency. These x-rays are used to explain general qualitative observations. Additional x-rays were taken at Position 2 to gather enough bubble size measurements to determine bubble size distributions. Typically, 6 to 18 additional x-rays, depending on consistency, were required to obtain the desired bubble sample size.

Table 3: Experimental conditions addressed in this report.

System	Consistency	Air Flow Rate (slpm)	System Chemistry
Water only	0%	0.25	None added
Water only	0%	0.25	BRD 2360 - 1.7 ml/kg
Water only	0%	0.25	BRD 2360 - 3.3 ml/kg
Water only	0%	0.25	BRD 2360 - 6.7 ml/kg
Water only	0%	0.25	BRD 2342 - 1.7 ml/kg
Water only	0%	0.25	BRD 2342 - 3.3 ml/kg
Water only	0%	0.25	BRD 2363 - 1.7 ml/kg
Water only	0%	0.25	BRD 2363 - 3.3 ml/kg
Water only	0%	2.0	None added
ONP	1%	0.25	None added
ONP	1%	0.25	BRD 2360 - 1.7 ml/kg
ONP	1%	0.25	BRD 2360 - 3.3 ml/kg
ONP	1%	0.25	BRD 2360 - 6.7 ml/kg
ONP	1%	0.25	BRD 2342 - 1.7 ml/kg
ONP	1%	0.25	BRD 2342 - 3.3 ml/kg
ONP	1%	0.25	BRD 2363 - 1.7 ml/kg
ONP	1%	0.25	BRD 2363 - 3.3 ml/kg
ONP	1%	2.0	None added
NBSK	0.1%	0.25	None added
NBSK	0.5%	0.25	None added
NBSK	0.5%	2.0	None added
NBSK	1.0%	2.0	None added
NBSK	1.5%	2.0	None added
Copy Paper	1%	2.0	None added

4. RESULTS

Flash x-rays of various air/water and air/water/fiber systems have been obtained at four locations in a planar bubble column. The air flow rate was fixed at either 0.25 slpm (standard liters per minute) or 2.0 slpm, and two different air injection techniques were investigated. Results detailed below address four different systems: (1) ONP systems with various chemistries and chemistry concentrations; (2) NBSK systems with various consistencies but no chemistry alterations; (3) copy paper systems; and (4) ONP systems with no added chemistry but with a higher gas flow rate. Each system will be addressed individually, and comparisons between the systems will be made when appropriate.

Recall that each x-ray composite image is a compilation of four x-ray images, each taken at a separate time interval (e.g., Fig. 2). Also, the gap between the channel bottom where the air is introduced and the beginning of the first image is due to the flange and bolts that are used to attach the column to the diffuser, preventing the film cassette from being placed any lower. The gaps between Positions 1 and 2, Positions 2 and 3, and Positions 3 and 4 are caused by the film cassette holder being fixed at specific locations. The actual image dimensions that encompassed the column interior were 20 cm × 20 cm, with approximately 2.5 cm of film overhanging each side. The overhanging portions include the lead position indicators and the radiograph identification label, and have been digitally removed from the images presented here to increase clarity. The reproduced and reduced images do have some loss of detail, but they are representative of the originals, which are available at IPST. All observations and measurements presented in this report are based on the original x-ray images.

4.1 ONP Chemistry Effects

The effect of system chemistry conditions on bubble size in an ONP suspension was addressed by modifying an air/water/1% ONP fiber system with three different deinking chemistries. First, results will be presented when BRD 2360, a fatty acid, was added to the ONP system. Second, results with BRD 2342, a nonionic surfactant, will be addressed. Third, results for BRD 2363, a fatty acid and nonionic surfactant blend, will be presented. Finally, this section will conclude by making comparisons between the different system chemistries.

All system chemistry variations were investigated in 0 and 1% ONP consistency systems. The 0% consistency system corresponds to an air/water system, where the chemical concentration is based on the mass of dry fiber in the 1% ONP system. Additionally, all tests were conducted at a constant air flow rate of 0.25 slpm, and both the gasket and sparger air injection techniques were investigated.

4.1.1 BRD 2360 Results

System chemistry was modified using BRD 2360, a fatty acid produced by Buckman Laboratories. Results for three different BRD 2360 concentrations, based on dry fiber weight, are presented below.

4.1.1.1 BRD 2360 Concentration of 1.7 ml/kg

Figure 2 shows a composite of four x-ray images taken in an air/water system with the addition of 1.7 ml/kg (3 lbs/ton) of BRD 2360. This is a composite of the gas flow in the bubble column with the gasket air injection and a volumetric gas flow rate of 0.25 slpm. The small dark regions in the central portion of each x-ray are air bubbles rising through the column. The bubbles are fairly small (to be discussed further below) and rise in an oscillating serpentine pattern and become dispersed as they rise in the column. These observations are similar to those observed in an air/water system with no added chemistry [1].

Figure 3 shows the same gasket air injection with the same chemistry conditions (i.e., 1.7 ml/kg of BRD 2360), but with the addition of 1% ONP fiber. The bubbles are much larger and there are fewer in number, indicating one of two possibilities: (1) the bubbles have coalesced right after being introduced into the system, or (2) the bubbles leaving the single-holed gasket are larger because a larger buoyant force is required for the bubble to rise. The larger bubbles are able to break through any fiber networks that have formed because they have a larger buoyant force. On some of the x-rays, bubble groupings can also be identified. These groupings will coalesce if the thin liquid film between the individual bubbles ruptures as they rise through the suspension. Additionally, the rising bubbles remain in the central region of the column and do not significantly disperse as they rise through the suspension. These observations are also similar to those displayed in the 1% ONP system without added chemistry [1].

Employing the same chemistry conditions, but using the sparger to introduce air into the system produces many more bubbles in the air/water system (Fig. 4). These bubbles readily disperse as they rise through the column in an oscillating serpentine flow pattern. When 1% ONP fiber is added to this system, many bubbles of various sizes are observed (Fig. 5). The bubbles do disperse somewhat as they rise through the column. One interesting feature of the sparger observations with 1% ONP is that it was the only system that produced visible foaming at the air/fluid interface.

Bubble size measurements were taken of the preceding images at Position 2 using image analysis. All of these data can be found in Appendix A, Tables A1 and A4. Bubble size distributions were obtained with these data, with at least 248 bubbles making up the bubble population. This required multiple x-rays to be taken at Position 2 under the appropriate experimental conditions.

Figure 6 summarizes the bubble size distributions obtained from the 0 and 1% ONP systems with 1.7 ml/kg BRD 2360 when the gasket (G) and sparger (S) were used to introduce the air. The x-axis in Fig. 6 is read in the following manner: the bin marked "1" represents all bubbles with an equivalent bubble diameter less than or equal to 1 mm; the next tick mark is 1.5 and the data point associated with this value represents all bubbles with equivalent bubble diameter in the 1.0-1.5 mm size range; the tick mark labeled "2" represents all bubbles in the 1.5-2.0 mm diameter range, etc. The last bin is labeled ">10" and represents all bubbles with equivalent diameters greater than 10 mm. The average bubble size and standard deviation (a measure of the size uniformity) for each experimental condition are also shown in the figure. Both the gasket and sparger produce relatively small bubbles with a narrow distribution when no fiber is present. For this situation, very little difference between the gasket and sparger results is observed. When 1% ONP fiber is added, the average bubble size increases for both injection techniques and the distributions are much broader. The gasket produces larger bubbles than the sparger. The bubble size distribution obtained with the sparger is also heavily skewed to the smaller equivalent bubble diameters.

These data will be compared to the results from other BRD 2360 concentrations in Section 4.1.1.4 and other system chemistries in Section 4.1.4.

4.1.1.2 BRD 2360 Concentration of 3.3 ml/kg

A typical BRD 2360 concentration recommended by the chemical supplier (Buckman Laboratories) for ONP deinking corresponds to 3.3 ml/kg (6 lbs/ton). Figures 7 and 8 reveal the composite x-rays for the 0 and 1% ONP consistency, respectively, for the gasket air injection technique. The qualitative observations for these conditions do not differ significantly from those observed with a BRD 2360 concentration of 1.7 ml/kg. Similar results are obtained when the sparger air injection technique is used (Figs. 9 and 10). Again, only the sparger with 1% ONP showed any significant foaming at the air/liquid interface.

Bubble size measurements for these conditions are shown in Fig. 11, and the data are tabulated in Appendix A, Tables A2 and A4. These measurements correspond to a bubble population size of more than 250, and in most cases, is over three times this number. Increasing the consistency shows a general trend of increasing the average bubble size and broadening the bubble size distribution. In both the 0 and 1% ONP consistency systems, the average bubble size obtained with the gasket air injection technique is larger than that observed with the sparger. At 1% ONP, this difference is considerable (almost 2 mm). We will have more to say about this later.

4.1.1.3 BRD 2360 Concentration of 6.7 ml/kg

Increasing the BRD 2360 concentration to 6.7 ml/kg (12 lbs/ton) reveals similar qualitative observations from the composite x-ray images to those previously described for the gasket and sparger at 0 and 1% ONP consistency (Figs. 12-15). Foaming at the air/liquid interface was again observed only with the sparger at 1% ONP consistency.

The bubble size distributions for these conditions were obtained from more than 220 bubbles in each population sample, and each data point is tabulated in Appendix A, Tables A3 and A4. Figure 16 reveals that similar trends to those previously discussed for the smaller BRD 2360 concentrations are also observed here: (1) increasing the ONP consistency from 0 to 1% results in larger average bubble sizes and broader bubble size distributions; (2) the gasket produces larger bubble diameters for both consistencies; and (3) the sparger bubble size distribution at 1% ONP is skewed to smaller diameters, whereas the gasket distribution is not.

4.1.1.4 BRD 2360 Summary

The bubble size distributions from the various concentrations of BRD 2360 for each test condition can be compared to determine the effect, if any, of BRD 2360 concentration. Figure 17 displays the bubble size distribution obtained in an air/water system with gasket air injection for four different BRD 2360 concentrations. The data corresponding to 0.0 ml/kg were obtained from the system with no added chemistry and were originally presented in Report 3 [1]. Figure 17 reveals that for an air/water system with gasket air injection, the BRD 2360 concentration has only a small influence on the bubble size distribution. That is, when BRD 2360 is present, the bubble size distribution is slightly narrower than when no BRD 2360 is in the system. However, the data reveal that this trend is not very strong.

Figure 18 shows the bubble size distributions for the gasket air injection in 1% ONP for each BRD 2360 concentration. The general shape of the distribution is similar between concentration levels but the peak shifts, corresponding to a shift in average bubble diameter. When BRD 2360 is present, larger average bubble diameters are observed. For this system, a maximum average bubble diameter appears to be produced when the BRD 2360 concentration is 3.3 ml/kg, and this corresponds to the concentration newsprint mills typically employ.

Comparing the results obtained with the sparger air injection technique at 0% consistency (Fig. 19), very little change in bubble size distribution is observed as the BRD 2360 concentration increases. The distribution is fairly narrow and centered between 2.5 and 3.0 mm. The average bubble size at 0.0 ml/kg is slightly smaller than that obtained when BRD 2360 is present, but the difference is not that significant.

When 1% ONP is present in the system and the sparger is used for air injection, similar bubble size distributions for all BRD 2360 concentrations are observed. The average bubble diameter and standard deviation for each condition is between 3.3 and 3.7 mm and 1.2 and 1.6 mm, respectively, revealing similar trends with little influence from different BRD 2360 concentrations.

The average bubble diameters are summarized in Fig. 21 as a function of BRD 2360 concentration. The typical chemical concentration of 3.3 ml/kg is identified for reference. It appears that only the gasket at 1% ONP consistency is significantly affected by the BRD 2360 concentration. This may be more of a function of the physical system than chemical concentration. In the air/water system, the average bubble diameter is not significantly affected by the BRD 2360 concentration for either air injection method because the bubbles are free to disperse and coalescence is limited. When 1% ONP is added to the system, the average bubble diameter increases, but it is relatively unaffected by BRD 2360 concentration when the sparger air injection technique is used. This is because the sparger head allows air into the system over a relatively large surface area. The bubbles require a sufficient buoyant force to rise through the fiber network, resulting in the increased bubble diameter. Since they enter the system at different locations along the sparger head, depending on the path of lowest pressure drop, the fiber suspension remains fairly well-mixed and the bubble diameters remain uniform for each system chemical concentration. In contrast, for the gasket air injection technique, air enters the system through a single port. The air bubbles again must have a sufficient buoyant force to rise through the fiber network. If the system does not remain well-mixed, a fiber network slightly different from the previous test condition may form, which may require larger (or smaller) bubbles to break through this network. It is hypothesized that this type of system was present at 3.3 ml/kg of BRD 2360 with the gasket air injection, resulting in a significant change in average bubble diameter.

4.1.2 BRD 2342 Results

System chemistry was also modified with BRD 2342, a nonionic surfactant produced by Buckman Laboratories. Results summarized below were obtained at two different BRD 2342 concentrations, based on dry fiber weight.

4.1.2.1 BRD 2342 Concentration of 1.7 ml/kg

Figure 22 shows air bubbles rising through an air/water system with 1.7 ml/kg of BRD 2342 (based on dry fiber weight of 1% ONP) and gasket air injection. As before, the bubbles are rather small and rise in an oscillating serpentine fashion. When 1% ONP is present (Fig. 23), the bubbles are less dispersed and larger. Position 1 also shows that a channel had formed and a train of air bubbles rise in this region. Toward the top of Position 1, the channel breaks apart and the air bubbles become somewhat dispersed.

Figures 24 and 25 show the composite radiographs for the sparger air injection. In the air/water system (Fig. 24), the bubbles are small and become well dispersed as they rise in the column. With 1% ONP (Fig. 25), the bubbles are larger and grouped as they rise in the bubble column. As with the BRD 2360, foaming at the air/liquid interface is only observed with the sparger and 1% ONP. However, based on visible observations, the BRD 2342 produced much more foam than the BRD 2360, as well as the BRD 2363 (to be discussed below).

The bubble size distributions at Position 2 for this system are compared in Fig. 26, with more than 300 bubbles comprising each population sample (tabulated in Appendix A, Tables A5 and A7). For this system chemistry, the gasket produced slightly smaller bubbles than the sparger in both the 0 and 1% ONP consistency levels. As before, with the 1% ONP fiber system, the average bubble size is larger and the bubble size distribution is shifted to a larger bubble size range. Both the gasket and sparger, for each consistency level, show very similar bubble distribution patterns, with the sparger results shifted slightly to larger bubble sizes.

Comparisons between these results and those obtained at other chemistries are presented in Section 4.1.4.

4.1.2.2 BRD 2342 Concentration of 3.3 ml/kg

Figures 27-31 reveal representative composite x-ray images when the BRD 2342 concentration is increased to 3.3 ml/kg (6 lbs/ton). With the gasket air injection in an air/water system (Fig. 27), the bubbles remain small and still rise in an oscillating serpentine fashion, but they do not disperse as much as they rise through the column. With 1% ONP added to this same system (Fig. 28), a channel and train of bubbles are observed at Position 1, which break apart before reaching Position 2. The bubbles are visibly larger, as expected, when 1% ONP is present.

The sparger produces a stream of small bubbles in the air/water system that become well dispersed by the time they reach Position 4 (Fig. 29). When 1% ONP is added, larger bubbles and bubble groupings are observed (Fig. 30), with much smaller bubbles also visible in the original x-ray. The large bubbles rise in a confined region and are followed by the smaller ones. This system again produced foaming at the air/water interface.

The bubble size distributions were obtained for this system chemistry with more than 250 bubbles representing each population size. The individual data for these test conditions are found in Appendix A, Tables A6 and A7. Figure 31 reveals that the bubble size distributions obtained with the gasket and sparger air injection are identical in the air/water system. When 1% ONP is added, the bubble size distributions shift to larger bubble sizes, and the sparger produces a slightly larger average bubble diameter than the gasket.

4.1.2.3 BRD 2342 Summary

The bubble size distributions from the various concentrations of BRD 2342 are summarized in Figs. 32-35. Figure 32 reveals the distributions for the air/water system with gasket air injection. When BRD 2342 is added to this system, the average bubble size is reduced and the bubble size distribution covers a smaller range of bubble diameters. This trend is not consistent with the others discussed below. When 1% ONP is added to the gasket air injection system with BRD 2342 (Fig. 33), the average bubble size increases slightly, accompanied by a shift in bubble size distribution to larger bubble sizes, with increasing BRD 2342 concentration.

In the air/water system with sparger air injection, the bubble size distributions and resulting average bubble size are very similar for the two BRD 2342 concentrations and the system without any added chemistry (Fig. 34). However, when 1% ONP is added, Fig. 35 shows that the average bubble size increases slightly with increasing BRD 2342 concentration. The bubble size distributions are also similar, but with a small shift to larger bubble sizes with increasing BRD 2342 concentration. This system also produced the most foam observed in any of the experiments.

Figure 36 shows the average bubble diameters for the two different BRD 2342 concentrations and the system without added chemistry (0.0 ml/kg). As previously discussed, the 1% ONP results yield larger average bubble diameters than the air/water systems (0% consistency) for all test conditions. In the air/water system, the sparger results show a slight increase in bubble size when the BRD 2342 concentration increases. The gasket data do not follow this trend. Although there is a lot of scatter in the individual bubble size measurements as indicated by the standard deviations (tabulated on the preceding figures), when 1% ONP is added to the system, the average bubble size reveals an increasing trend with increasing BRD 2342 concentration for both air injection techniques. Additionally, on average, the sparger produces larger bubbles than the gasket at Position 2.

4.1.3 BRD 2363 Results

System chemistry was also altered by the addition of BRD 2363, a fatty acid/nonionic surfactant blend. Bubble size results for two different concentrations (1.7 and 3.3 ml/kg), as well as those with no added chemistry (0.0 ml/kg), are presented below.

4.1.3.1 BRD 2363 Concentration of 1.7 ml/kg

A BRD 2363 concentration of 1.7 ml/kg (3 lbs/ton) was added to an air/water system, and the x-ray composite of the rising air bubbles with gasket air injection is shown in Fig. 37. The bubbles appear as in the other air/water systems – small and rising in an oscillating serpentine pattern. However, they do not appear to disperse very much as they rise through the column. When 1% ONP is added to this system with gasket air injection (Fig. 38), the bubbles are larger and slightly dispersed at Positions 2, 3, and 4. A small channel is apparent at Position 1 and results in the air bubbles rising off-center in the column.

Figures 39 and 40 reveal the results for the sparger air injection. With 0% consistency (Fig. 39), the bubbles are more dispersed than those resulting from the gasket injection. At 1% ONP (Fig. 40), large and small bubbles are observed, and are grouped together in some regions. Position 1 is also free of air channels. The 1% ONP system with sparger injection was the only system to show any foaming at the air/liquid interface. The amount of foam generated appeared to be less than that produced with BRD 2342, but more than that exhibited by BRD 2360.

Figure 41 shows the bubble size distributions obtained with a BRD 2363 concentration of 1.7 ml/kg. These results were obtained with a bubble population size of more than 215 (Appendix A, Tables A8 and A10). For both the gasket and sparger air injection techniques, the 1% ONP system results in a wider range of bubble sizes, with a few equivalent bubble diameters reported with the sparger being greater than 10 mm. In both the 0 and 1% consistency systems, the gasket air injection produces a larger average bubble diameter than that produced by the sparger.

4.1.3.2 BRD 2363 Concentration of 3.3 ml/kg

Increasing the BRD 2363 concentration to 3.3 ml/kg (6 lbs/ton) does not significantly affect the qualitative observations. The air/water system with gasket air injection produces a stream of bubbles that remains confined to the central region of the column (Fig. 42). At 1% ONP, the gasket air injection produces a channel near the bottom of Position 1, but the bubbles either coalesce or disperse as they rise in the column (Fig. 43). With the sparger air injection, the bubbles disperse and rise in an oscillating serpentine pattern in the air/water system (Fig. 44). With 1% ONP, the resulting bubbles appear to have a broad range, with small ones rising near very large ones, while foam forms at the air/liquid interface (Fig. 45).

The bubble size distributions for these conditions are shown in Fig. 46 and were obtained from analyzing more than 190 bubbles for each test condition (which are tabulated in Appendix A, Tables A9 and A10). The gasket produced larger average bubble sizes than the sparger in both the 0 and 1% consistency systems. Additionally, the 1% ONP system produced a larger range of bubble sizes.

4.1.3.3 BRD 2363 Summary

For the air/water system with gasket air injection, increasing the BRD 2363 concentration had a small effect of increasing the average bubble size. The bubble size distribution is also more uniform when BRD 2363 is present (Fig. 47). With 1% ONP and gasket air injection, the bubble size distributions cover a range of bubble sizes, as shown in Fig. 48, and the average bubble size increases with BRD 2363 concentration.

The sparger air injection technique results in a narrow bubble size distribution in the air/water system (Fig. 49), and the average bubble size increases with BRD 2363 concentration. Figure 50 reveals that the preceding trends are no longer apparent at 1% ONP with sparger air injection. The bubble size distributions cover a wide range of bubble sizes. The significant difference is that the smallest average bubble size is produced when the BRD 2363 concentration is 3.3 ml/kg. This result may be influenced more by the fiber network formation than by BRD 2363 concentration, and will be discussed further in Section 4.1.5.

A plot of average bubble size as a function of BRD 2363 concentration is shown in Fig. 51. Although there are significant standard deviations associated with each average bubble size measurement (see preceding figures for standard deviation values), a general trend of increasing average bubble size with increasing BRD 2363 concentration is revealed for all test conditions, except the 1% ONP sparger data.

4.1.4 ONP Chemistry Comparisons

Comparisons between the measured bubble size distributions obtained from the various system chemistries are presented in this section. Data obtained with no added system chemistry (originally reported in [1]) have also been included for reference. Data will be presented first for a chemical concentration of 1.7 ml/kg and then for 3.3 ml/kg.

4.1.4.1 Chemical Concentration of 1.7 ml/kg

Figures 52-55 detail the bubble size distributions obtained with the 0 and 1% gasket and sparger injection techniques, respectively, for a chemical concentration of 1.7 ml/kg (3 lbs/ton). Data obtained with no added system chemistry are also included in these figures for reference. Focusing on the distributions obtained when the system chemistry was altered, the air/water systems (Figs. 52 and 54) produced similarly shaped distributions for all chemistries and air injection techniques, that is, a sharp-peaked bubble size distribution with a relatively small standard deviation. When 1% ONP is added with the various chemistries, the bubble size distributions are also similar to each other (Figs. 53 and 55), but differ from those obtained with 0% ONP. At 1% ONP, the bubble size distributions cover a wider range of bubbles sizes, as displayed by the large standard deviations in the average bubble diameters. It is interesting to note that the BRD 2342 produces the smallest standard deviation for both the gasket and sparger injection techniques when comparing the three different chemistries at a concentration of 1.7 ml/kg and 1% ONP.

Figure 56 shows the average bubble diameters for the three different chemistries at a concentration of 1.7 ml/kg. Focusing on the gasket results, the average bubble size trends for the 0 and 1% ONP consistency systems coincide when the chemistry type is altered. In contrast, when the sparger is used as the air injection technique, the average bubble size trends for the 0 and 1% ONP systems counter one another when the system chemistry changes. The results reveal that

BRD 2342 produced the largest average bubble diameters at 1% ONP with the sparger air injection technique. For all other systems, this trend is reversed and BRD 2342 results in the smallest average bubble size.

4.1.4.2 Chemical Concentration of 3.3 ml/kg

Comparisons between the various system chemistries at a concentration of 3.3 ml/kg (6 lbs/ton) are shown in Figs. 57-60. Data without added chemistry are also included for reference. In the air/water system, the distributions are again similar for both air injection techniques (Figs. 57 and 59), and the small standard deviations reveal the narrow distributions. With 1% ONP, the gasket produces similar distributions with the exception of the BRD 2360 data (Fig. 58). This significant change is hypothesized to be caused mainly by changes in the fiber network structure and not by system chemistry (see Section 4.1.1.4). When the sparger is used with 1% ONP and a chemical concentration of 3.3 ml/kg, the bubble size distributions are again similar between the various system chemistries.

Comparisons between the average bubble size for the three different chemistries are shown in Fig. 61. Again, the gasket data for the 0 and 1% ONP systems follow the same trends, but the sparger data follow opposite trends. Additionally, BRD 2342 produced the largest average bubble diameters when 1% ONP and the sparger are used, but results in the smallest average bubble diameter for all other systems.

4.1.5 System Chemistry General Conclusions

In general, increasing the fiber consistency from 0 to 1% ONP increases the average bubble size for all chemistries addressed in this study. The bubble flow patterns also change from a well-dispersed system at 0% to a confined system with large bubbles and some channeling at 1% ONP.

For the specific chemistries addressed here, the following general conclusions are realized:

(i) Increasing the BRD 2360 concentration (a fatty acid) results in negligible changes in average bubble size, except for the 1% ONP with gasket air injection. It is hypothesized that this change may be more a result of differences in the fiber network structure, and not BRD 2360 concentration.

(ii) Increasing the BRD 2342 concentration (a nonionic surfactant) in the presence of 1% ONP results in an increase in the average bubble diameter, with the sparger injection technique producing larger bubbles than the gasket at Position 2. Clear trends are difficult to discern for the 0% data.

(iii) Increasing the BRD 2363 concentration (a fatty acid/nonionic surfactant blend) results in a general increase in the average bubble size in all systems addressed here, except the 1% ONP sparger data.

(iv) BRD 2342 produced the most foam of all three chemistries.

(v) By comparing the three different chemistries at fixed concentrations of 1.7 and 3.3 ml/kg, the BRD 2342 produces the smallest average bubble diameter for all systems addressed here, except the 1% ONP sparger system, where the BRD 2342 produces the largest average bubble diameter.

A large amount of data has been gathered for the bubble size in a quiescent bubble column with different air injection techniques (gasket and sparger), different chemistries (type and concentration), and different fiber consistencies (0 and 1% ONP). Conclusions from these data are often not very clear and sometimes even contradictory.

It was suggested by various PAC members that surface tension may be a significant parameter and may make it difficult to determine specific chemistry effects. This was not recorded for the specific samples utilized in these experiments (but will be recorded for all future experiments). To determine what effect, if any, surface tension has on the bubble size in the air/water system, the various chemicals addressed in this study were individually added to deionized water in the specified concentration. The surface tension was measured with a Wilhelmy plate balance. In general, the higher the chemical concentration, the lower the surface tension, indicating that the CMC (critical micelle concentration) was not reached [6].

Figure 62 is a plot of average bubble size obtained in our experiments as a function of surface tension and shows no significant trends. In bubble size studies in air/water systems by other researchers, the effect of surfactants is not clear. Kim et al. [7] cite prior work they completed where increasing the surface tension increased the bubble size only by a small amount. Nicol and Davidson [8] state that surfactants stabilize the bubble surface and hinder bubble coalescence, so their presence should reduce the mean bubble size, assuming considerable bubble coalescence would occur without the added surfactant. This type of system was not observed in our quiescent bubble column. Additionally, Schulze [9] provides a relationship between bubble size, surface tension, fluid density, and mixing intensity which would indicate bubble size should decrease with decreasing surface tension. In contrast, Lin et al. [10] conclude that bubble diameter is a complex function of surface tension, fluid density, bubble contact diameter at the injection port, and contact angle at the bubble-fluid-solid interface (i.e., the injector location). They further remark that the dominant factor influencing the bubble size in their system is the contact angle, measured in the fluid at the orifice surface. Therefore, bubble size is influenced strongly by the surface energy of the injection port. Based on this literature, and as shown in this study, bubble size is not a simple function of surface tension.

It was also suggested by PAC members that viscosity may also play a significant role and should be measured for each system. However, fluid viscosity measurements in dilute fiber systems (~1%) are difficult with common viscometers because these devices require the medium to be continuous at dimensions similar to those of individual fibers. The 1% ONP system used in this study does not satisfy this requirement. Additionally, Chase et al. [11] have indicated that using rotational viscometers, such as the cup and bob, cone and plate, or spindle types, resulted in apparent viscosity measurements approaching that of water when testing pulp suspensions at consistencies as high as 1.5%. They also record viscosities close to that of water for hardwood pulps with consistencies less than 3% and a freeness of 300-400 ml CSF. These measurements were recorded in a rotating viscometer they developed. Therefore, viscosity may not be the most appropriate measure to determine the effect the fibers have on bubble formation. The crowding factor [12-15] may be a better measure of fiber-fiber interactions and their effect on bubble size. Research in this area is continuing (see Section 6).

4.2 NBSK Results

Experiments in a quiescent bubble column using northern bleached softwood kraft (NBSK) fibers have also been completed to determine if these chemically pulped fibers have a significant influence on the recorded bubble diameters. The fibers used in this portion of the study have a weight-weighted average fiber length and ash content of 2.8 mm and 0.3%, respectively. Deionized water was used as the fiber suspending fluid and no additional chemistry was added to the system.

4.2.1 Air Injection Rate of 0.25 slpm

Experiments were first initiated with an air flow rate of 0.25 slpm to correspond to that utilized in the ONP experiments. Figure 63 shows the combined x-ray images taken at the four column positions with the gasket air injection technique for 0.1% NBSK fibers with a 0.25 slpm air injection rate. Observations reveal that the general bubble characteristics and flow patterns do not differ significantly from those observed with 0.1% ONP operating under similar conditions [1].

When the sparger air injection technique is used with 0.1% NBSK (Fig. 64), observations differ from those with 0.1% ONP (i.e., see Report 3 [1]). The bubbles are considerably larger and are much more confined when NBSK is used. Table 4 summarizes the bubble size measurements obtained with the NBSK fibers (the data are tabulated in Appendix B, Tables B1 and B2) and compares these measurements with those obtained with ONP under identical operating conditions. The increase in bubble size when the sparger is used is evident in this table. This increase in size is due to the longer kraft fibers creating fiber networks at relatively low consistencies that prevent dispersion of the small bubbles formed by the sparger. These bubbles coalesce upon introduction into the system.

Table 4: ONP and NBSK comparison of bubble size measurements obtained with the gasket and sparger air injection techniques for an air/water/0.1% fiber system at an air injection rate of 0.25 slpm.

Test Conditions:	System Slurry Charge: 3.2 liters (to the 80 cm mark) Air Flow Rate: 0.25 slpm Added Chemicals: None Column Position: 2 Consistency: 0.1%			
Equivalent Diameters	**Air Injection Technique**			
	Gasket		**Sparger**	
	ONP	NBSK	ONP	NBSK
Average (mm)	3.1	2.8	2.3	3.9
Median (mm)	3.0	2.7	2.3	3.9
Minimum (mm)	1.0	1.0	1.0	1.0
Maximum (mm)	6.4	5.4	6.8	6.9
Standard Deviation (mm)	1.0	0.7	0.8	1.0
Sauter Mean Diameter (mm)	3.6	3.2	2.9	4.3
Bubble Population Size	978	759	799	752

When the consistency is increased to 0.5% NBSK, significant changes take place, which are revealed in Figs. 65 and 66, respectively, for the gasket and sparger air injection techniques. The longer fibers create a stronger fiber network, which considerably constrains the bubble rise and dispersion. The result is a significant reduction in the number of bubbles present in the column with the air flow rate of 0.25 slpm, and bubbles that are much larger than those observed with 0.5% ONP (i.e., see Report 3 [1]). These results are amplified when the sparger air injection technique is used (Fig. 66). The bubbles are so infrequent that only a single large bubble is observed at Position 3 in Fig. 66 and none are recorded at Position 4. However, by the "bump" at the air/fluid interface, we hypothesize that a large bubble broke through the surface right before the radiograph was taken at Position 4.

So few bubbles are recorded in the 0.5% NBSK system with 0.25 slpm air injection rate that to determine a bubble size distribution with a sufficient bubble population size, between 100 and 200 x-rays would have to be taken. This was deemed too costly. Therefore, experiments were initiated at a much higher air injection flow rate (i.e., 2 slpm) to produce more bubbles in the system for image analysis.

4.2.2 Air Injection Rate of 2 slpm

A series of experiments were completed in which an air flow rate of 2 slpm was used in the quiescent bubble column. Results were obtained with NBSK fiber consistencies of 0, 0.5, 1.0, and 1.5%. All other conditions remained the same. This section summarizes these results, first with qualitative observations obtained with the gasket and sparger air injection techniques, then with quantitative bubble size measurements.

4.2.2.1 Gasket Observations

Baseline observations in an air/water system (0% consistency) at this higher air flow rate are presented in Fig. 67. At an air flow rate of 2 slpm, air introduced into the system from a single-holed gasket forms many bubbles and bubble groupings. A main channel of rising bubbles ascend through the column central region in an oscillating serpentine fashion and disperse as they rise. The many rising bubbles carry small amounts of fluid in their wakes as they rise, moving the fluid from the column bottom to the top. Due to continuity considerations, this fluid is replaced by fluid descending along the column sides. This general phenomenon is typically termed backmixing. Small air bubbles are caught in this backmixing and descend with it along the column sides. This flow pattern is visibly apparent but not recorded in the radiographs. However, based on visible observations, the small bubbles on the right-hand side of Position 2 in Fig. 67 are caught in the backmixed flow, while the bulk air flow is along the left-hand side in Position 2. The small bubbles that descend in the backmixed flow are eventually entrained in the bulk rising column of air.

The large number of bubbles and backmixing have a visible effect on the gas holdup of the system, defined as the gas percent by volume. This is the first time this has been observed in these experiments and results in the height increase of the air/liquid interface at Position 4 (recall that the system was originally charged to a fluid level of 80 cm). In Fig. 67, the air/liquid interface at Position 4 has increased to approximately 81 cm when the air flow rate is set at 2 slpm, resulting in a gas holdup of more than 1%.

Adding 0.5% NBSK to the system has a significant effect on the bubble flow patterns (Fig. 68). The bubbles still rise in a serpentine pattern, but they are fewer in number and larger in size. A few small bubbles are present and may get caught in the backmixed flow. These small bubbles are clearly visible in the original radiographs, but difficult to identify in the composite image presented in Fig. 68.

Increasing the NBSK consistency to 1% reveals a similar flow pattern (Fig. 69). A small air channel is apparent at Position 1, but as the air rises, discrete bubbles form. Few small bubbles are observed for this test condition. Figure 70 reveals the flow patterns for 1.5% NBSK with a gasket air injection rate of 2 slpm. The serpentine flow pattern is still observed in the column, but the bubbles rise in clumps, which break apart and reform as they encounter differences in the fiber network. The bubble clumps may coalesce to form large individual bubbles if the liquid film (separating the bubbles) ruptures.

4.2.2.2 Sparger Observations

In addition to the gasket air injection results, data were also obtained with the sparger air injection technique. Although the air flow rate was maintained at 2 slpm, the sparger produced much different flow patterns and results because the air entered the bubble column from a sparger head that had many small holes.

Figure 71 shows the x-ray composite for the air/water system at 2 slpm with the sparger air injection. The Tygon tubing used as the air line is clearly visible on the left-hand side of the column. Many bubbles are observed with this type of air injection, as indicated by the many dark regions on the radiographs. These bubbles are rather small and rise in a turbulent fashion and encompass the entire column width. Severe backmixing is also observed and results in the many small bubbles recorded on the left-hand side of Position 1 in Fig. 71. The sparger air injection also increases the gas holdup considerably (as shown by the location of the air/liquid interface at Position 4). The increase in fluid height to approximately 84 cm results in a gas holdup of almost 5% for these conditions.

Adding 0.5% NBSK into the system with sparger air injection results in a change in flow conditions (Fig. 72). Many small bubbles are still present, but periodically very larger bubbles develop near the sparger head and rise through the system. The bulk rising air flow oscillates in a serpentine fashion, and the larger bubbles follow this pattern. Some of the smaller bubbles are caught in the backmixed flow, but are eventually entrained in the bulk flow. The increase in gas holdup is clearly visible, but its value is difficult to determine due to the waviness at the air/liquid interface. This is caused by the large bubbles breaking through the surface, which is just about to happen in Fig. 72 at Position 4.

When 1 and 1.5% NBSK is present, similar observations are recorded (Figs. 73 and 74). However, the frequency of very large bubbles increases with increasing consistency. Note that Position 4 in Fig. 73 shows three large bubbles just prior to disrupting the air/liquid interface and exiting the system.

4.2.2.3 NBSK Consistency Comparisons

Quantitative bubble size results are presented here for the various NBSK fiber consistencies. Discrete data points are tabulated in Appendix B, Tables B3 and B4, for the NBSK consistencies of 0.5, 1.0, and 1.5%, and Tables B5 and B6 for the air/water results.

Figure 75 reveals the bubble size distributions obtained from Position 2 radiographs. At least nine Position 2 radiographs were taken at each fiber consistency to obtain a bubble population size of 342, 211, 52, and 118 for NBSK consistencies of 0, 0.5, 1.0, and 1.5%, respectively. For these test conditions, the bubble size distributions cover a broad range, and the data are tabulated in bins representing 1 mm variations (as opposed to 0.5 mm variations reported for the ONP data).

The 0, 0.5, and 1.5% bubble distributions are similar in the sense that a peak is observed in the smaller bubble size range, and a broad spectrum of larger, but fewer, bubble sizes is recorded. Additionally, for these three consistencies, the number of bubbles in the smaller size range decreased, while the number in the larger size range increased, with increasing NBSK consistency. This is also revealed in the average bubble diameters recorded in Fig. 75.

The 1% NBSK results do not follow these trends, and much larger, but fewer, bubbles are recorded. It is hypothesized that, although experimental procedures are designed to maintain the various systems as uniform as possible from one another, the fiber network at 1% NBSK was considerably different from the other consistencies. This change had a significant effect on the resulting average bubble size and bubble size distribution. This effect was also recognized in Section 4.1.

Figure 76 shows the bubble size distributions acquired with the sparger air injector and was obtained with more than 165 bubbles in the population size (the air/water results had 7.5 times this number). The average bubble size and standard deviation increase with increasing NBSK consistency, but this is primarily the result of the increase in the number of very large bubbles as the consistency increases. Most of the large bubbles have an equivalent diameter greater than 25 mm. Since the column thickness is only 20 mm, these bubbles can span the entire column depth if they are spherical and the equivalent bubble diameter for these large bubbles is not the appropriate term. (Recall, by definition, the equivalent bubble diameter is the diameter of the circle whose area equals that of the bubble area recorded on the x-ray film.) Although the number of these bubbles is rather small compared to the entire bubble population, the number clearly increases with increasing consistency. One very apparent feature of Fig. 76 is that the bubble size distribution is bimodal; there is a range of small bubbles and a range of very large bubbles, but few bubbles in the intermediate size range. The distribution of small bubbles (bubble diameters less than approximately 10 mm) is similar as NBSK consistency increases, with a peak in all cases in the 2-3 mm range. The main difference is that the magnitude of the peak decreases as NBSK consistency increases, and is due to the increase in the number of bubbles greater than 25 mm as consistency increases. Focusing on bubble diameters that are less than 10 mm and neglecting those that are greater, averages can be generated. For each test condition, the average is 3.0, 3.0, 3.0, and 3.3 mm for the 0, 0.5, 1.0, and 1.5% consistency systems, respectively, indicating the uniformity in this region.

Although the sparger produces few very large bubbles, which increase in number as the NBSK consistency increases, these large bubbles serve a very important function. They act as “mobile mixers” in this fiber suspension and maintain a uniform system throughout the bubble column. This allows for the majority of the bubbles to remain relatively small and free to move through the system. In terms of flotation deinking cells, the small bubbles would capture ink particles, and the large bubbles would keep the suspension homogeneous by preventing fiber network and air channel formation.

The average bubble size as a function of fiber consistency is shown in Fig. 77 for the NBSK results. The ONP results reported in [1] with no added system chemistry are also included for reference, although they correspond to an air injection rate of 0.25 slpm. Direct comparisons between NBSK and ONP at an air injection rate of 2 slpm will be made in Section 4.4.4. Focusing on the NBSK results, the gasket injection technique produces a larger average bubble diameter for all consistencies addressed. The large average bubble diameter at 1% NBSK from the gasket injection is hypothesized to be the result of nonuniform fiber networks between the various consistencies. There is, however, a general trend of increasing bubble diameter with increasing consistency. This trend is more apparent with the sparger air injection technique. As discussed above, the increase in average bubble diameter for the sparger with increasing consistency is due to the increase in the number of large bubbles, but constitutes a small percentage of the overall bubble population.

4.3 Copy Paper Results

Various PAC members suggested that experiments should be performed in a bleached kraft fiber system more representative of that found in the recycling of typical printing and writing grade papers. Hence, a series of experiments using copy paper (as supplied to IPST) as the fiber source were initiated. This paper had a weight-weighted fiber length and ash content of 2.0 mm and 6.6%, respectively, and experiments were conducted in a 1% fiber system with no added system chemistry. Additionally, the air flow rate was fixed at 2.0 slpm. These data are tabulated in Appendix B, Tables B5 and B6.

Figure 78 shows the composite x-ray image of air bubbles rising through the copy paper system with a gasket air injection rate of 2 slpm. The flow patterns are generally similar to those observed in the 1% NBSK system (Fig. 69).

The bubble size distributions for this system and the 1% NBSK are shown in Fig. 79. Although there is a lot of scatter in the data, general distribution trends are similar.

When the sparger air injection technique is used in this fiber system (Fig. 80), qualitative observations are similar to those displayed in the 1% NBSK system (i.e., Fig. 73). A large number of small bubbles and a few large bubbles are present, and backmixing is prevalent. However, the gas holdup is slightly lower than that observed in Fig. 73.

Figure 81 shows the bubble size distributions for the copy paper results with the sparger air injection and compares them to those obtained with 1% NBSK. The bubble size distributions, average bubble size, and standard deviations are all very comparable.

These results imply that the NBSK results are representative of those obtained with typical copy paper found in recycling office-type printing and writing grade papers for the conditions addressed in this study.

4.4 ONP Results at 2.0 slpm

To allow for comparisons between the bubble size results for NBSK and ONP, additional bubble size measurements were recorded in a 1% ONP system with 2 slpm air flow rate. This ONP system did not have any additional added chemistry and was identical to that reported in [1] (i.e., weight-weighted fiber length of 1.4 mm and ash content of 0.7%). These additional data also allow for comparisons between air flow rates for ONP, as well as fiber type at an air injection rate of 2 slpm. These data are presented below, first for the gasket air injection, then for the sparger.

4.4.1 Gasket Results

A composite x-ray image, representing typical bubble flow patterns in a 1% ONP system with gasket air injection at 2 slpm, is shown in Fig. 82. The bubbles rise in groups only in the central region of the bubble column. These bubble groups will coalesce if the liquid film ruptures between the rising bubbles before they reach the air/liquid interface. Some backmixing is also visually observed in this system.

The bubble size distribution obtained from multiple radiographs of Position 2 is shown in Fig. 83 (the data are tabulated in Appendix B, Tables B5 and B6). The distributions from the air/water system with gasket air injection at 2 slpm, as well as the 0 and 1% ONP results obtained with the gasket at 0.25 slpm, are also shown. In both the 0 and 1% consistency systems, increasing the air flow rate results in a shift to larger bubble diameters, and the increase in bubble diameter is more pronounced at 1% ONP. Similar results have been observed by Kim et al. [16] for gas/liquid and gas/liquid/solid systems. Dobby and Finch [17] also recorded similar results for an air/water system. However, in a gas/liquid system, Lin et al. [10] showed that bubble volume (diameter) did not change when the air flow rate was increased, only the frequency of expelled bubbles increased.

Figure 84 compares the 1% ONP bubble size results with those obtained with 1% NBSK. For the gasket system with an air injection rate of 2 slpm, NBSK produces larger bubbles, and they span a much larger range of bubble sizes.

4.4.2 Sparger Results

Figure 85 reveals the composite x-ray images taken of the 1% ONP system with sparger air injection at an air flow rate of 2 slpm. Again, at this flow rate with sparger air injection, many small bubbles are observed throughout the column and few very large bubbles rise in an oscillating serpentine pattern in the column center. Some of the small bubbles are visually observed in the backmixed fluid, but eventually are reentrained in the bulk air flow. The gas holdup also appears to be consistent with that observed for the 1% NBSK, but an exact value is difficult to identify because of the waviness at the air/liquid interface.

Bubble size distributions for the 0 and 1% ONP systems at air flow rates of 0.25 and 2 slpm are shown in Fig. 86 for the sparger air injection. In the air/water system, increasing the air flow rate increases the average bubble size and increases the range over which bubble sizes are recorded. In contrast, at 1% ONP, increasing the air flow rate from 0.25 to 2 slpm results in a bubble size distribution that has shifted toward smaller bubble diameters and a corresponding reduction in the average bubble size. It is hypothesized that the bubbles are smaller when the air flow rate is 2 slpm because, at 2 slpm, there are still a few bubbles recorded with a size much larger than all the others. These few large bubbles act as mobile mixers and keep the system well-agitated, preventing fiber network formation and the coalescence of smaller bubbles to form larger ones.

Figure 87 reveals similar trends when comparing the bubble size distributions for the 1% ONP and NBSK systems with a sparger air injection rate of 2 slpm. That is, most of the bubbles for both systems are confined to bubble diameters less than approximately 10 mm. The differences between these two systems are found outside this range, where a few bubbles are found for both systems. The ONP system has approximately 1% of its bubble population with a diameter greater than 10 mm, but these few bubbles are spread out over a variety of diameters. However, the NBSK system has approximately 5% of its bubble population with diameters greater than 10 mm, with 3% greater than 25 mm. The few, but very large, bubbles in the NBSK system cause the average bubble diameter to be larger than that recorded for the ONP system. One significant feature Fig. 87 displays is the importance of these few large bubbles; they create a uniform system that helps maintain the majority of the bubbles in a relatively narrow bubble size distribution, regardless of fiber type.

5. CONCLUSIONS

A large amount of qualitative and quantitative data has been presented in this report concerning bubble size in a quiescent bubble column with four different experimental systems: (1) ONP systems with various chemistries and chemistry concentrations; (2) NBSK systems with various consistencies but no added chemistry; (3) a copy paper system with no added chemistry; and (4) an ONP system with no added chemistry but a higher gas flow rate.

For the specific chemistries addressed here and added to an air/water system or an air/water/1% ONP (unprinted) system, the following general conclusions are realized:

- Increasing the BRD 2360 concentration (a fatty acid) results in negligible changes in average bubble size, except for the 1% ONP with gasket air injection. It is hypothesized that this change may be more a result of differences in the fiber network structure, and not BRD 2360 concentration.
- Increasing the BRD 2342 concentration (a nonionic surfactant) in the presence of 1% ONP results in an increase in the average bubble diameter, with the sparger injection technique producing larger bubbles than the gasket at Position 2. Clear trends are difficult to discern for the 0% data.
- Increasing the BRD 2363 concentration (a fatty acid/nonionic surfactant blend) results in a general increase in the average bubble size in all systems addressed here, except the 1% ONP sparger data.
- BRD 2342 produced the most foam of all three chemistries.
- By comparing the three different chemistries at fixed concentrations of 1.7 and 3.3 ml/kg, the BRD 2342 produces the smallest average bubble diameter for all systems addressed here, except the 1% ONP sparger system, where the BRD 2342 produces the largest average bubble diameter.
- Surface tension did not correlate the bubble results recorded in this study.

The northern bleached softwood kraft had a much longer fiber length than the ONP used in this study. The longer fibers promoted fiber network formation and bubble coalescence. The few, but large, bubbles recorded when the air flow rate is 0.25 slpm prevented statistically significant results from being realized except at the very low fiber consistency of 0.1%. Additional experiments were completed at an air flow rate of 2 slpm. General conclusion from these results are

- The higher gas flow rate promotes backmixed flow conditions where small bubbles descend along the column sides and are eventually reentrained in the bulk rising column of air.
- The sparger air injection technique results in a higher gas holdup when the air injection rate is held constant at 2 slpm.
- The average bubble size increases with NBSK fiber consistency.
- The gasket air injection technique produces larger average bubble diameters at Position 2 and does not keep the fiber suspension well-mixed, which may lead to fiber network nonuniformities and larger variations in the average bubble size and bubble size distribution.
- The sparger air injection technique produces a bimodal bubble size distribution, with the majority of the bubbles in the size range less than 10 mm in diameter and a peak in the 2-3 mm range. The bubbles in this range all have the same average bubble size (~3 mm) for all NBSK fiber consistencies addressed here, but the relative frequency decreases with increasing consistency. Few bubbles are greater than 10 mm in diameter, but those that are, are typically larger than 25 mm. The number of bubbles that fall in this category increases with increasing NBSK consistency. These larger bubbles also play an important role by acting as mobile mixers, which keeps the smaller bubbles uniform and the fiber suspension well-mixed and homogeneous.

The 1% copy paper system produced similar results to those obtained with 1% NBSK, implying that the NBSK results are representative of those obtained with typical copy paper found in recycling office-type printing and writing grade papers for the conditions of this study.

Flow patterns observed with the 1% ONP system with an air injection rate of 2 slpm are similar to those produced by the 1% NBSK system. However, the average bubble size was smaller with the ONP system. The bimodal bubble size distribution is also observed with the 1% ONP and sparger system with the air injection rate of 2 slpm, but the number of bubbles larger than 10 mm is much smaller than that produced with 1% NBSK.

6. FUTURE FXR WORK

Future bubble size measurement work utilizing the flash x-ray equipment will focus on cocurrent bubble columns, where the gas and fiber slurry is rising through the test section. This will be accomplished with a recently completed flow loop, schematically shown in Fig. 88. The flow loop consists of two baffled holding tanks to allow any gas in the system to escape, a pump, a flow meter, associated plumbing, and a bubble column. The bubble column consists of two 1 m sections attached end-to-end with interior dimensions 10 cm $\times$ 2 cm. A fiber slurry will travel from the column bottom to the top, and air will be injected at the column base. The flow loop will ensure that a uniform fiber suspension is maintained because of the continuous mixing. The flow loop is designed such that countercurrent flow could be produced, or, with slight modifications to the framing, the column could be orientated horizontally. Tests will be conducted to determine the effect of stock flow rate on bubble size. The fiber crowding factor will also be addressed, and surface tension will be recorded for all experimental conditions. X-rays will be taken at selected locations, and image analysis will be performed to determine the equivalent bubble diameters.

7. REFERENCES

[1] Heindel, T.J., A Method to Visualize Gas Bubbles in a Pulp Suspension, Institute of Paper Science and Technology, Atlanta, GA, Member Company Report, Project F00903, Report 3, (February 3, 1997).

[2] Cartz, L., *Nondestructive Testing*, ASM International, Materials Park, OH, 1995.

[3] TAPPI, "T 205 om-88 - Forming Handsheets for Physical Tests of Pulp," TAPPI Test Methods 1994-1995, Atlanta, TAPPI Press, (1994).

[4] TAPPI, "T 413 om-93 - Ash in Wood, Pulp, Paper, and Paperboard: Combustion at 900°C," TAPPI Test Methods 1996-1997, Atlanta, TAPPI Press, (1996).

[5] Jamet, F., and Thomer, G., *Flash Radiography*, Elsevier Publishing Company, Inc., New York, 1976.

[6] Shaw, D.J., *Introduction to Colloid and Surface Chemistry*, 4th Ed., Butterworth-Heinemann, Oxford, 1992.

[7] Kim, S.D., Kim, H.S., and Han, J.H., "Axial Dispersion Characteristics in Three-Phase Fluidized Beds," *Chemical Engineering Science*, **47**(13/14): 3419-3426 (1992).

[8] Nicol, R.S., and Davidson, J.F., "Effect of Surfactants on the Gas Hold-up in Circulating Bubble Columns," *Chemical Engineering Research and Design*, **66**: 159-164 (1988).

[9] Schulze, H.J., "Zur Hydrodynamik der Flotations-Elementarvorgänge," *Wochenblatt Für Papierfabrikation*, **122**(5): 160, 162, 164-168 (1994).

[10] Lin, J.N., Banerji, S.K., and Yasuda, H., "Role of Interfacial Tension in the Formation and the Detachment of Air Bubbles: 1. A Single Hole on a Horizontal Plate Immersed in Water," *Langmuir*, **10**: 936-942 (1994).

[11] Chase, W.C., Donatelli, A.A., and Walkinshaw, J.W., "Effects of Freeness and Consistency on the Viscosity of Hardwood and Softwood Pulp Suspensions," *TAPPI Journal*, **72**(5): 199-204 (1989).

[12] Kerekes, R.J., and Schell, C.J., "Characterization of Fibre Flocculation Regimes by a Crowding Factor," *Journal of Pulp and Paper Science*, **18**(1): J32-J38 (1992).

[13] Kerekes, R.J., and Schell, C.J., "Effects of Fiber Length and Coarseness on Pulp Flocculation," *TAPPI Journal*, **78**(2): 133-139 (1995).

[14] Kerekes, R.J., "Characterizing Fibre Suspensions," *1996 Engineering Conference*, Chicago, TAPPI Press, 21-28 (September 16-19, 1996).

[15] Dodson, C.T., "Fiber Crowding, Fiber Contacts, and Fiber Flocculation," *TAPPI Journal*, **79**(9): 211-216 (1996).

[16] Kim, S.D., Baker, C.G.J., and Bergougnou, M.A., "Hold-up and Axial Mixing Characteristics of Two and Three Phase Fluidized Beds," *The Canadian Journal of Chemical Engineering*, **50**: 695-701 (1972).

[17] Dobby, G.S., and Finch, J.A., "Particle Collection in Columns - Gas Rate and Bubble Size Effects," *Canadian Metallurgical Quarterly*, **25**(1): 9-13 (1986).

8. FIGURES

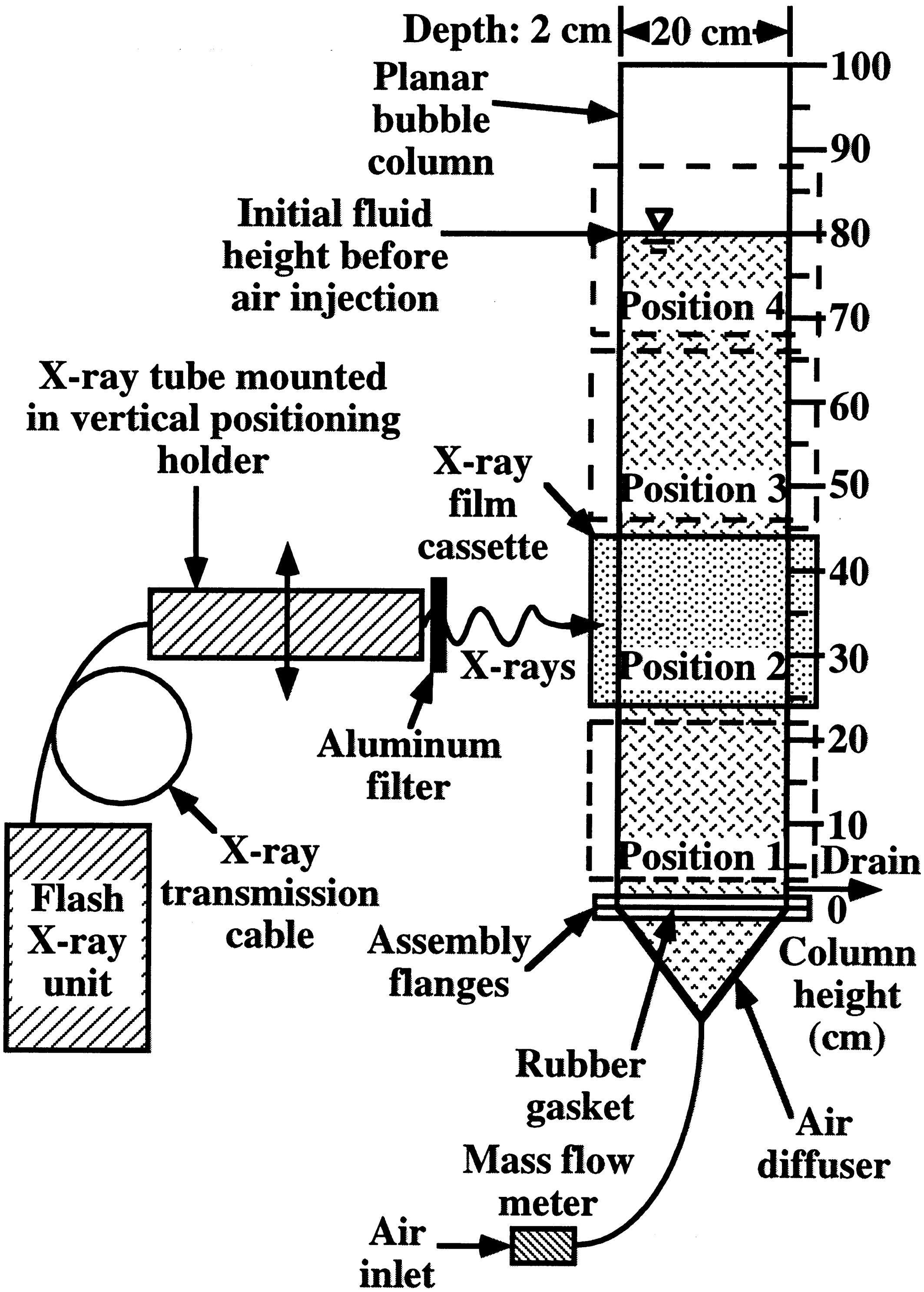

Figure 1: Schematic diagram of the flash x-ray radiographic experimental setup.

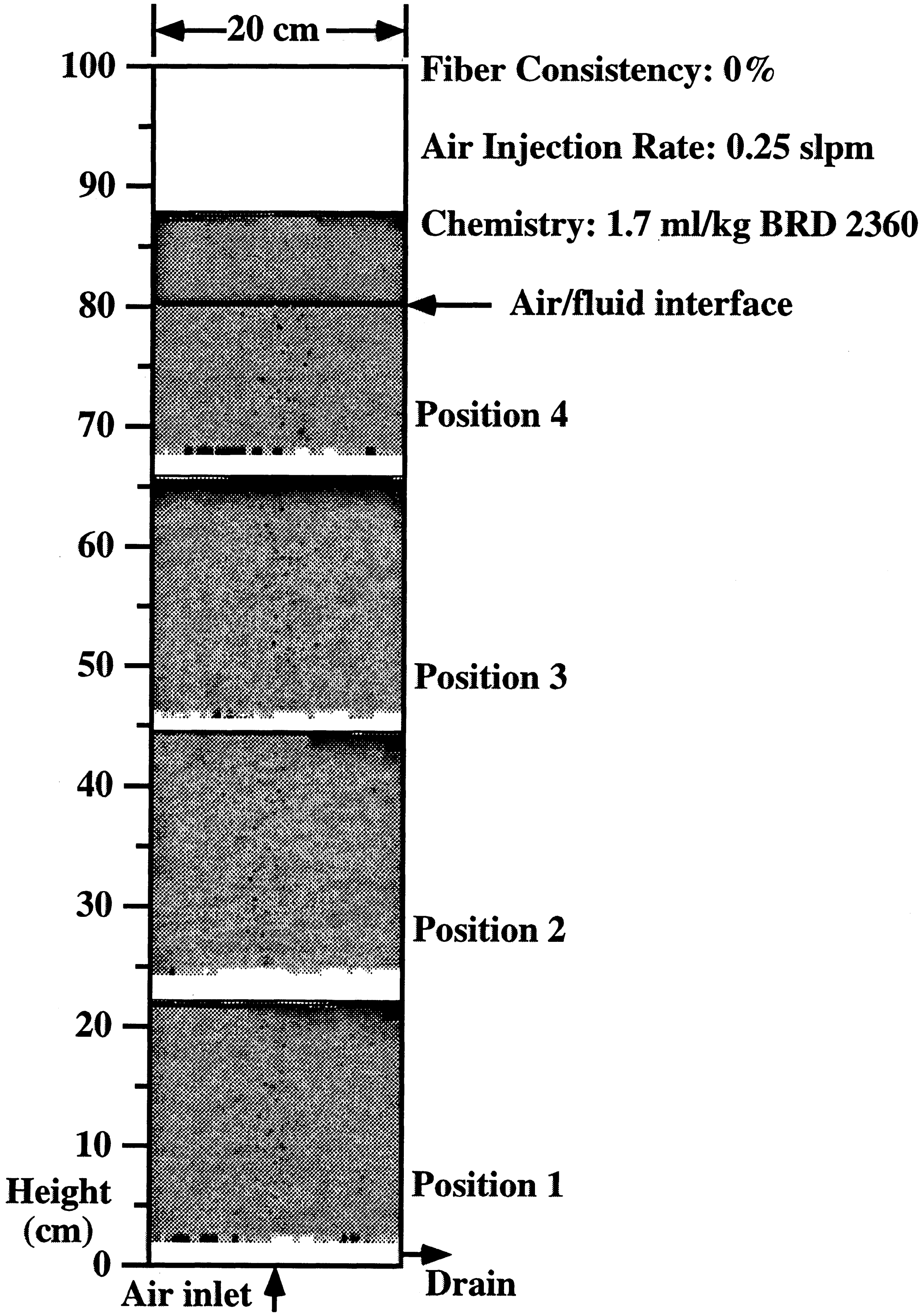

Figure 2: X-ray composite of air bubble flow patterns in an air/water system with 1.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

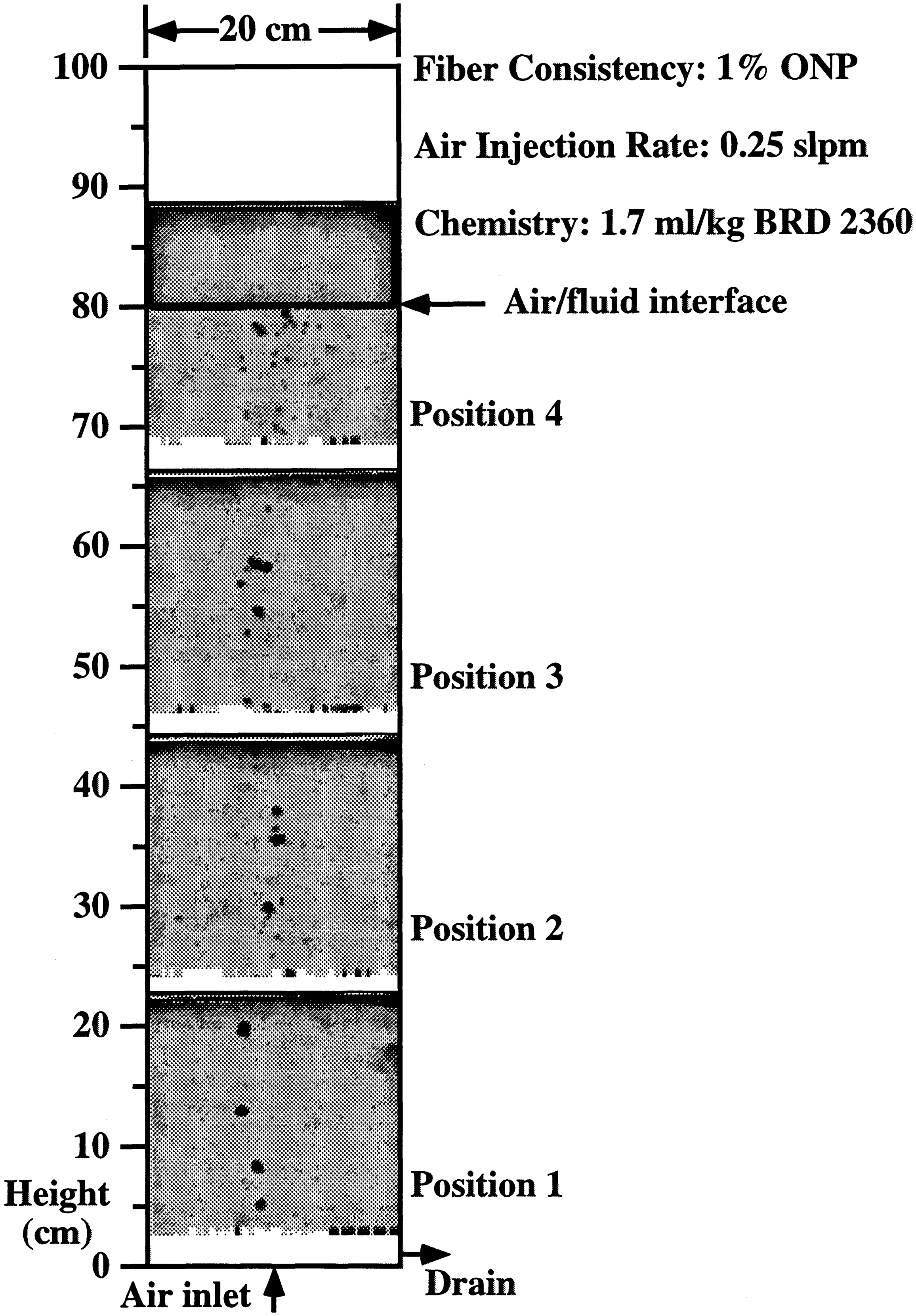

Figure 3: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 1.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

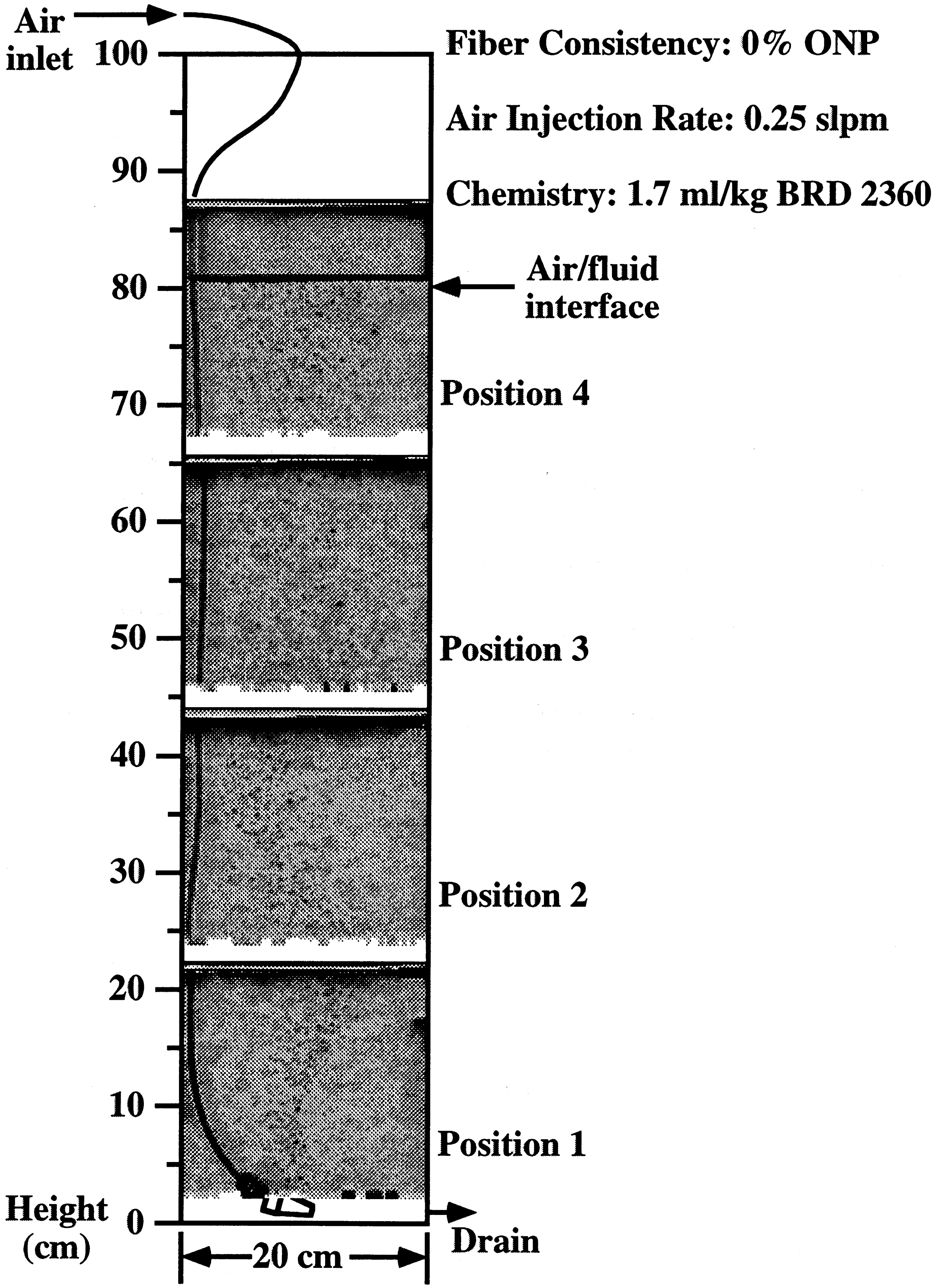

Figure 4: X-ray composite of air bubble flow patterns in an air/water system with 1.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

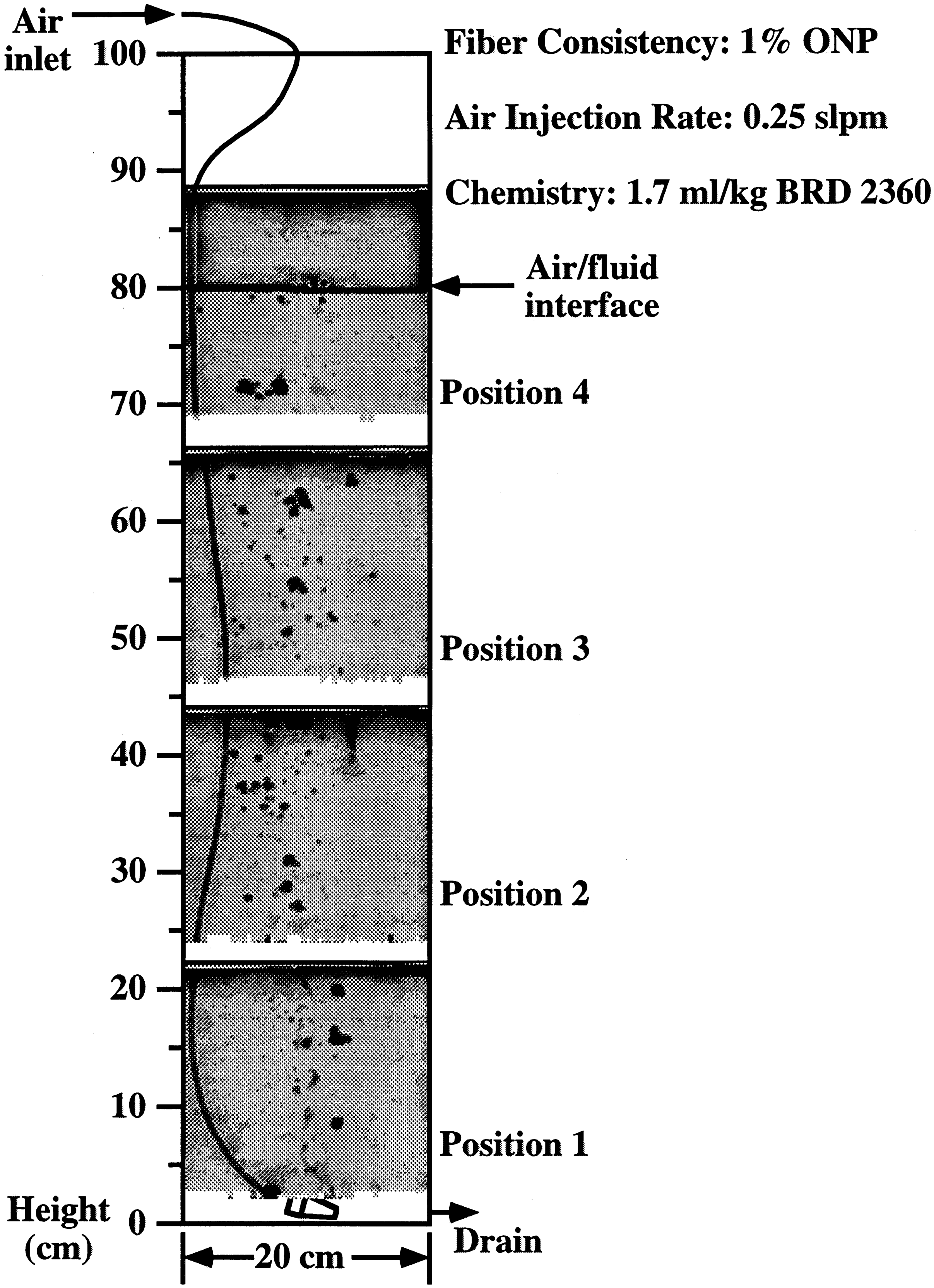

Figure 5: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 1.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

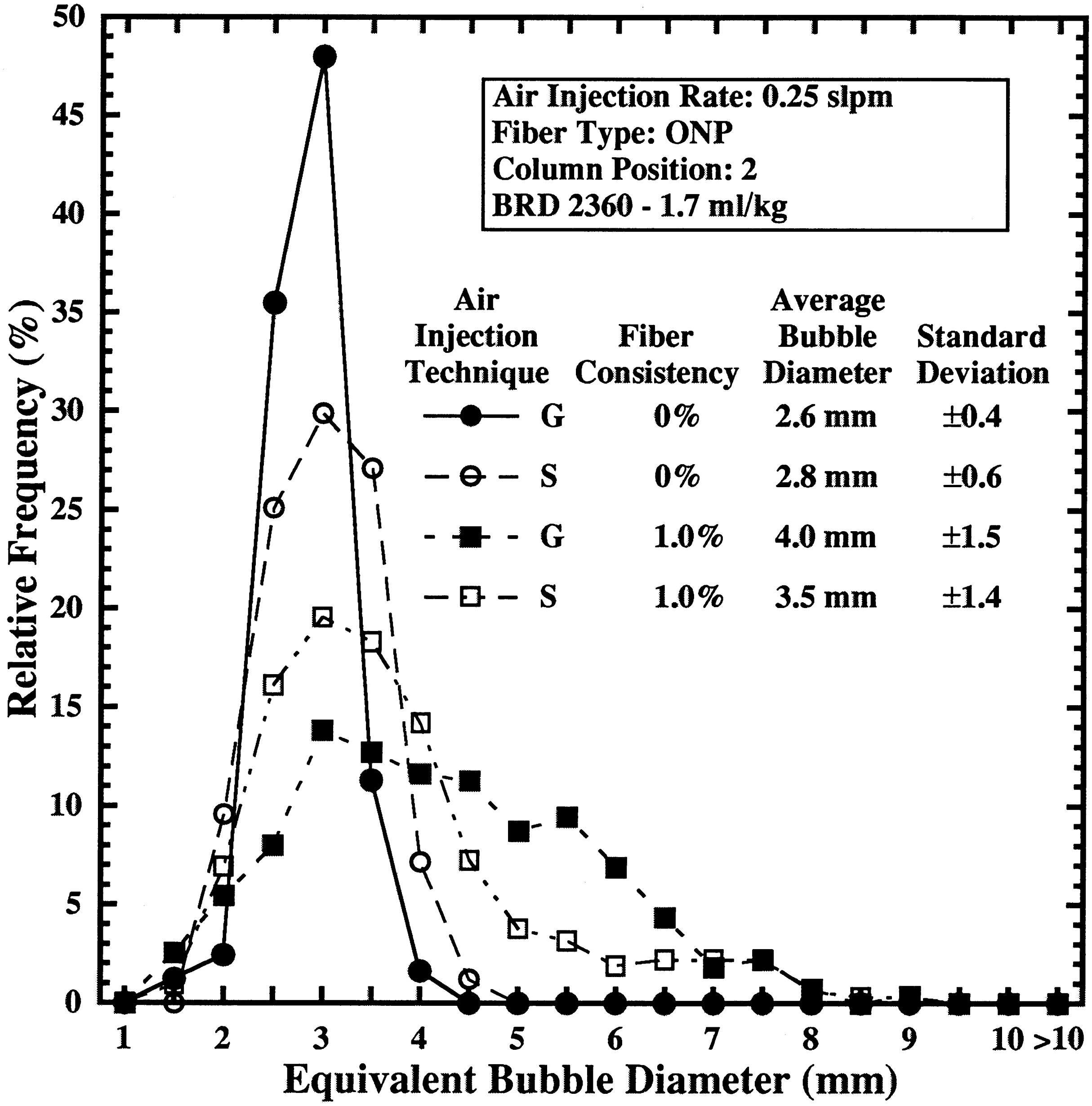

Figure 6: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 1.7 ml/kg of BRD 2360 added to the system.

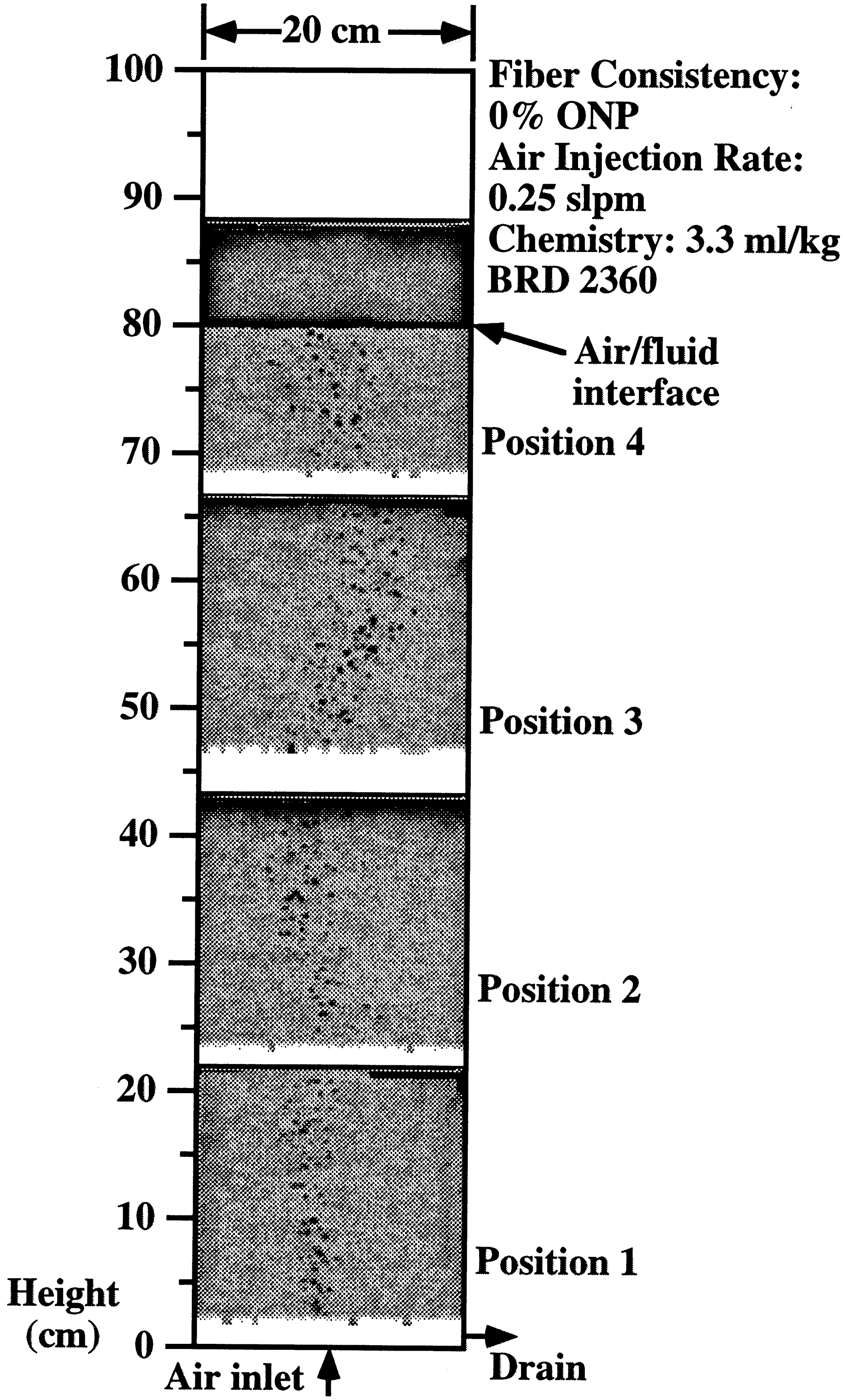

Figure 7: X-ray composite of air bubble flow patterns in an air/water system with 3.3 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

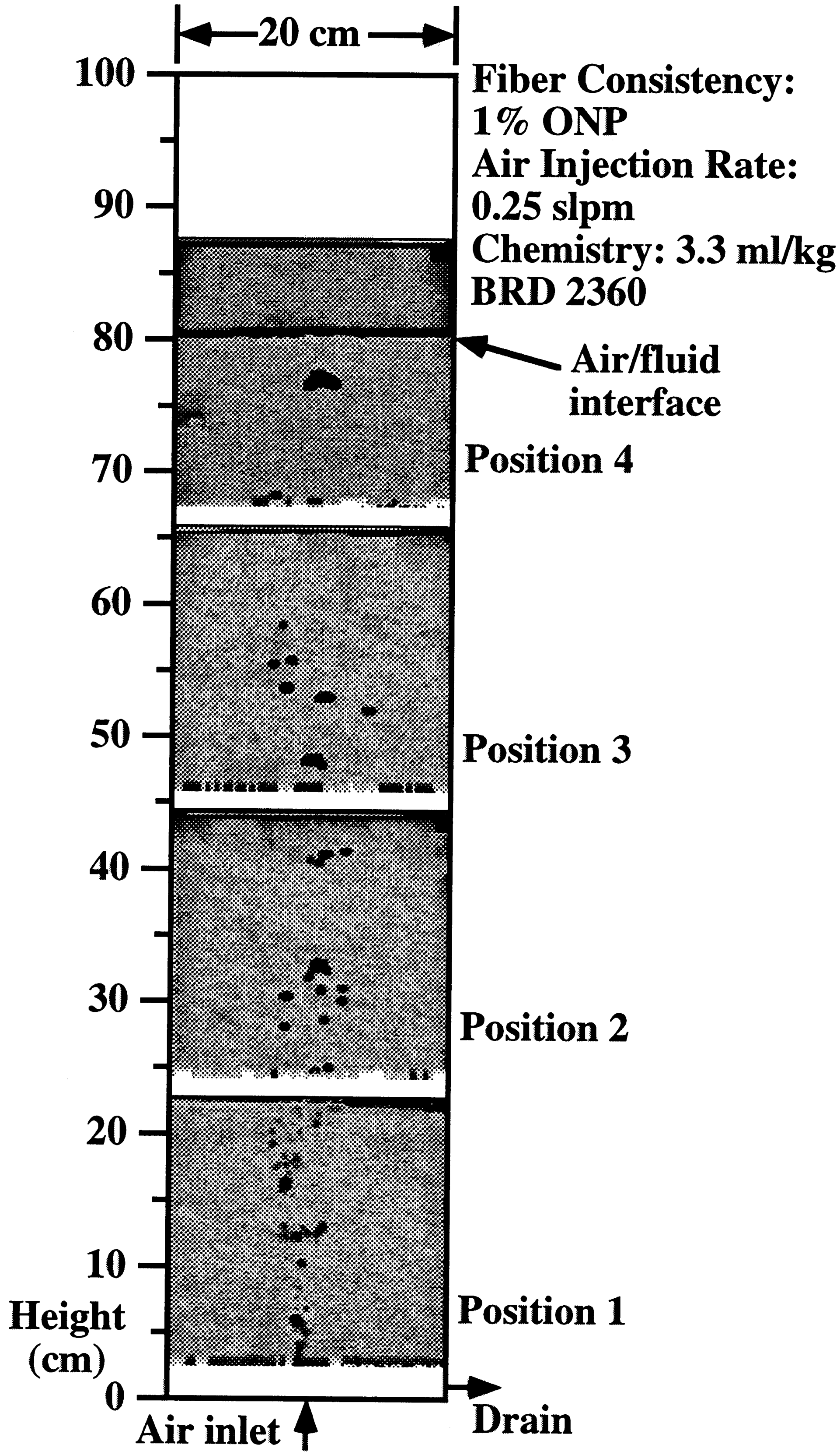

Figure 8: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 3.3 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

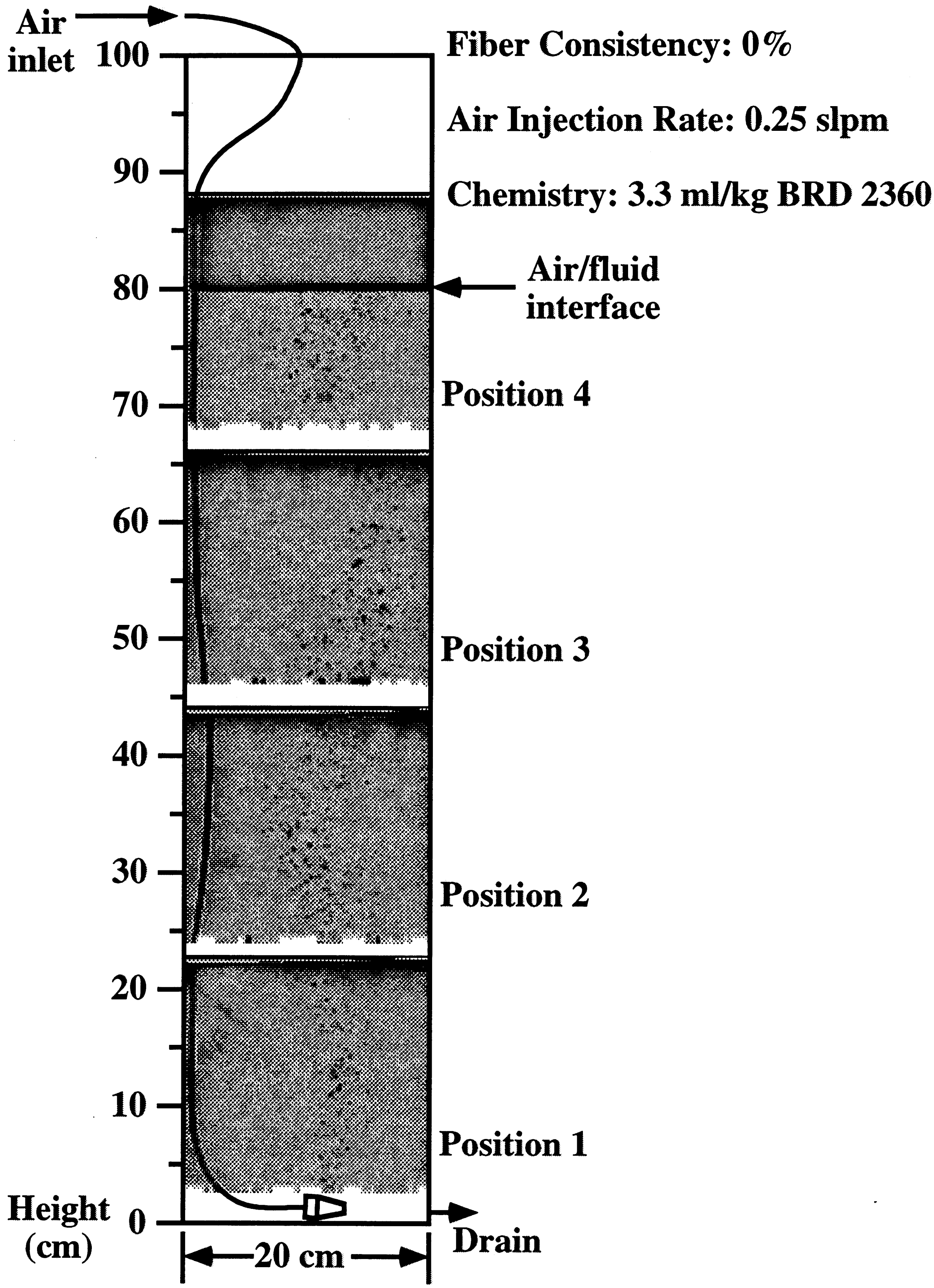

Figure 9: X-ray composite of air bubble flow patterns in an air/water system with 3.3 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

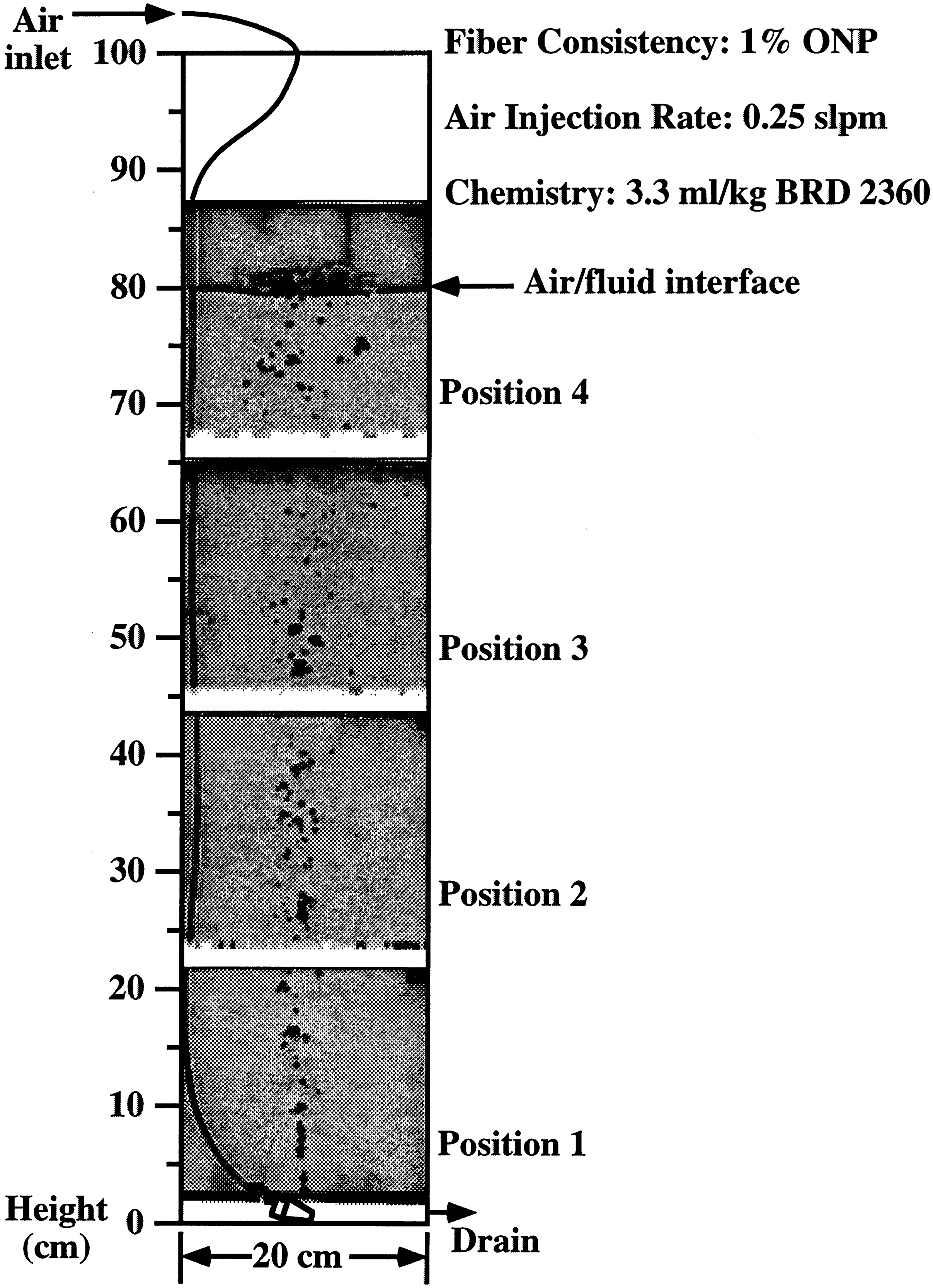

Figure 10: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 3.3 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

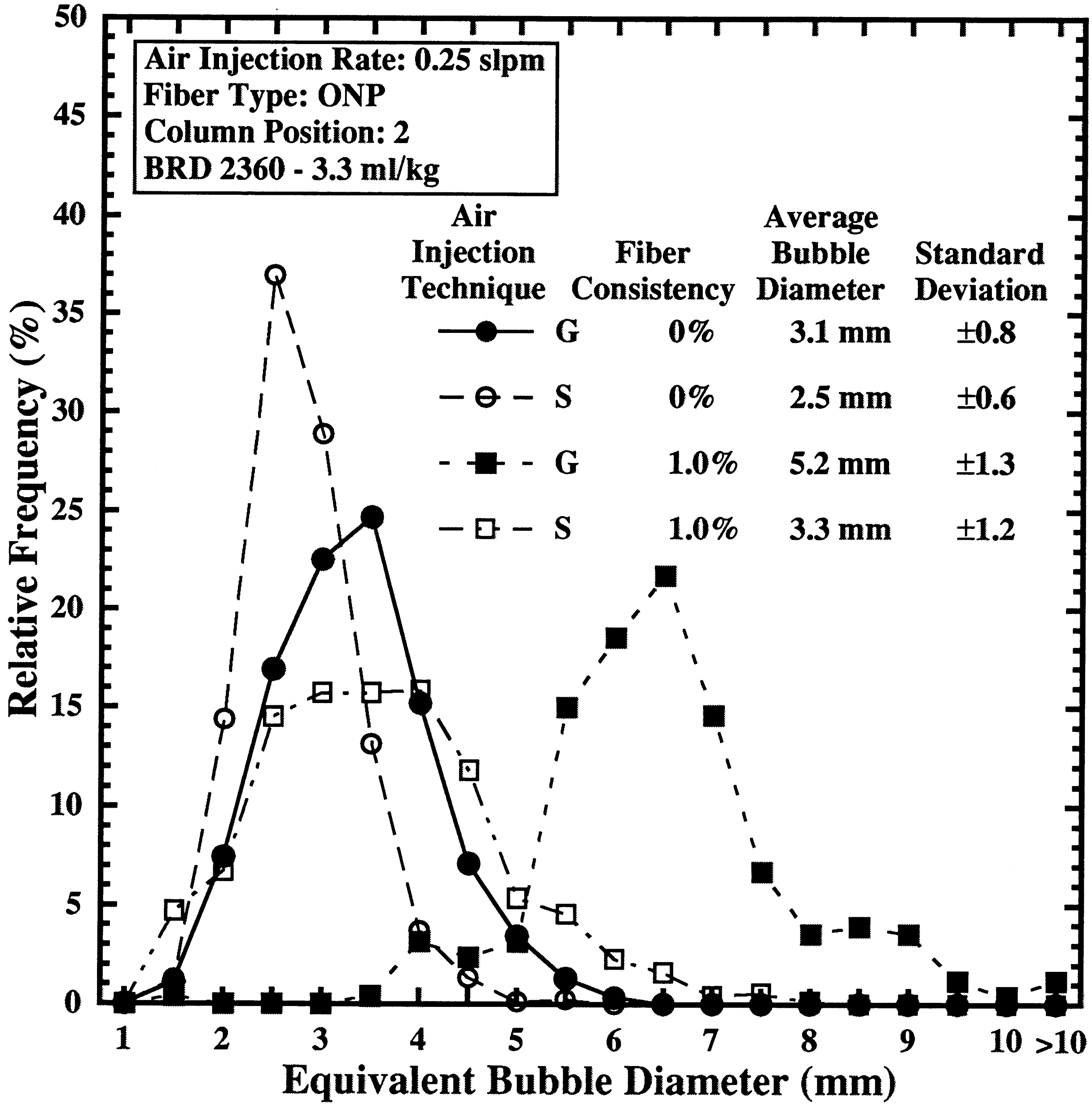

Figure 11: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 3.3 ml/kg of BRD 2360 added to the system.

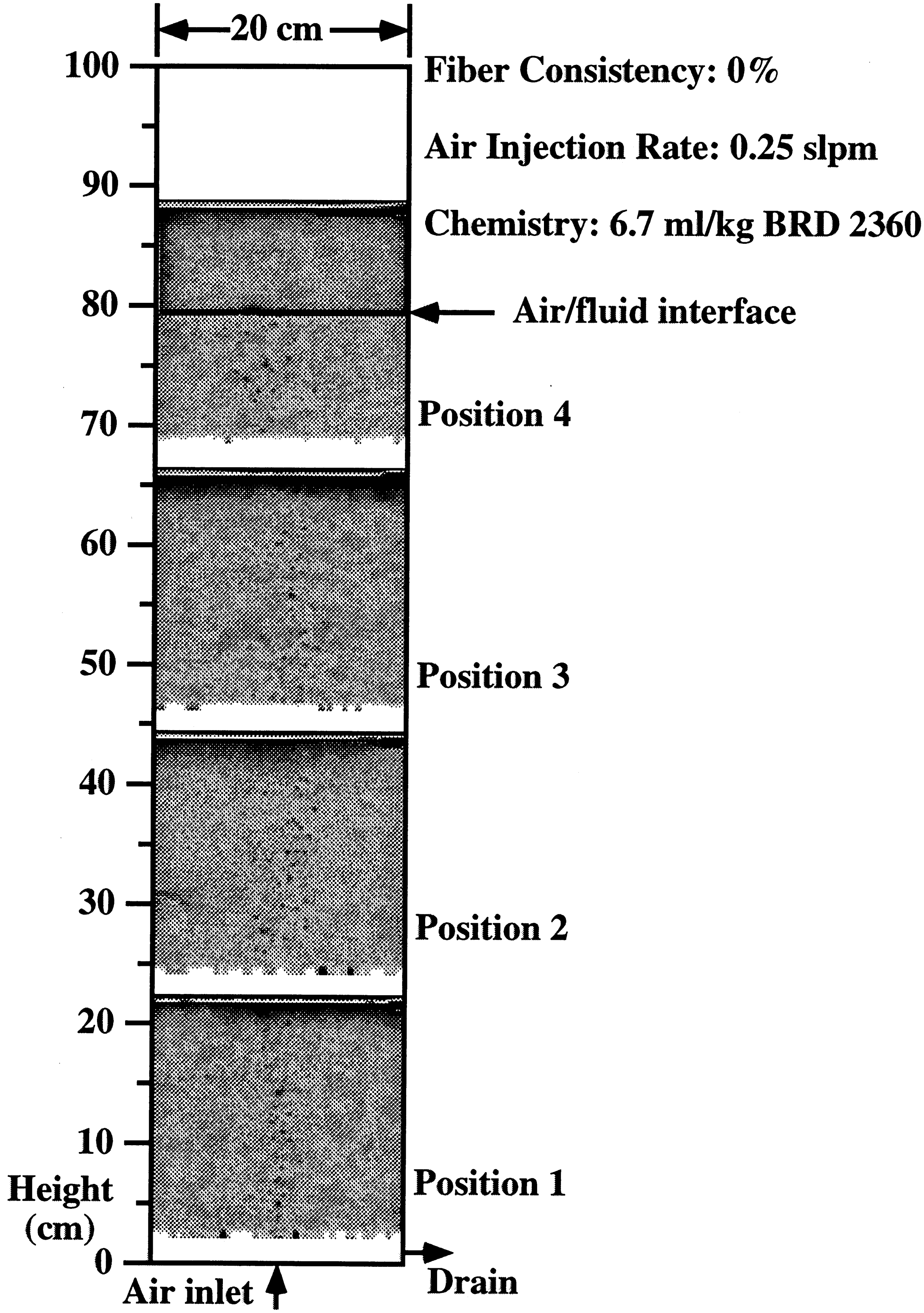

Figure 12: X-ray composite of air bubble flow patterns in an air/water system with 6.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

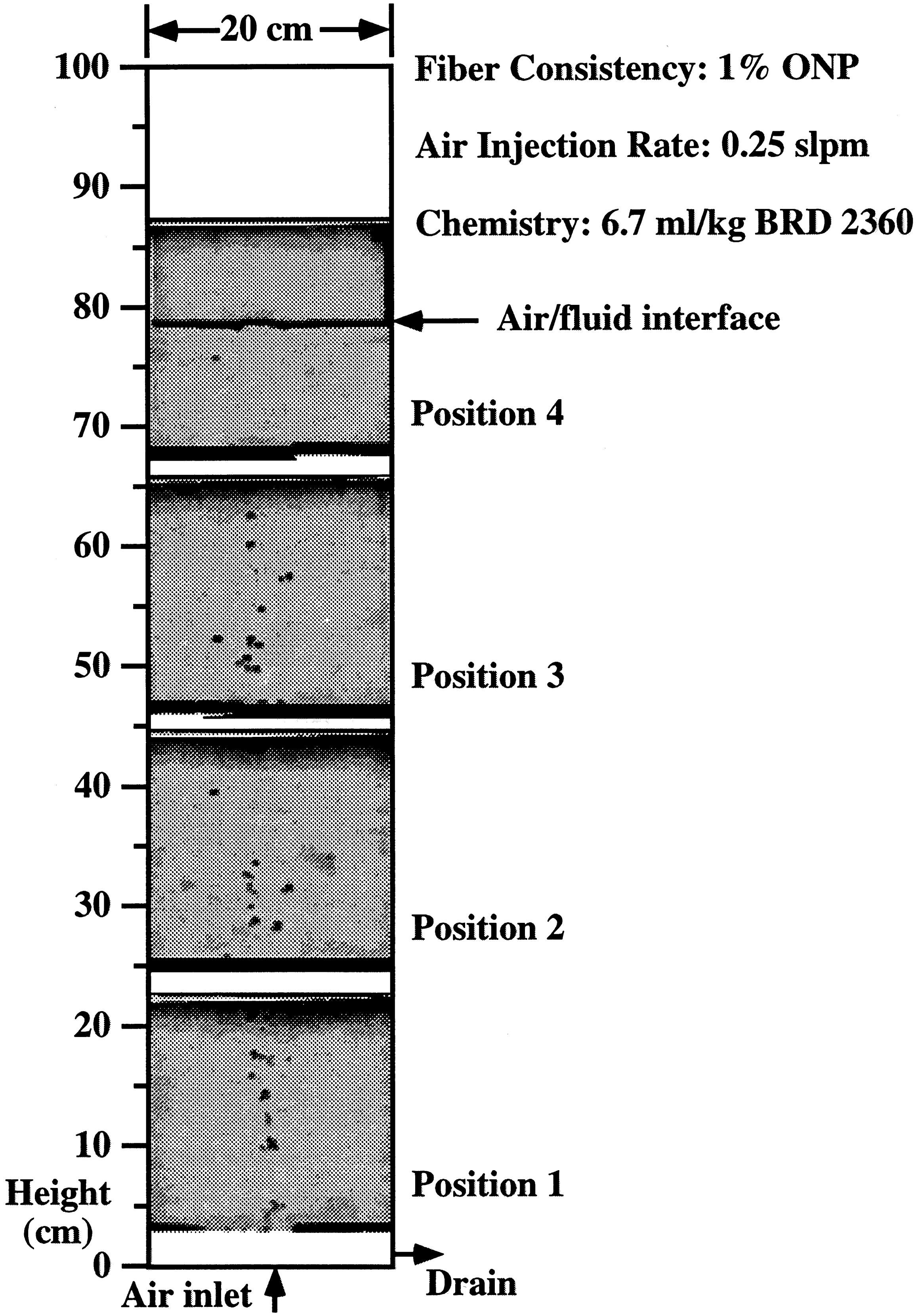

Figure 13: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 6.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

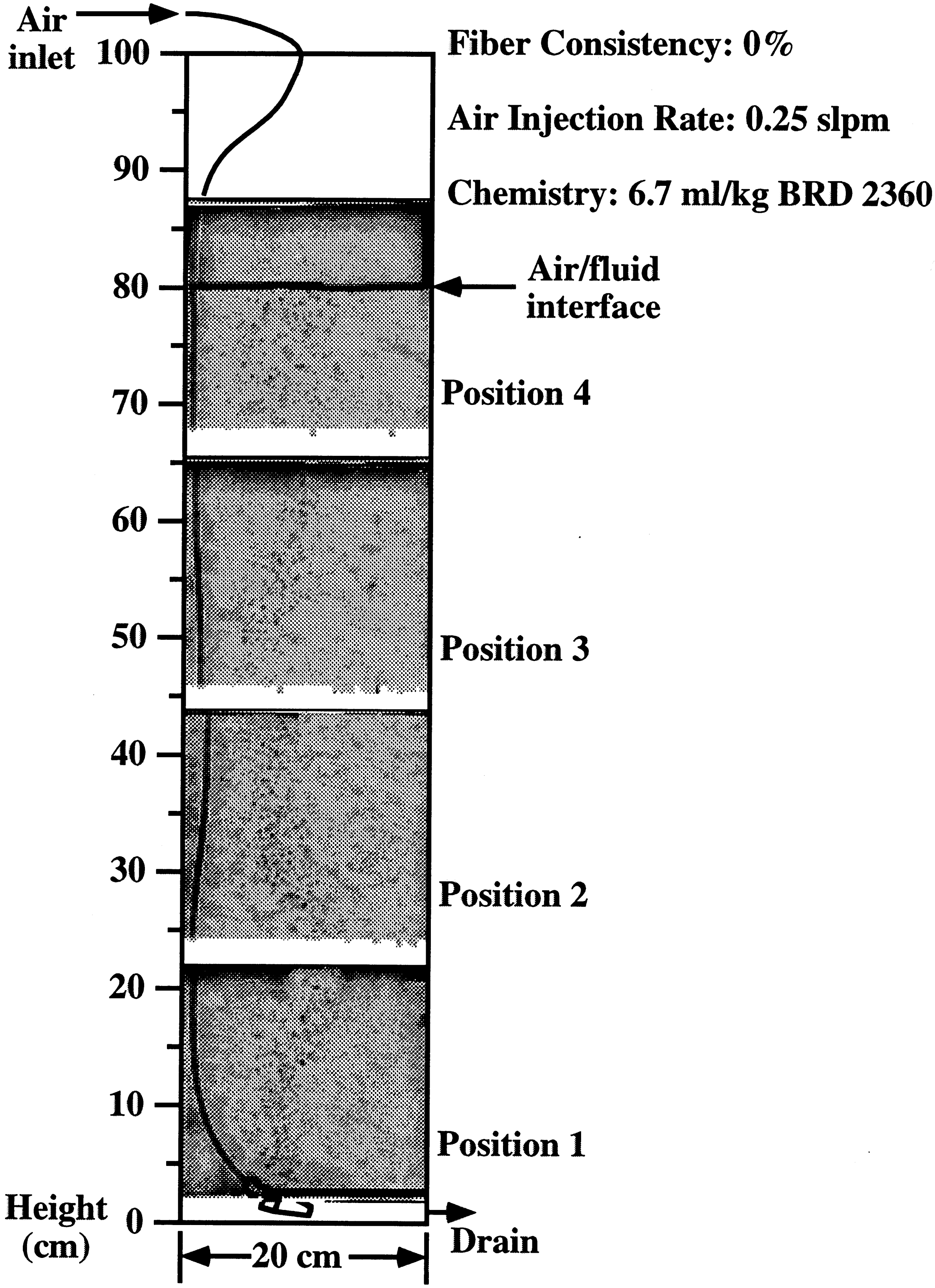

Figure 14: X-ray composite of air bubble flow patterns in an air/water system with 6.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

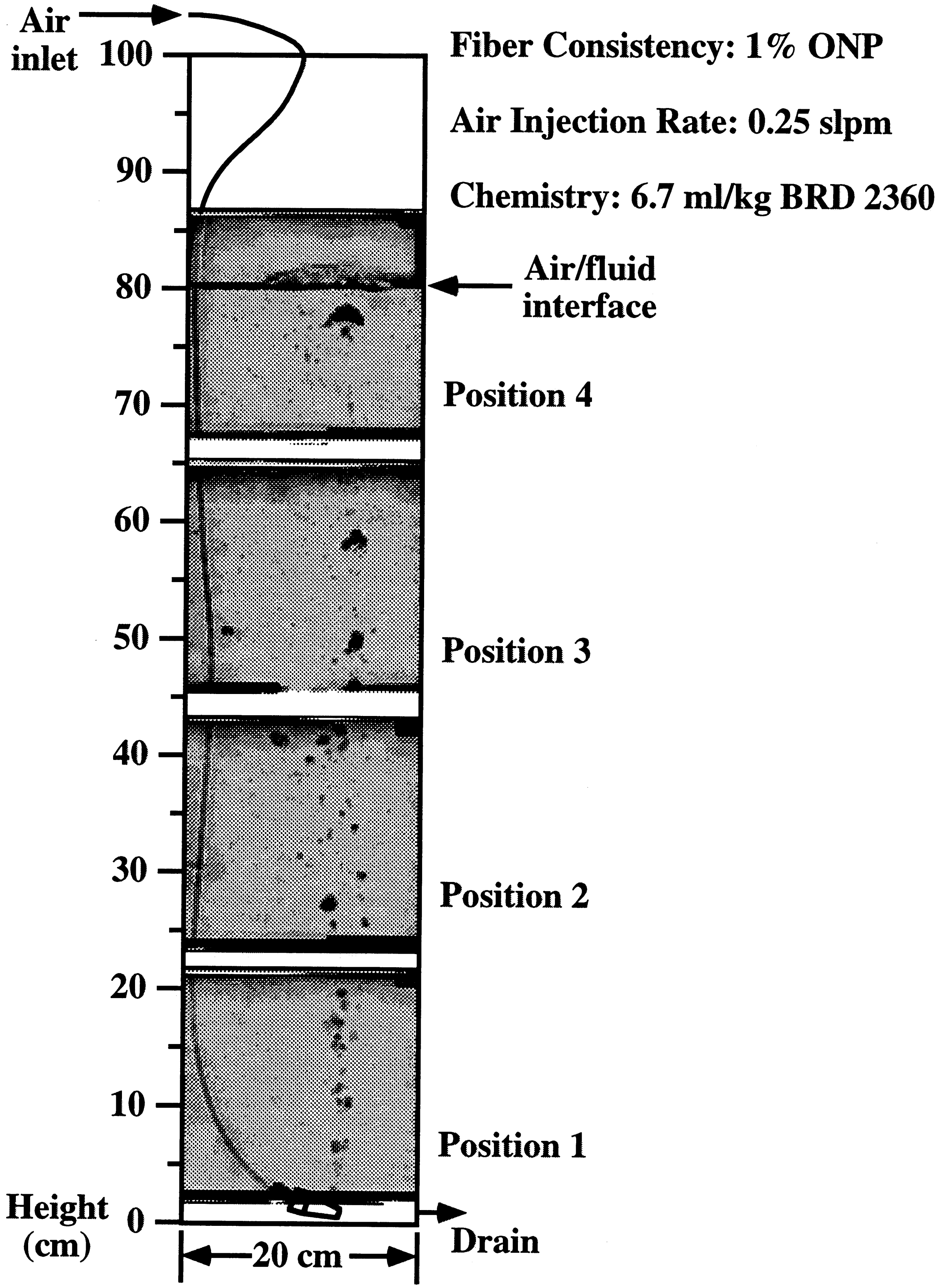

Figure 15: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 6.7 ml/kg of BRD 2360 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

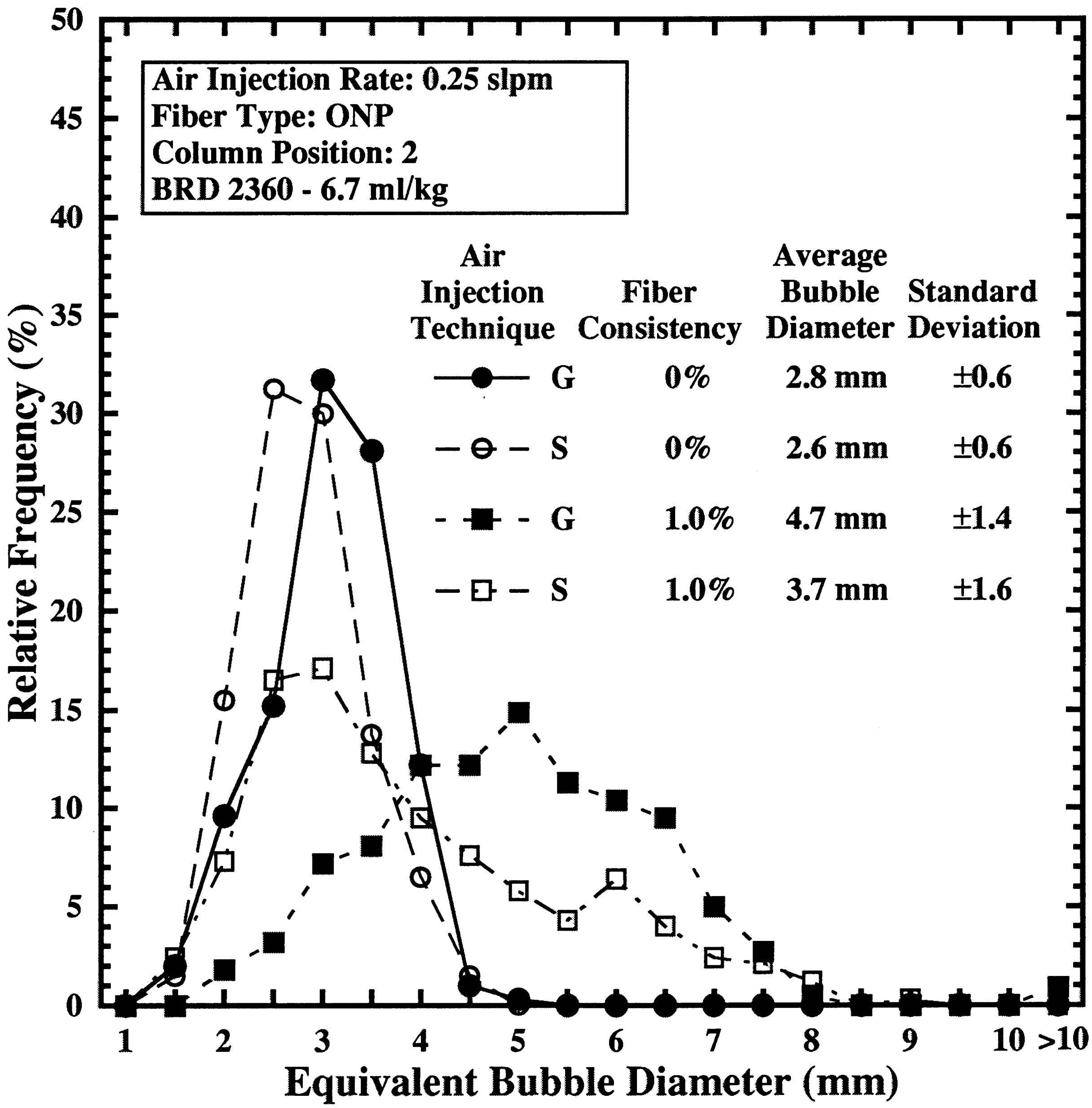

Figure 16: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 6.7 ml/kg of BRD 2360 added to the system.

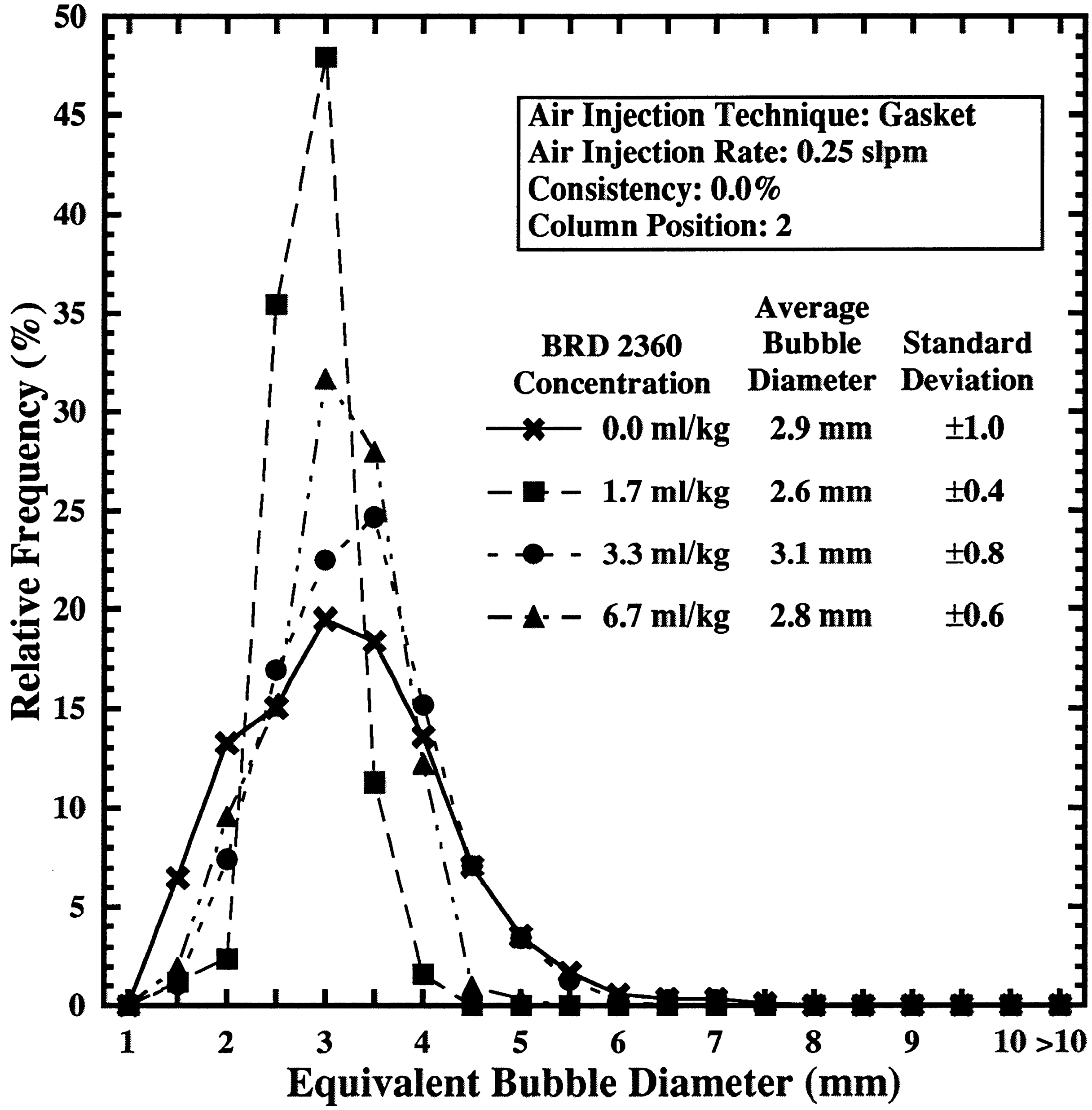

Figure 17: Effect of BRD 2360 concentration on the bubble size distribution for an air/water system with gasket air injection.

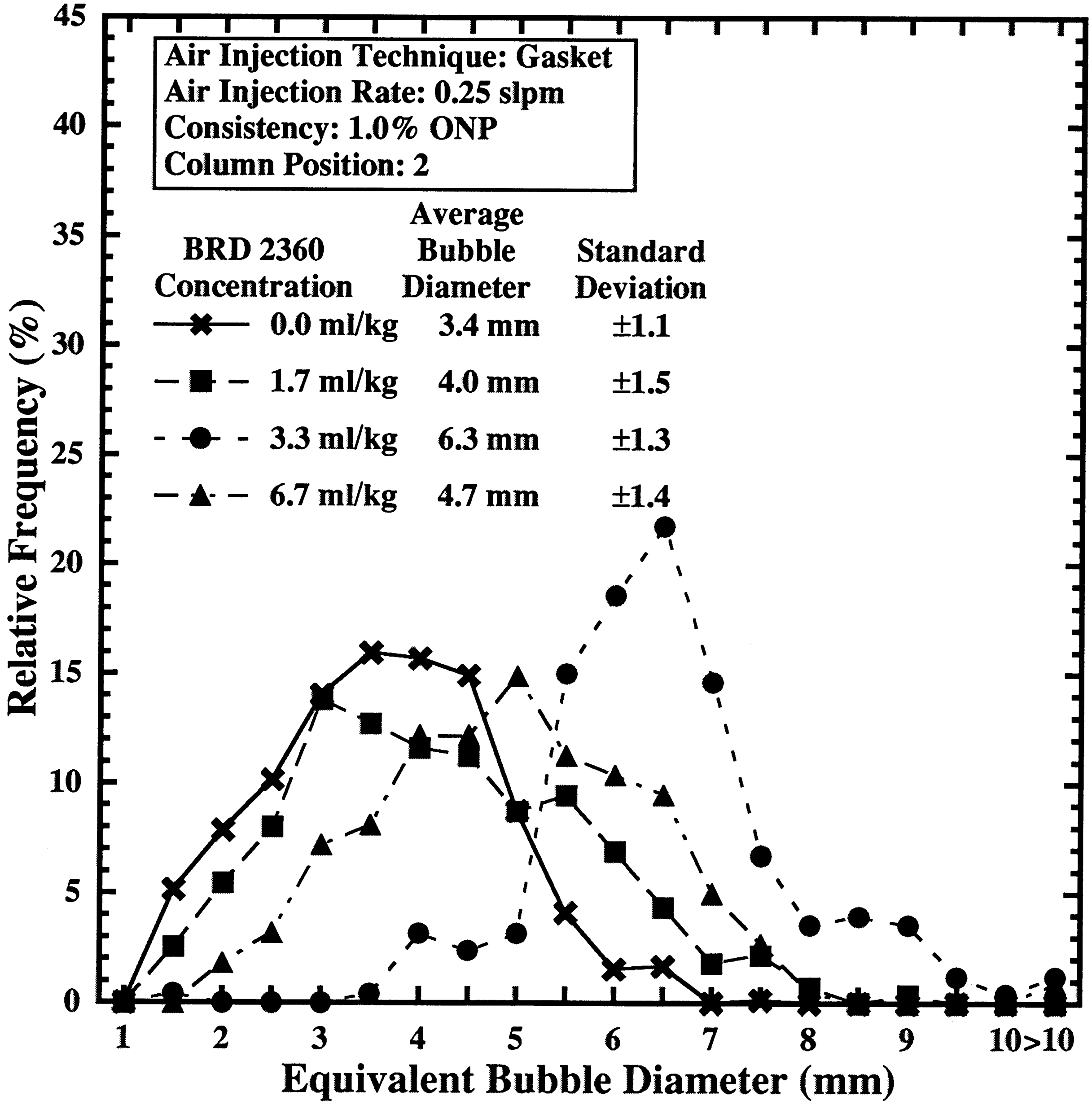

Figure 18: Effect of BRD 2360 concentration on the bubble size distribution for an air/water/1% ONP system with gasket air injection.

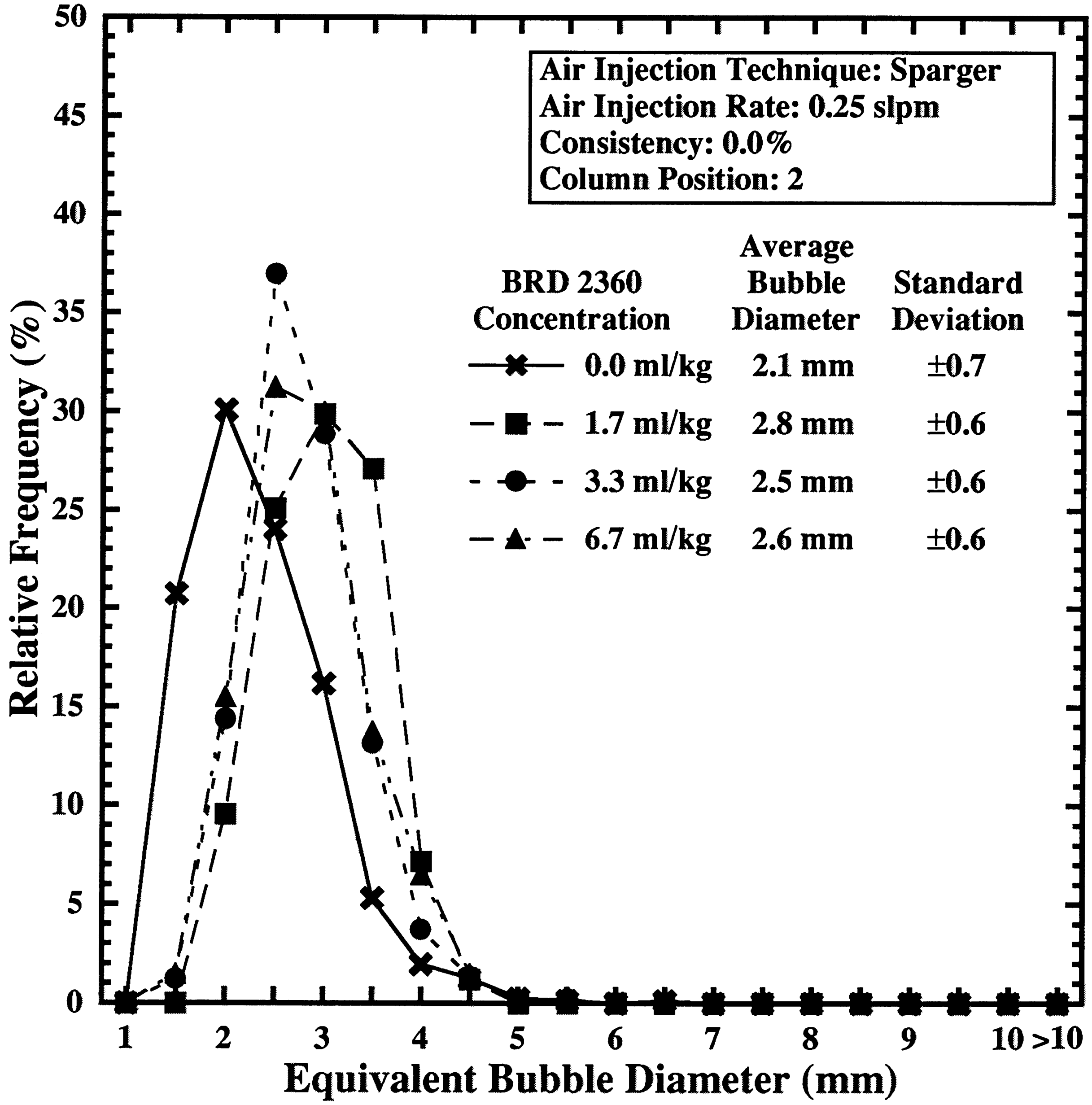

Figure 19: Effect of BRD 2360 concentration on the bubble size distribution for an air/water system with sparger air injection.

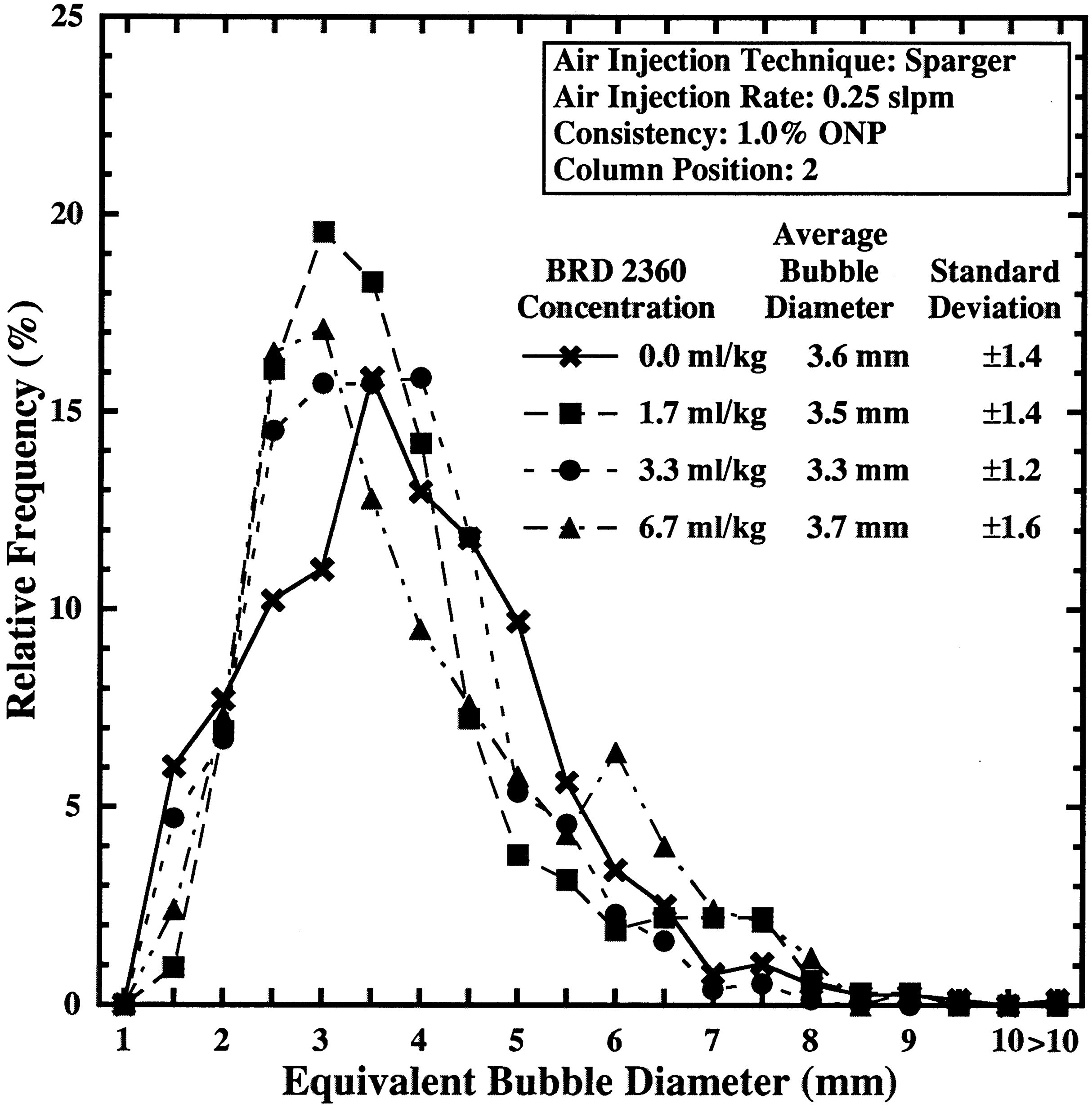

Figure 20: Effect of BRD 2360 concentration on the bubble size distribution for an air/water/1% ONP system with sparger air injection.

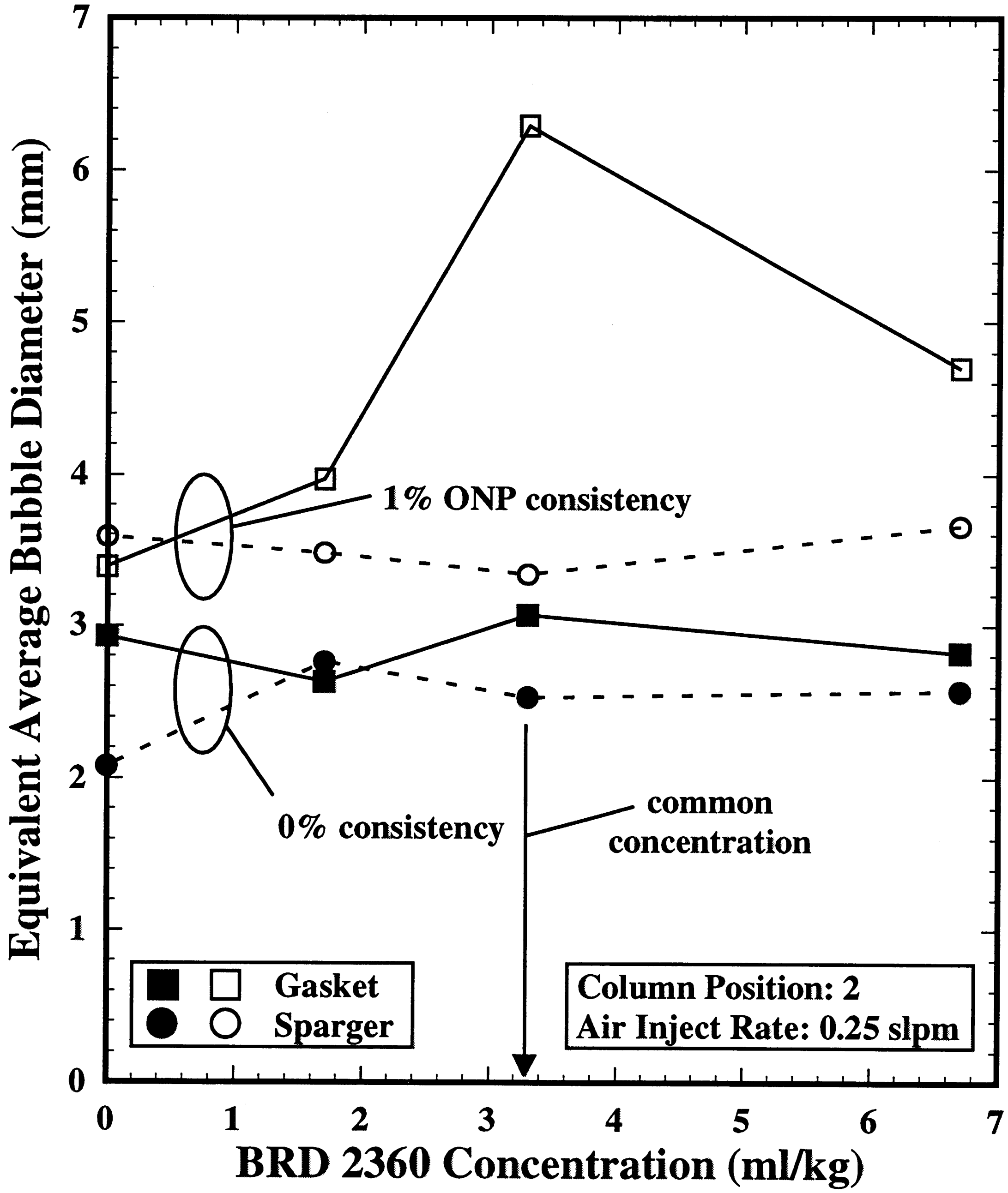

Figure 21: Effect of BRD 2360 concentration on the average bubble size.

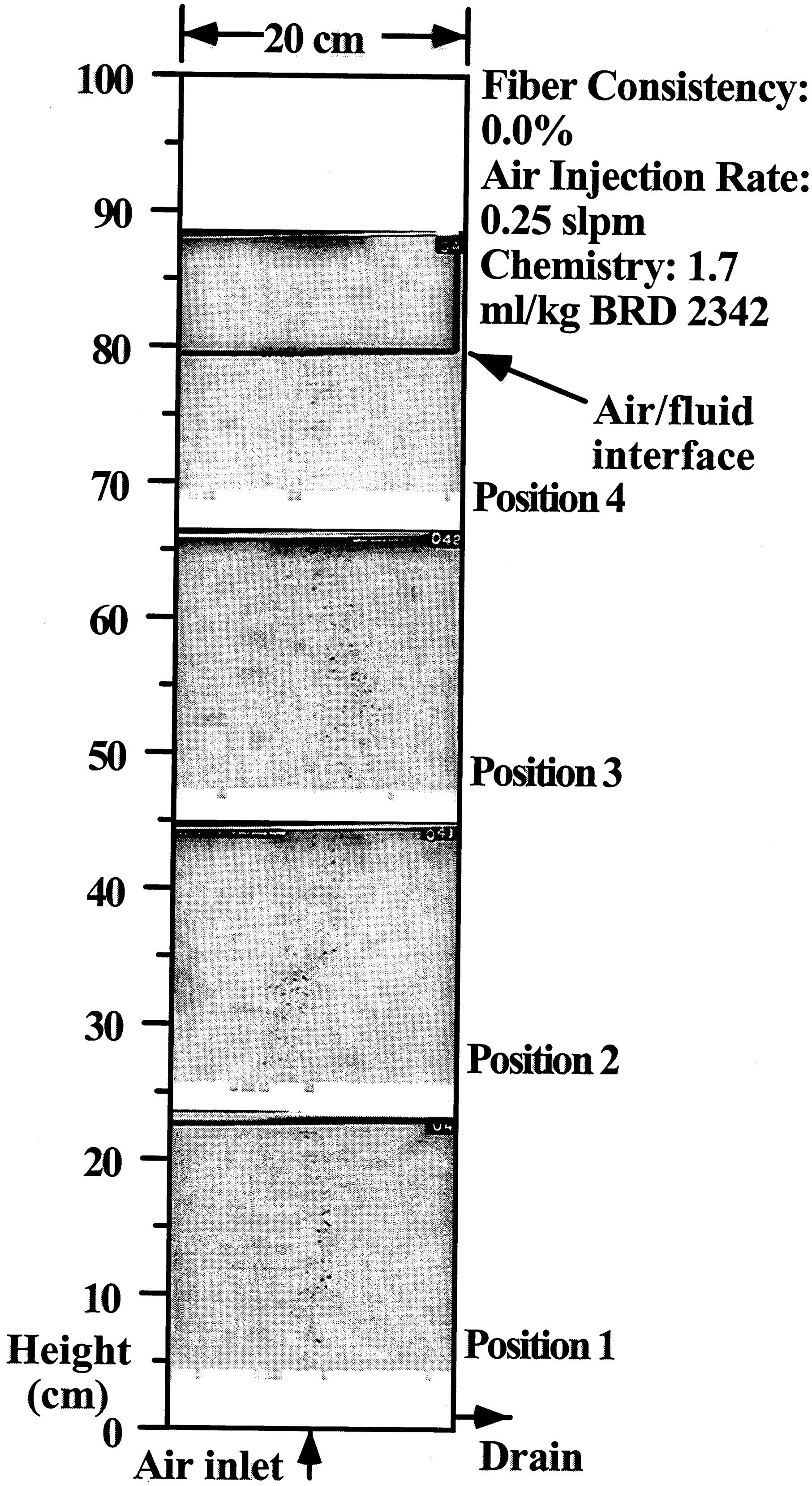

Figure 22: X-ray composite of air bubble flow patterns in an air/water system with 1.7 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

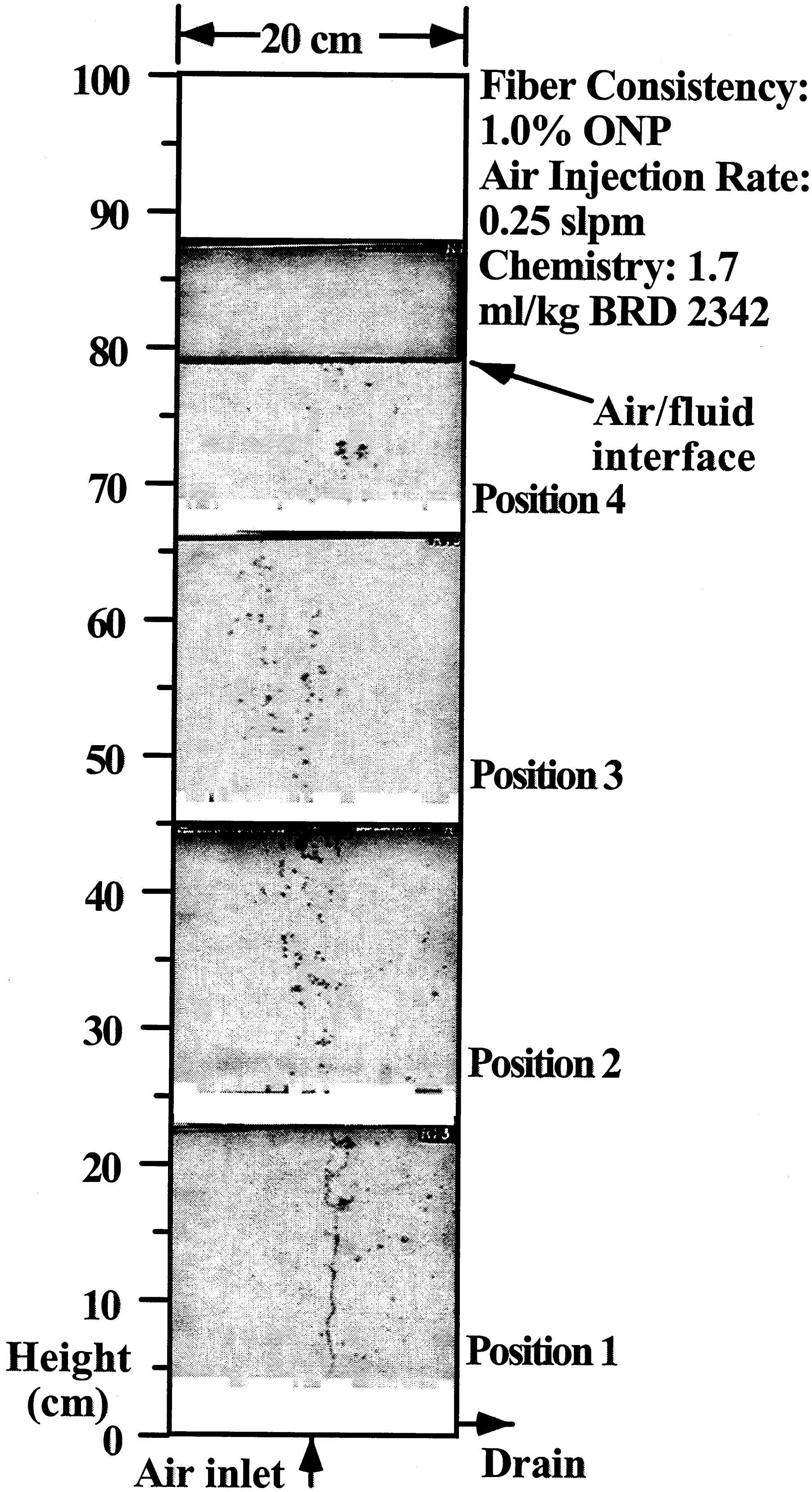

Figure 23: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 1.7 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

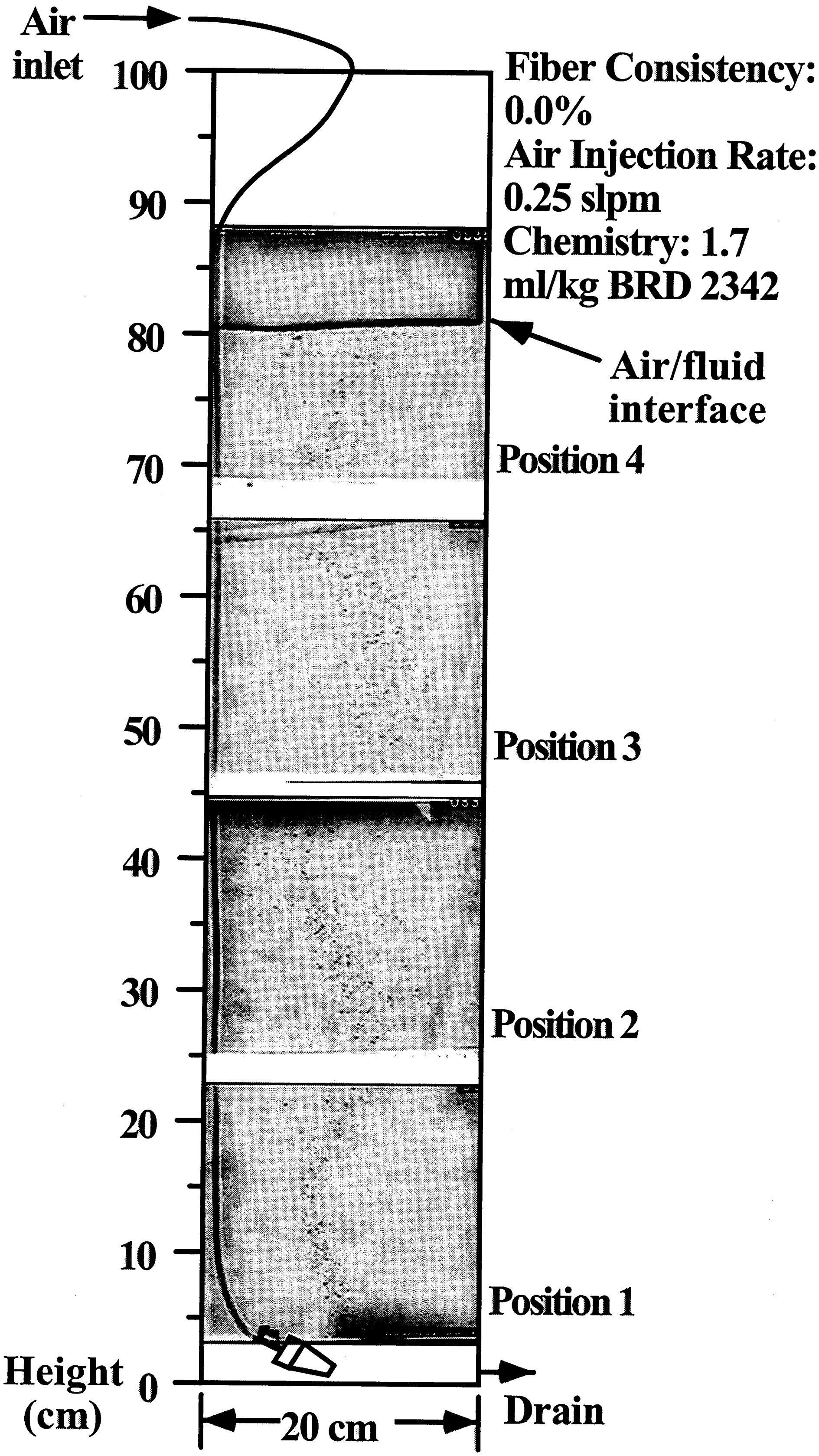

Figure 24: X-ray composite of air bubble flow patterns in an air/water system with 1.7 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

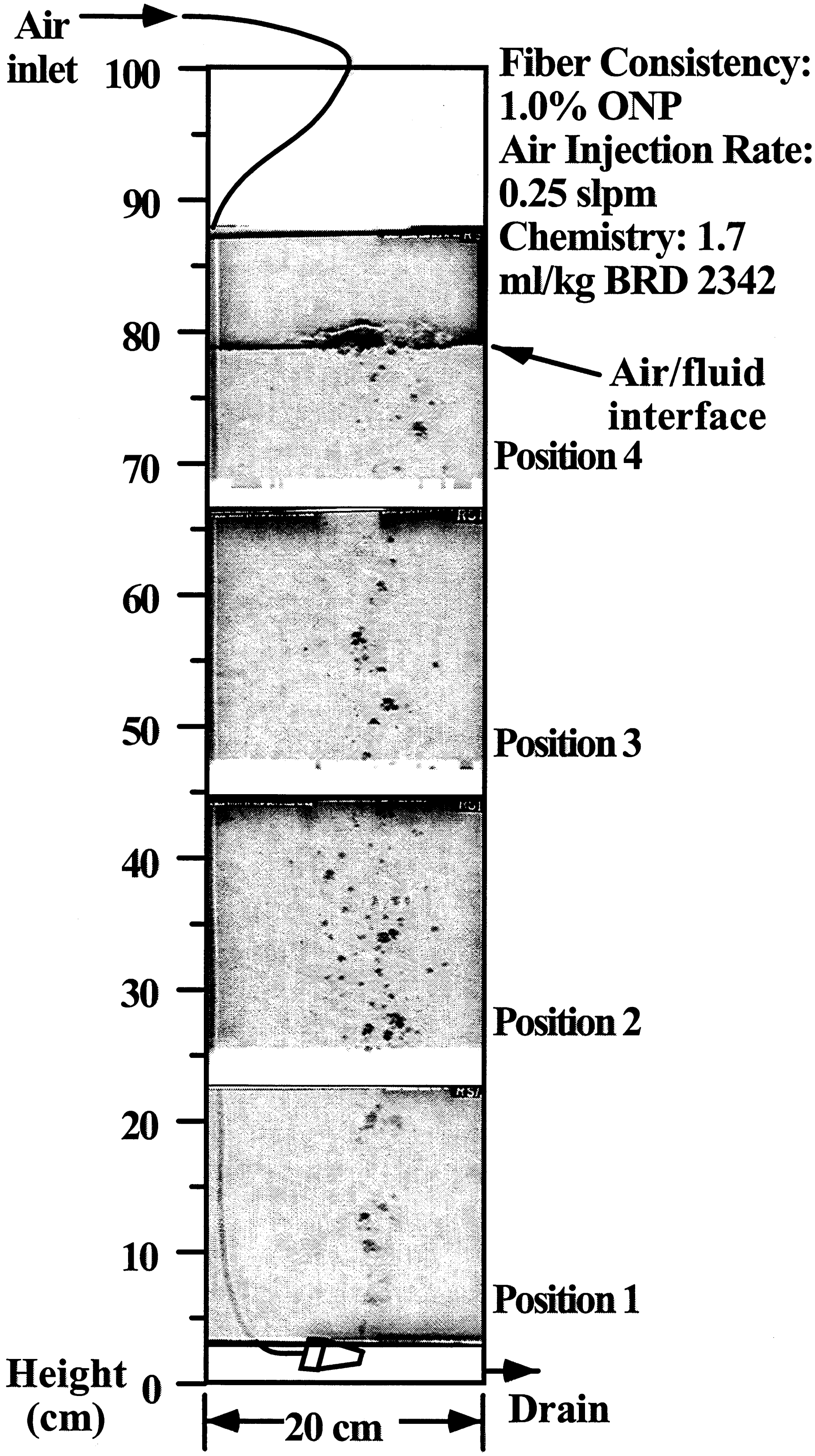

Figure 25: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 1.7 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

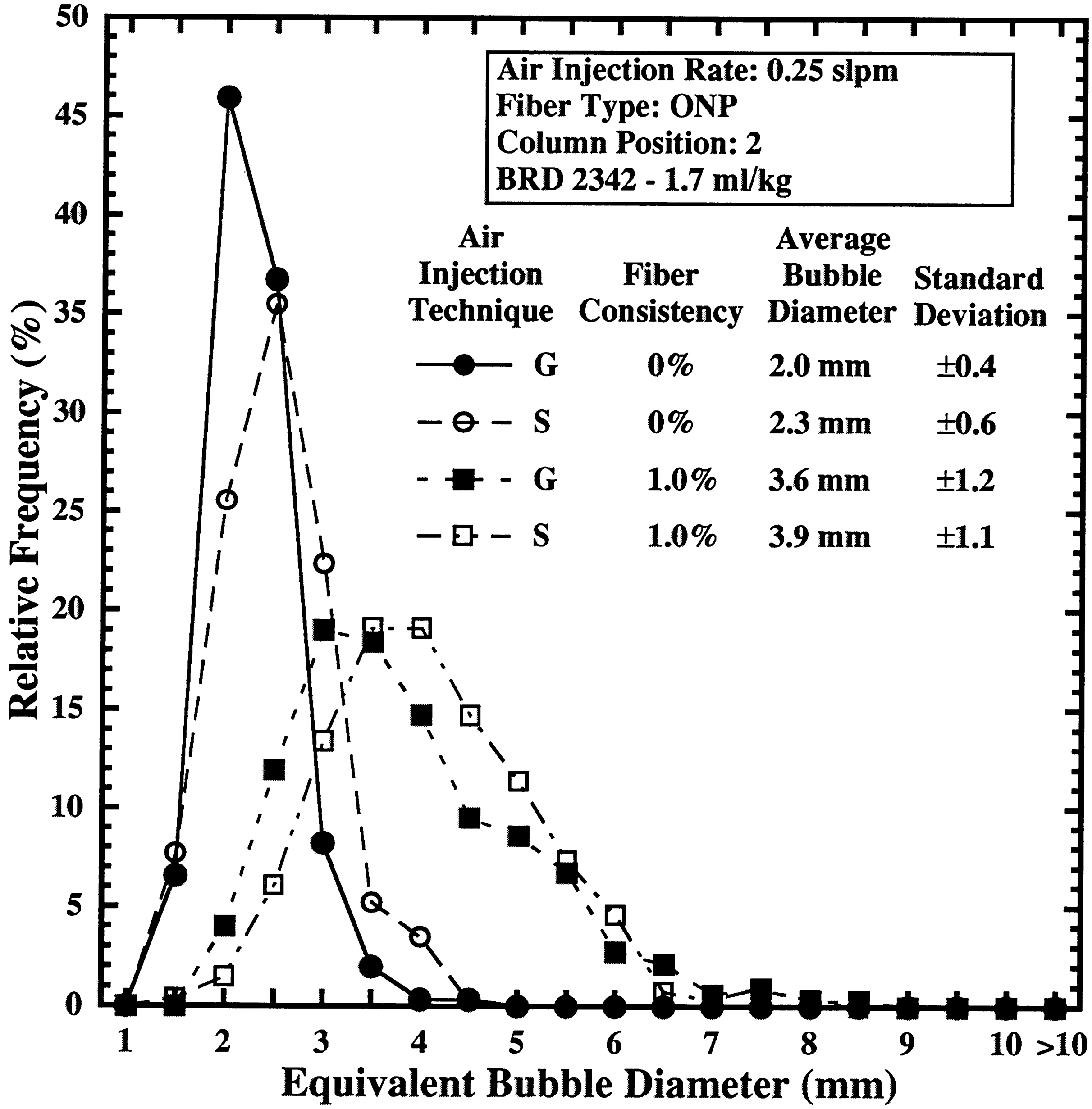

Figure 26: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 1.7 ml/kg of BRD 2342 added to the system.

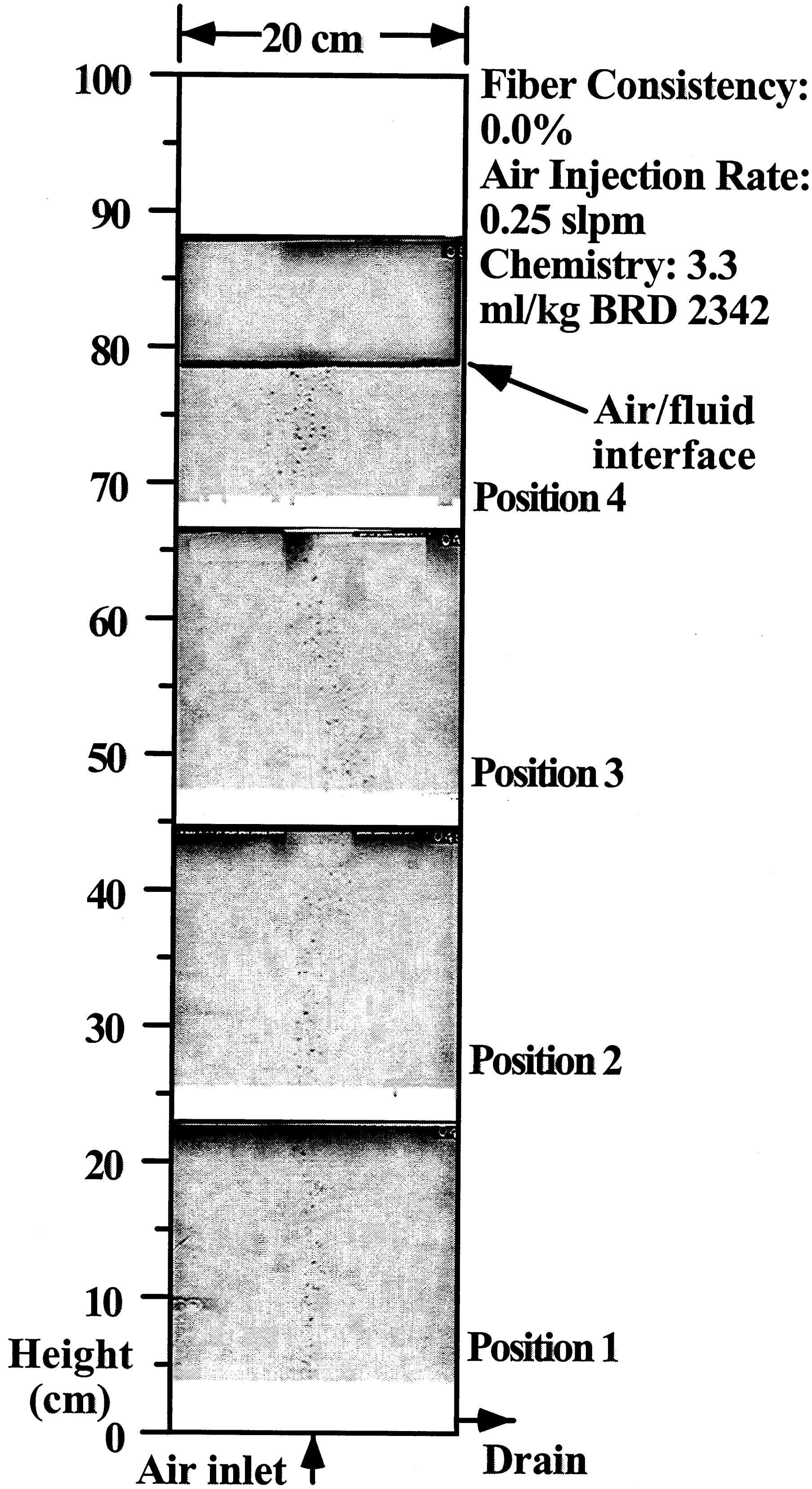

Figure 27: X-ray composite of air bubble flow patterns in an air/water system with 3.3 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

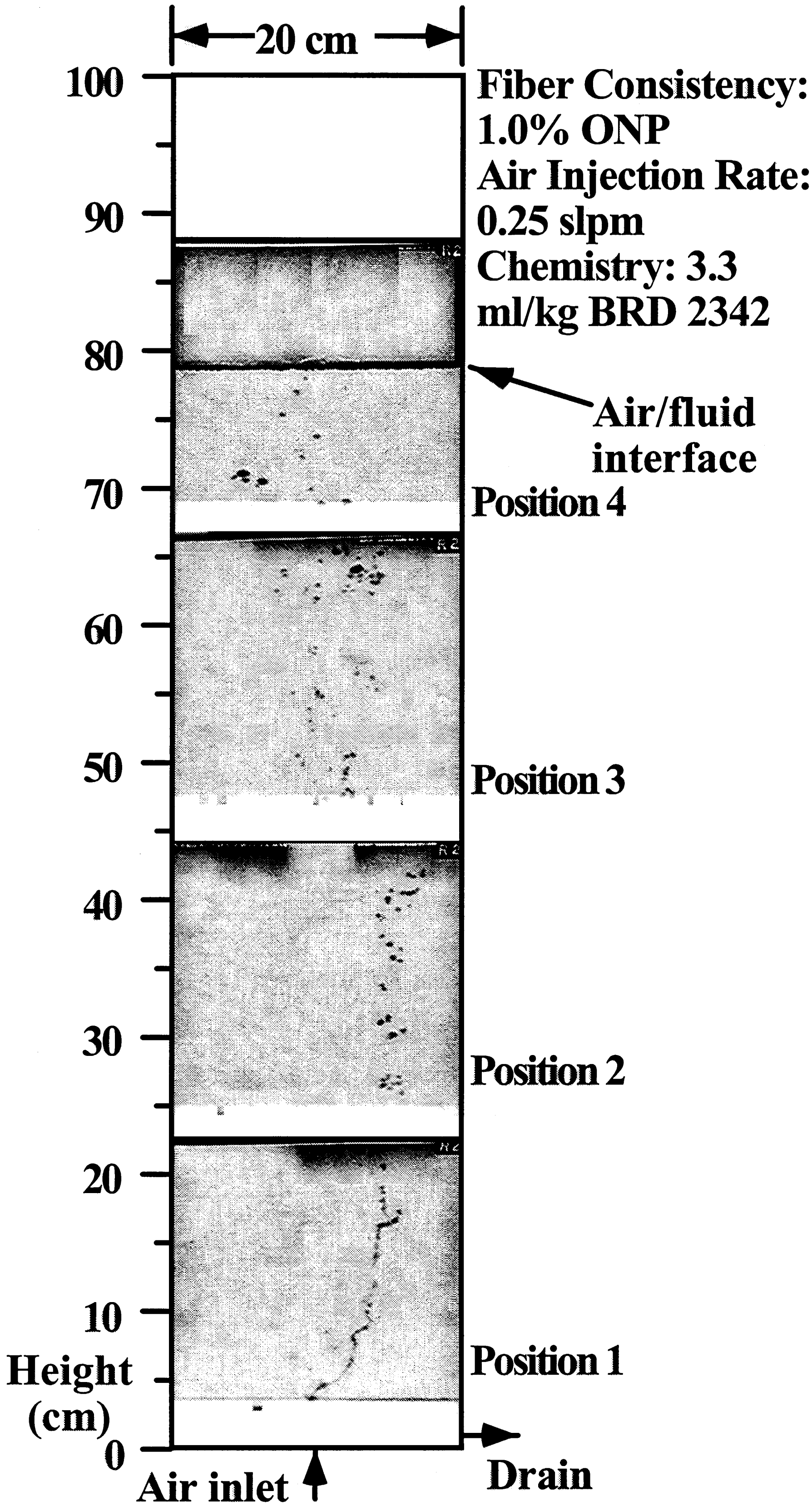

Figure 28: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 3.3 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

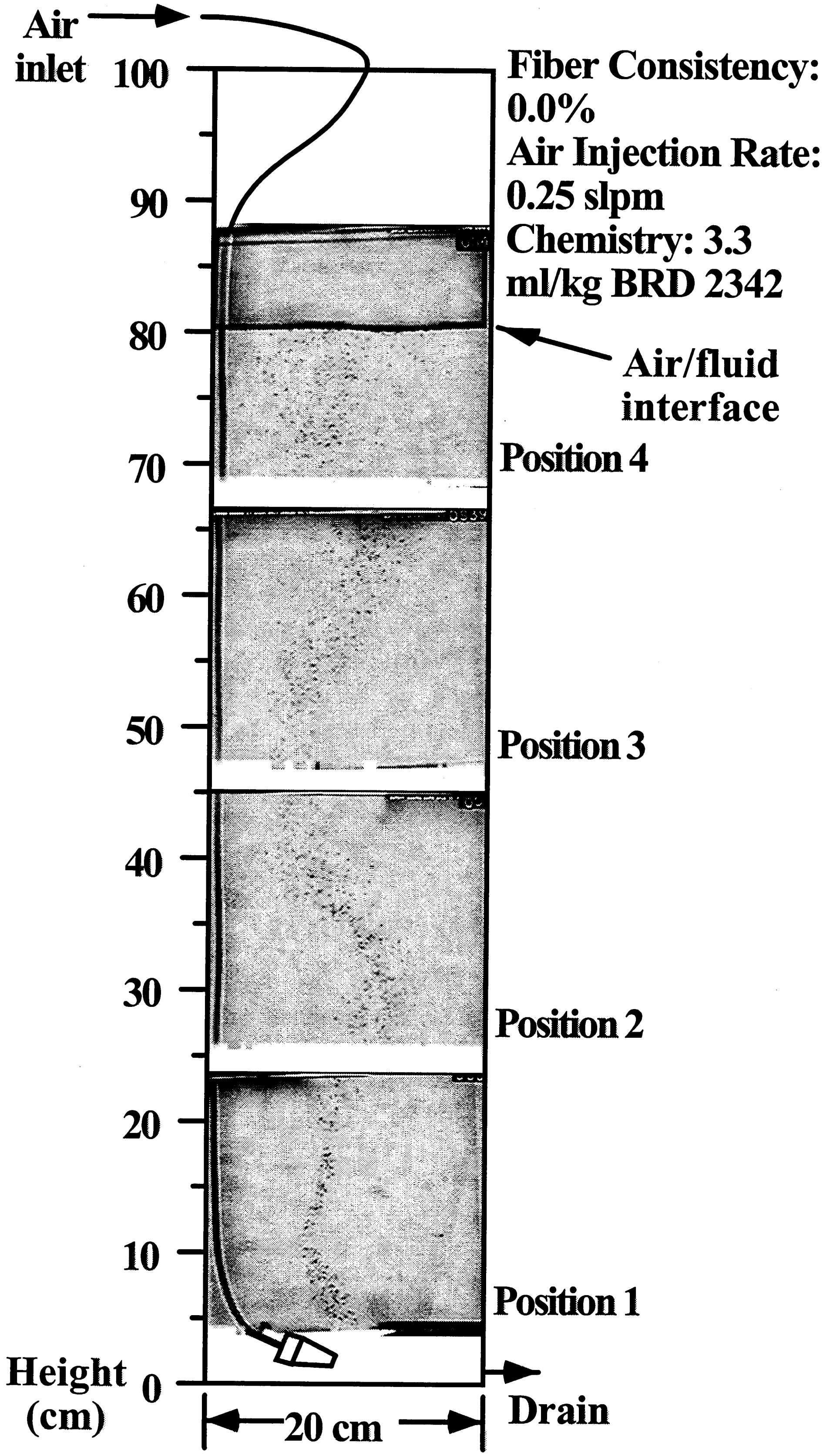

Figure 29: X-ray composite of air bubble flow patterns in an air/water system with 3.3 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

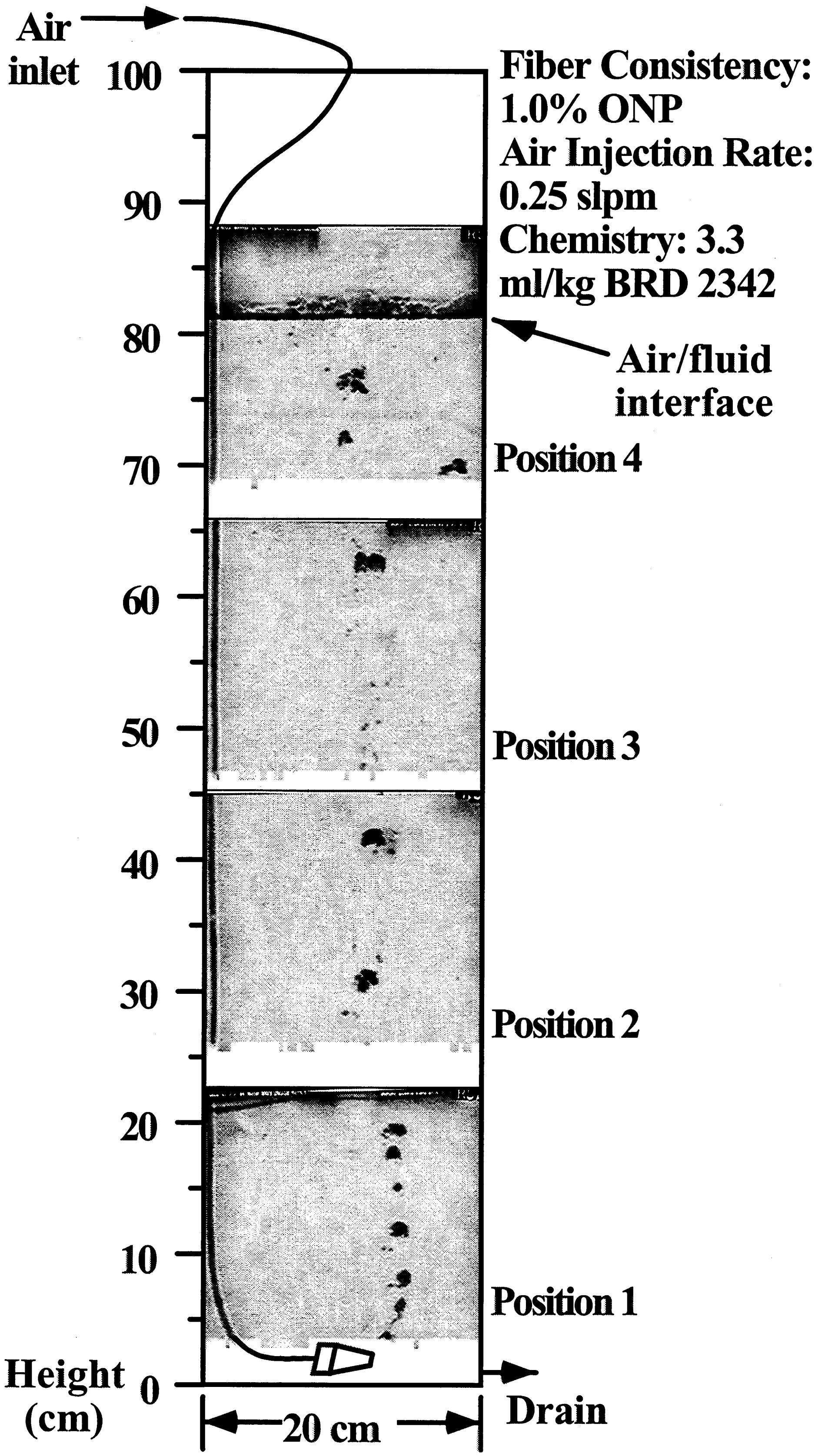

Figure 30: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 3.3 ml/kg of BRD 2342 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

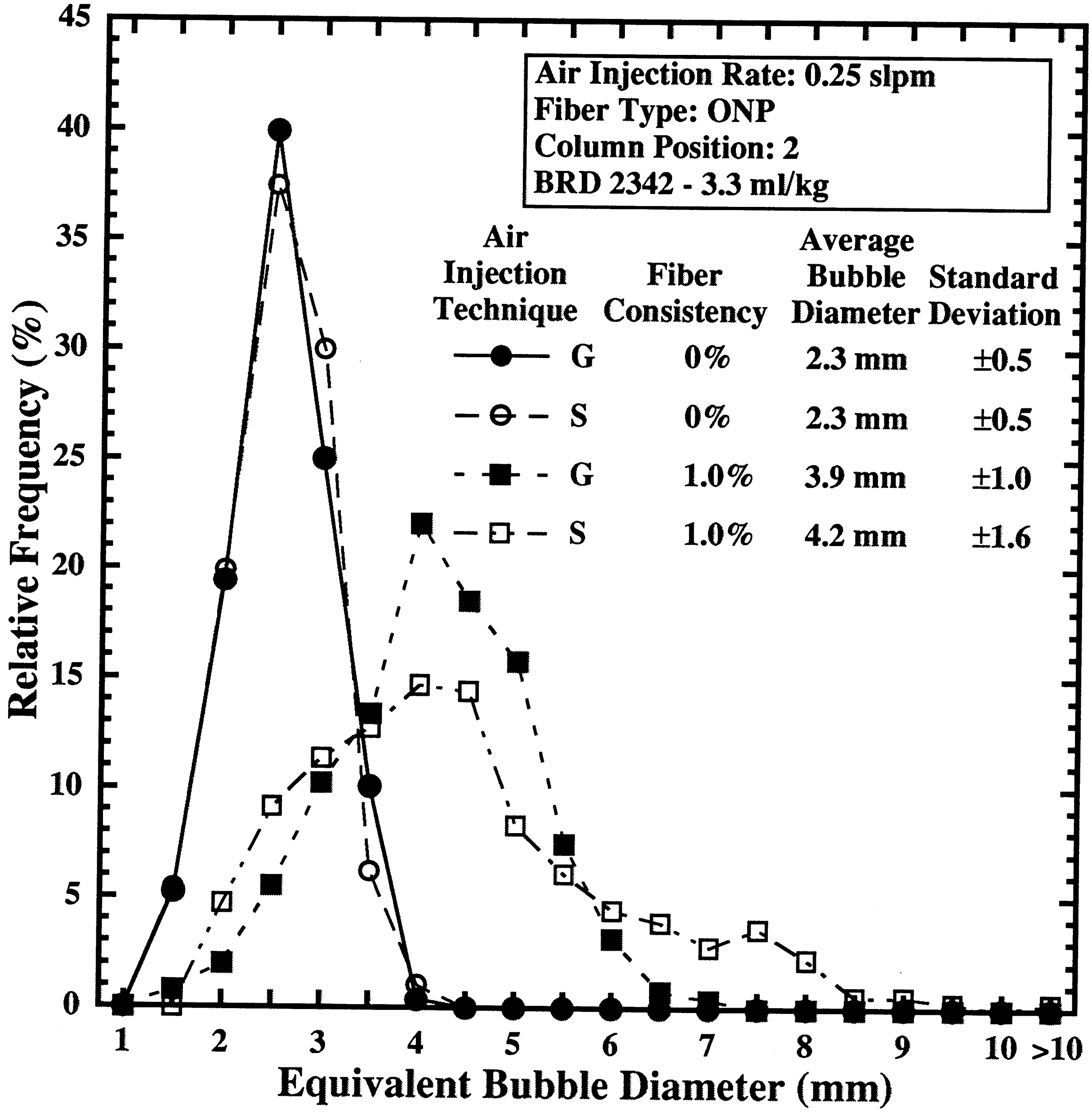

Figure 31: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 3.3 ml/kg of BRD 2342 added to the system.

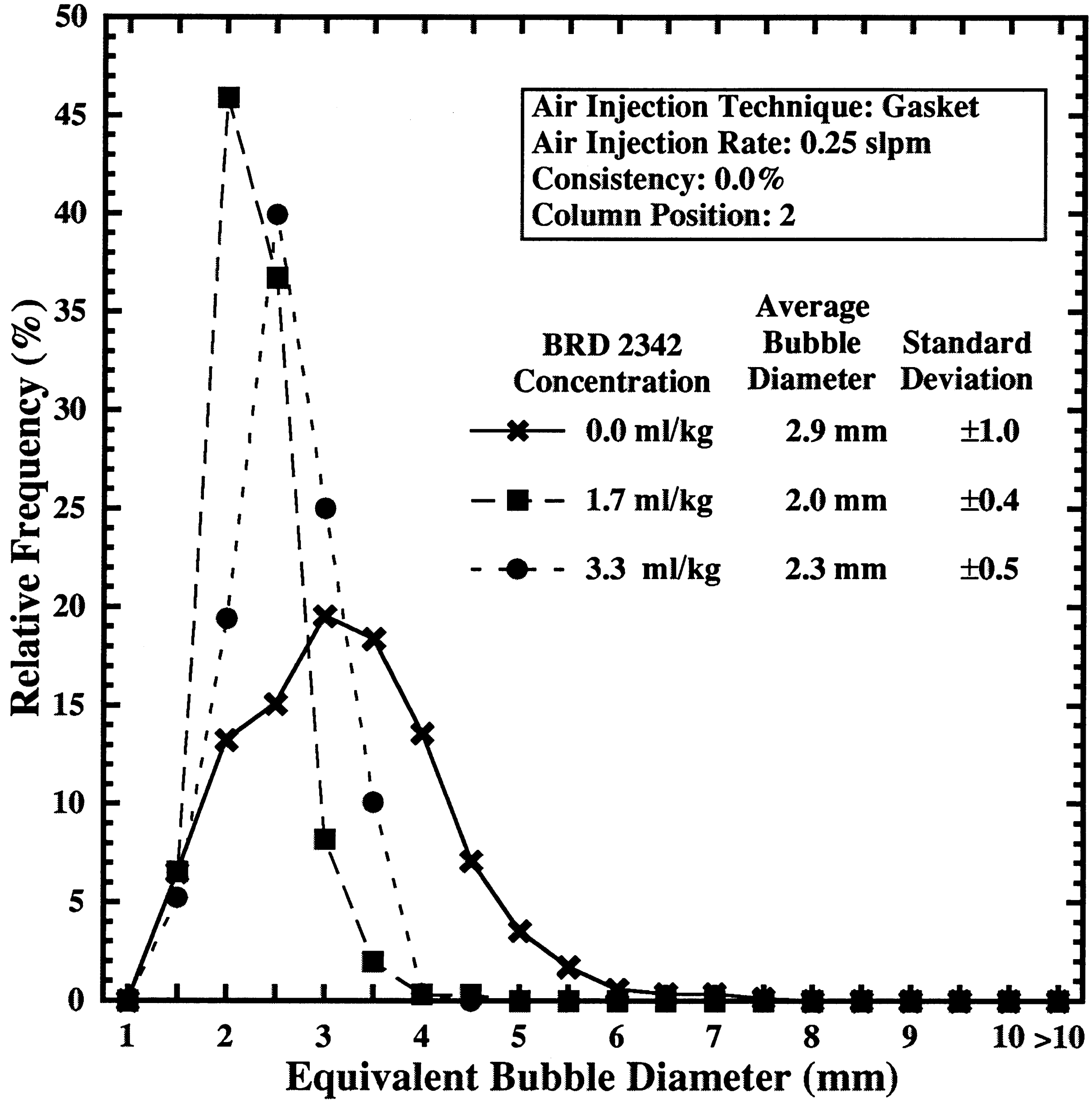

Figure 32: Effect of BRD 2342 concentration on the bubble size distribution for an air/water system with gasket air injection.

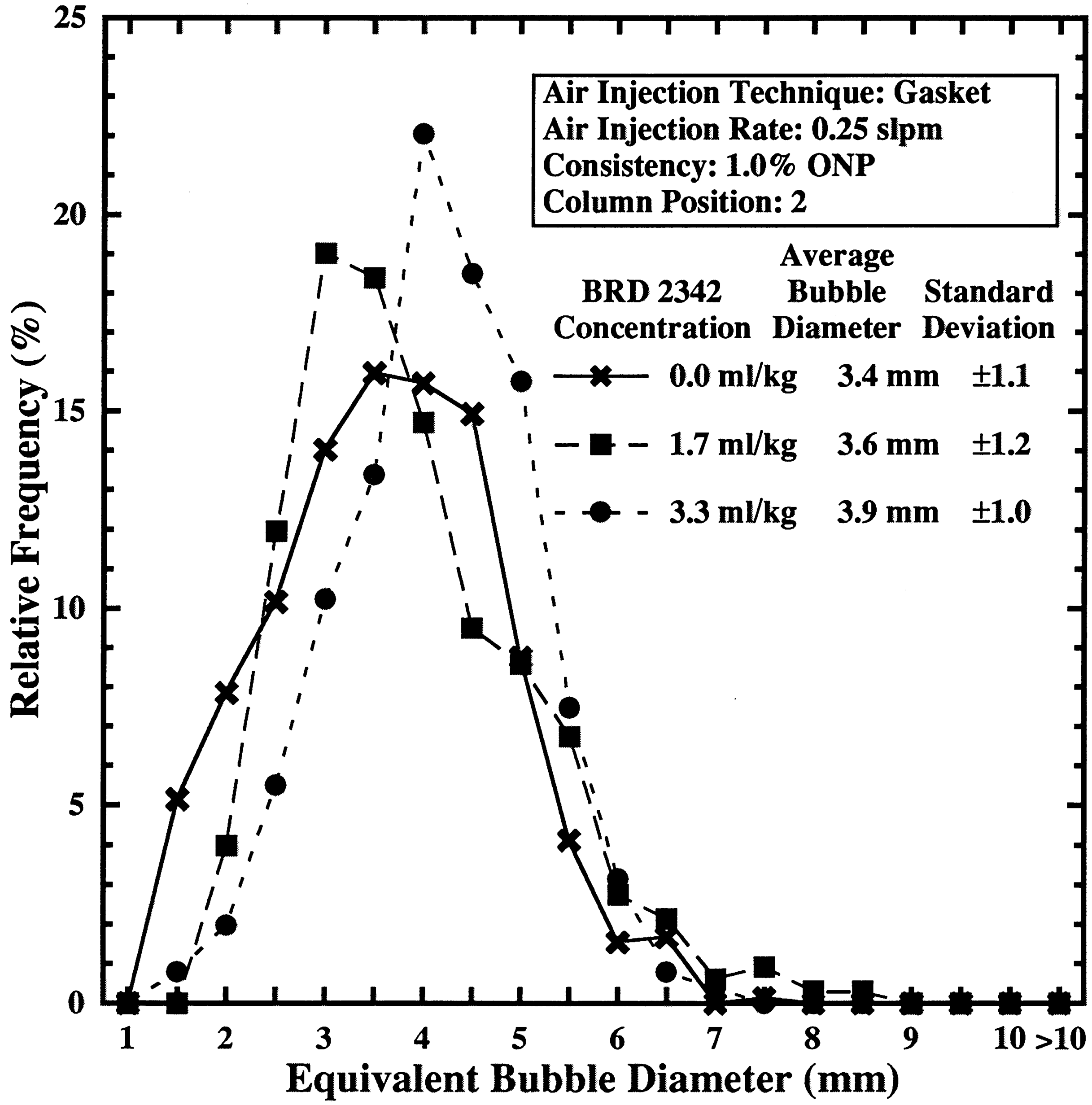

Figure 33: Effect of BRD 2342 concentration on the bubble size distribution for an air/water/1% ONP system with gasket air injection.

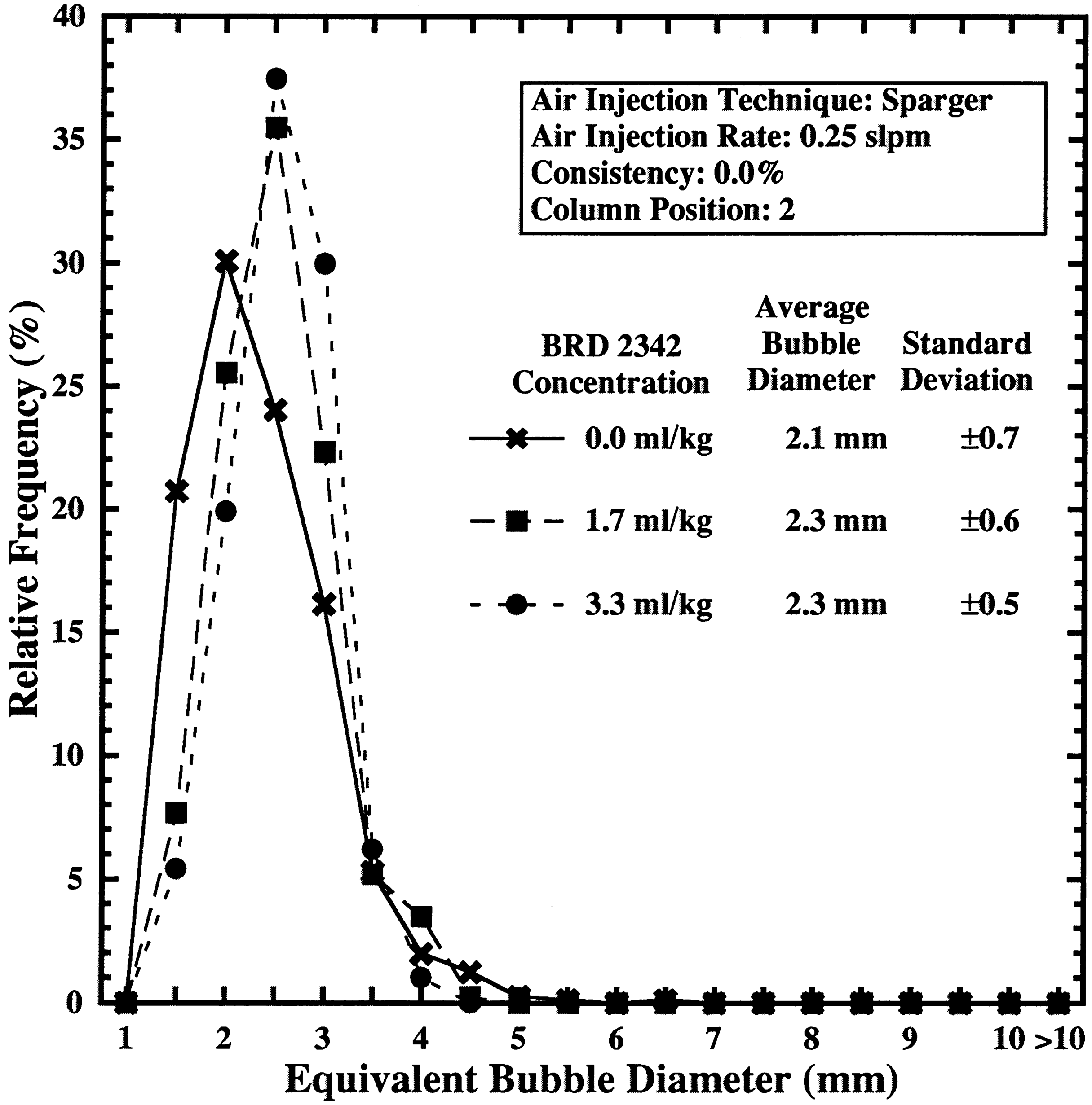

Figure 34: Effect of BRD 2342 concentration on the bubble size distribution for an air/water system with sparger air injection.

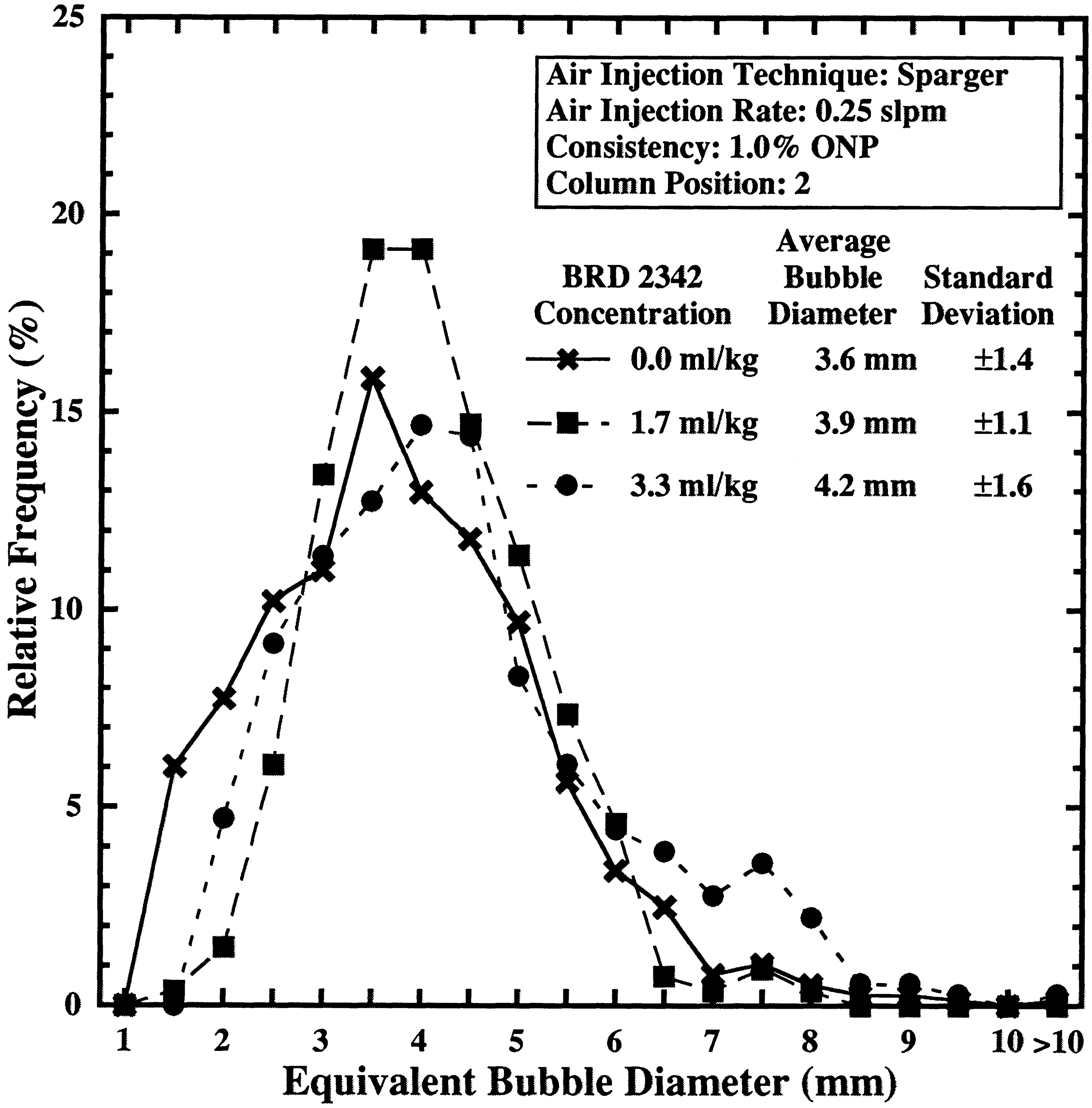

Figure 35: Effect of BRD 2342 concentration on the bubble size distribution for an air/water/1% ONP system with sparger air injection.

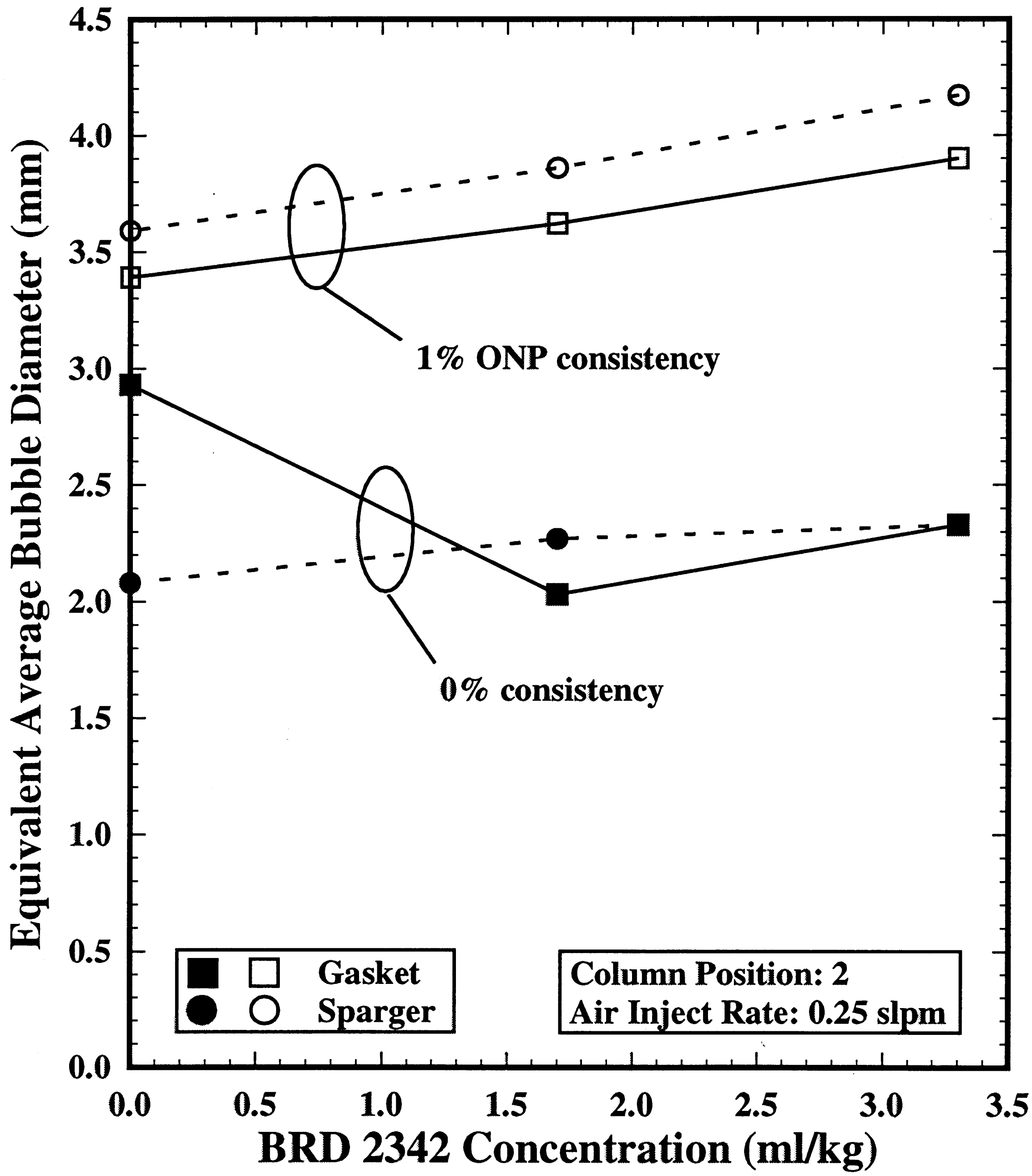

Figure 36: Effect of BRD 2342 concentration on the average bubble size.

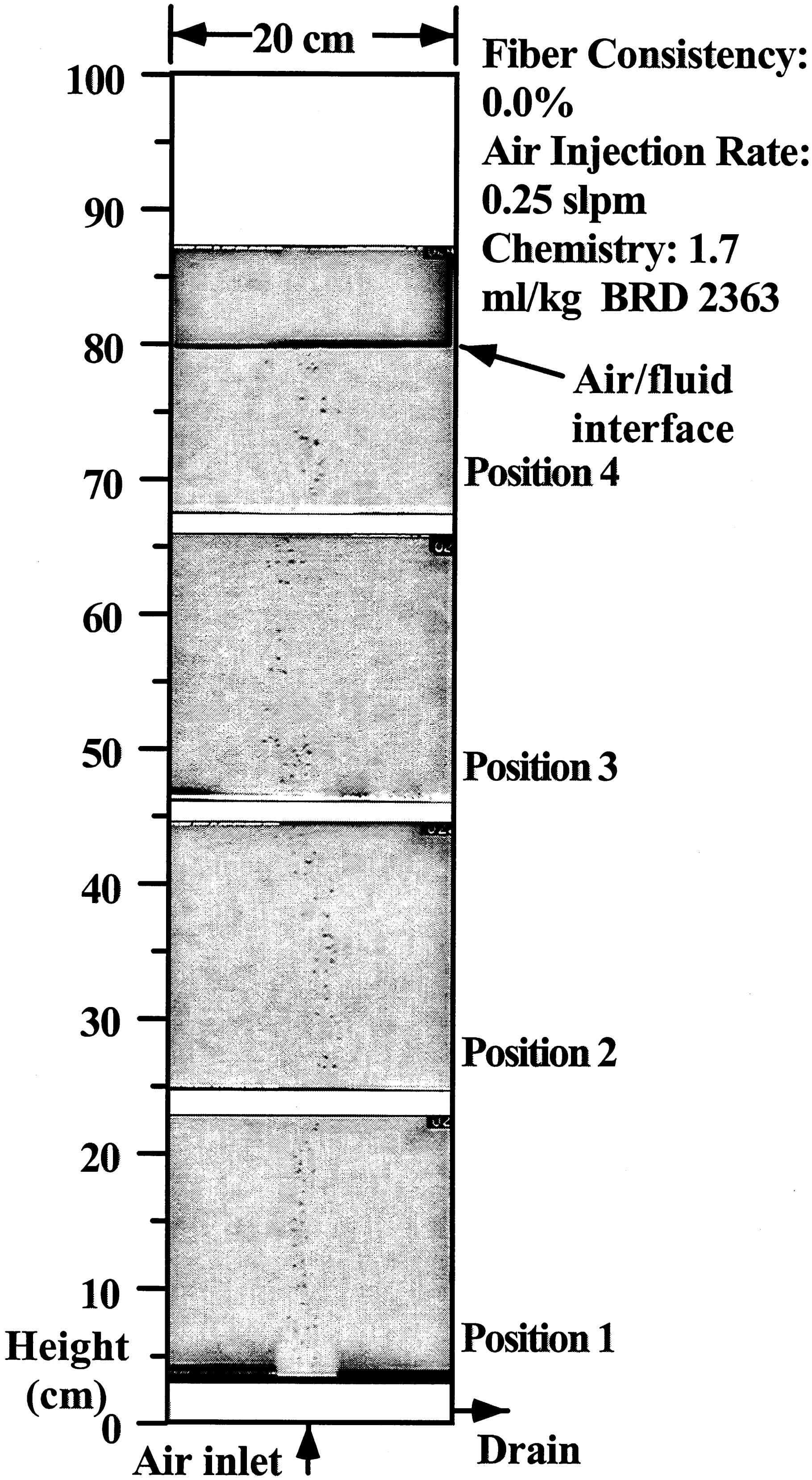

Figure 37: X-ray composite of air bubble flow patterns in an air/water system with 1.7 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

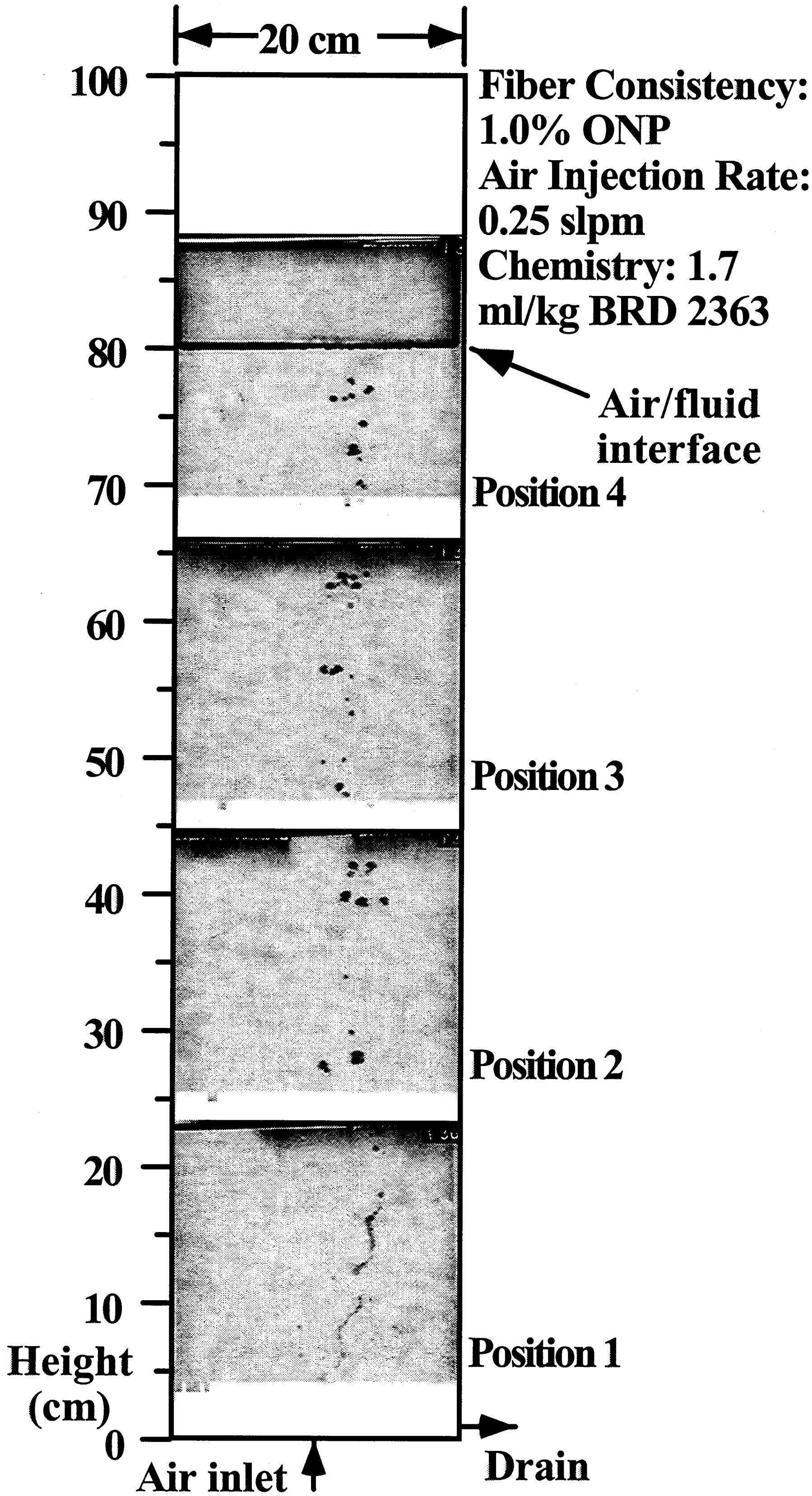

Figure 38: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 1.7 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

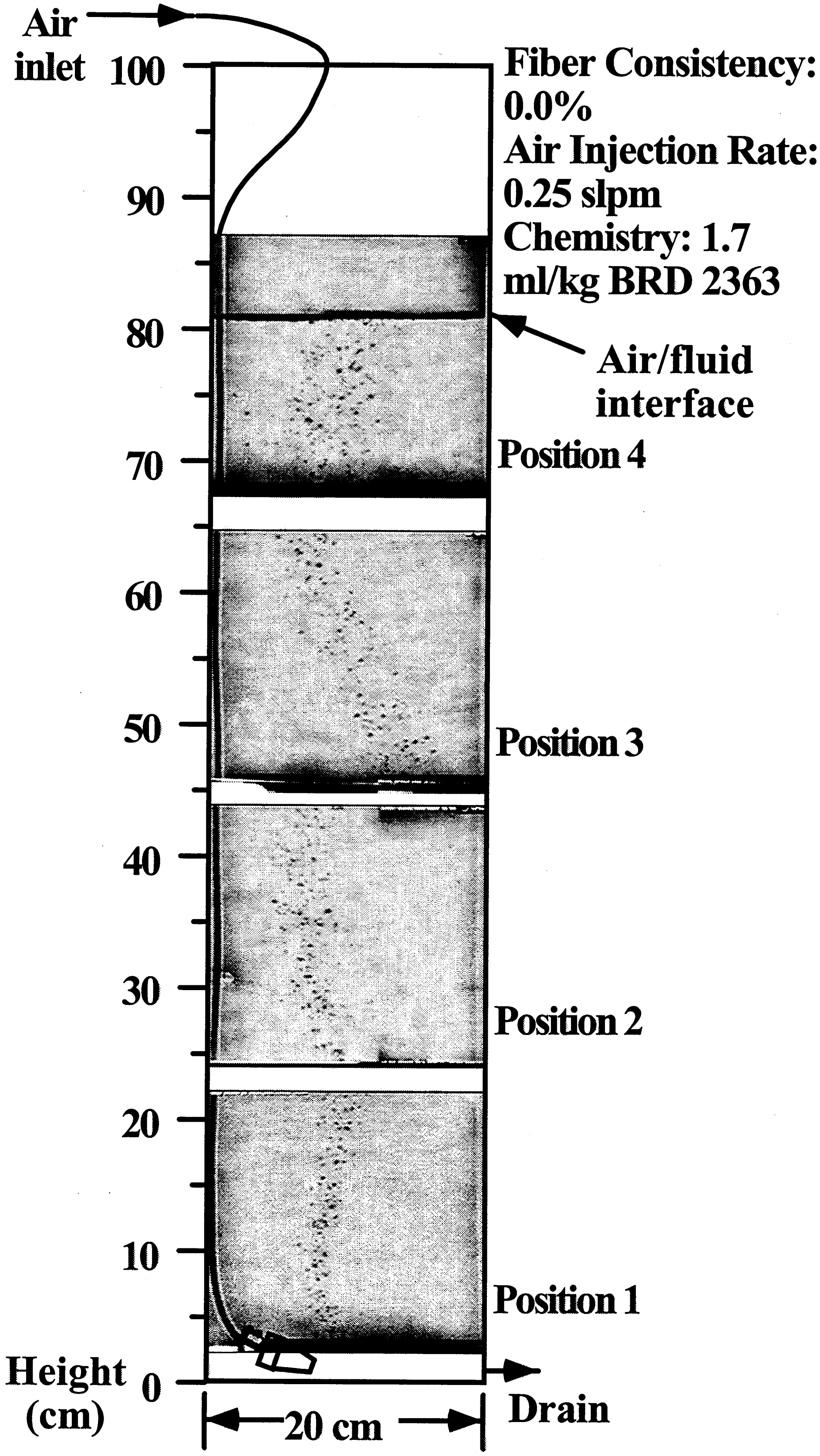

Figure 39: X-ray composite of air bubble flow patterns in an air/water system with 1.7 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

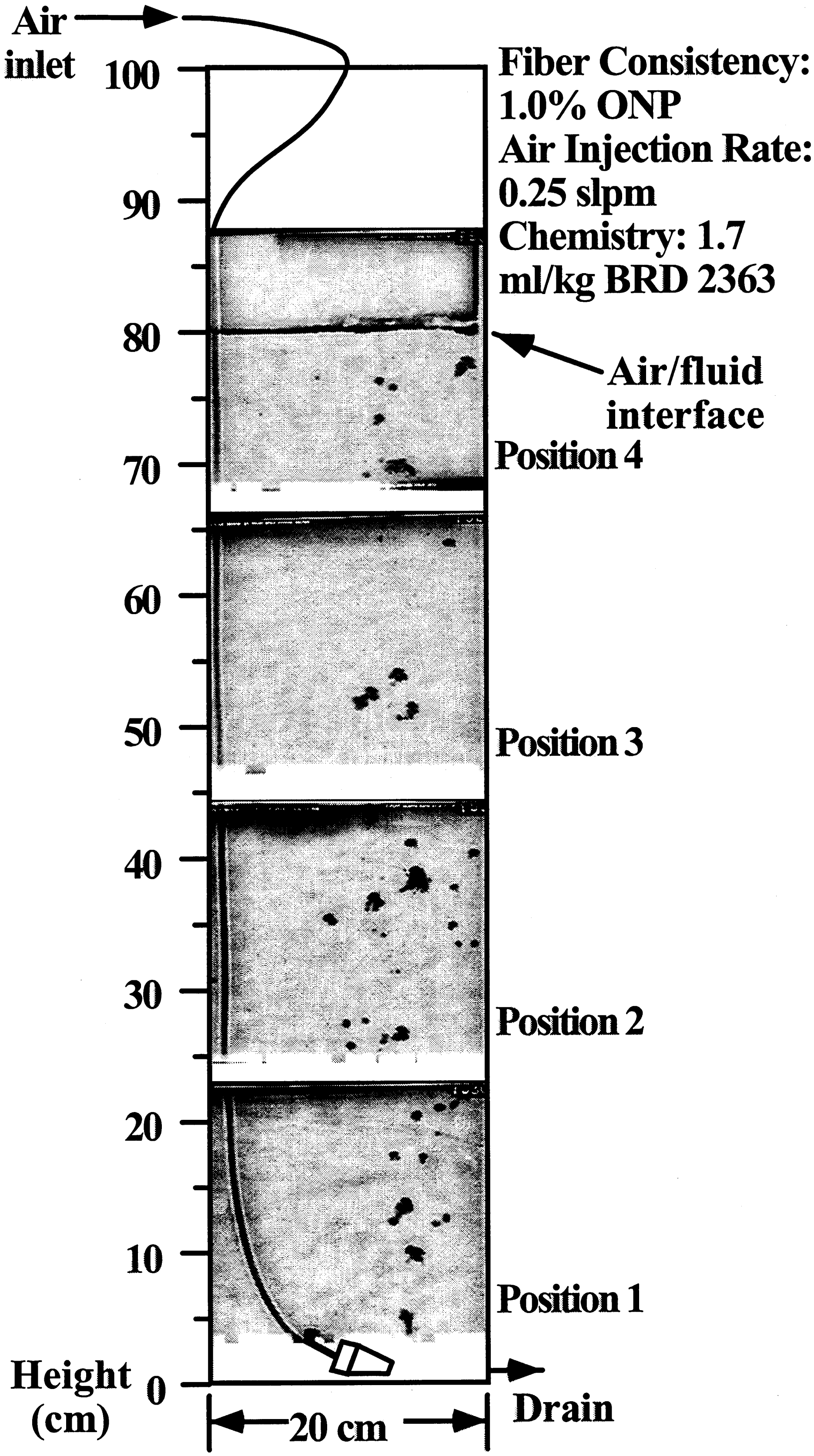

Figure 40: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 1.7 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 µm openings placed on the column bottom.

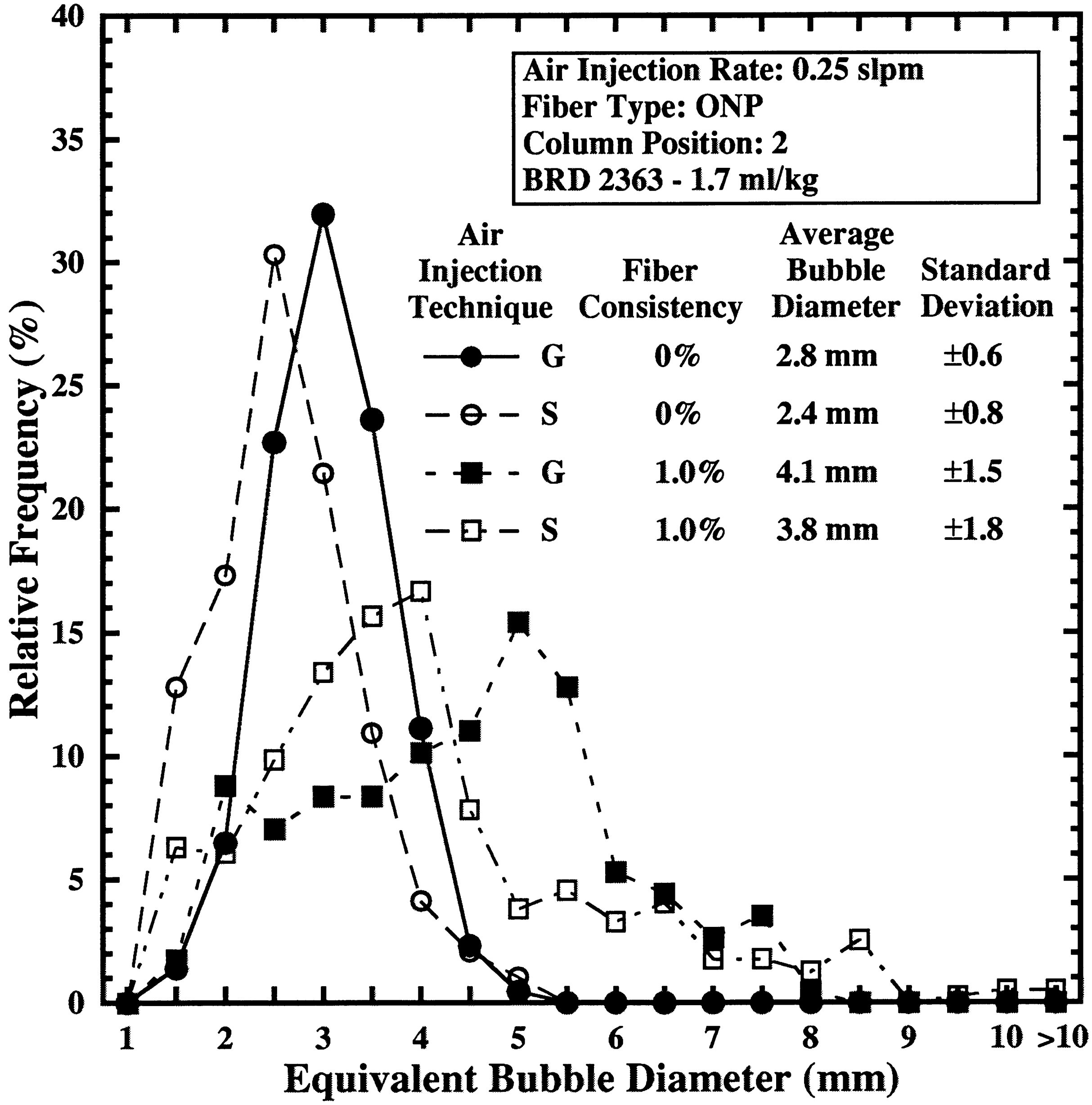

Figure 41: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 1.7 ml/kg of BRD 2363 added to the system.

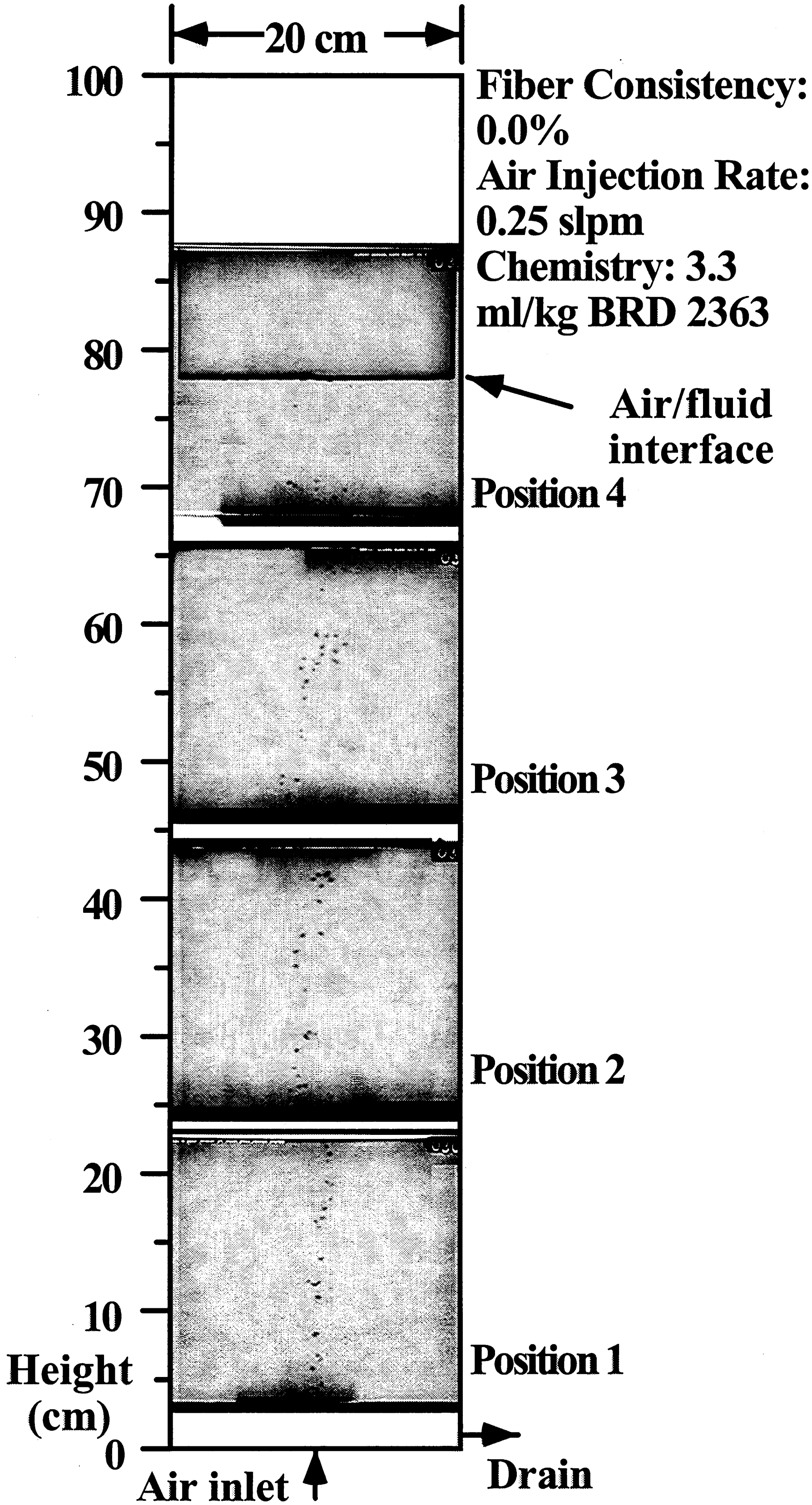

Figure 42: X-ray composite of air bubble flow patterns in an air/water system with 3.3 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

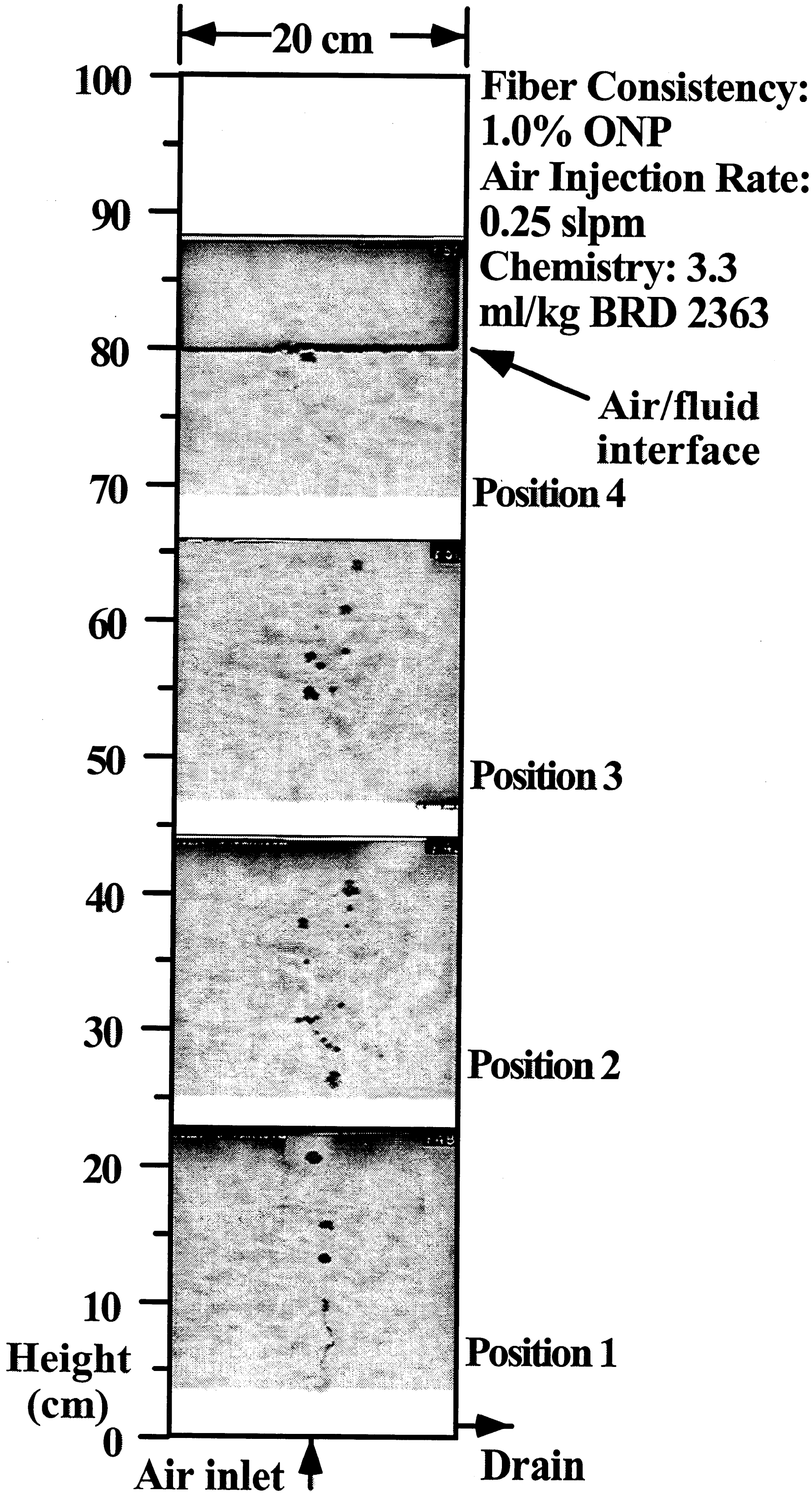

Figure 43: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 3.3 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a single-holed gasket located on the column bottom.

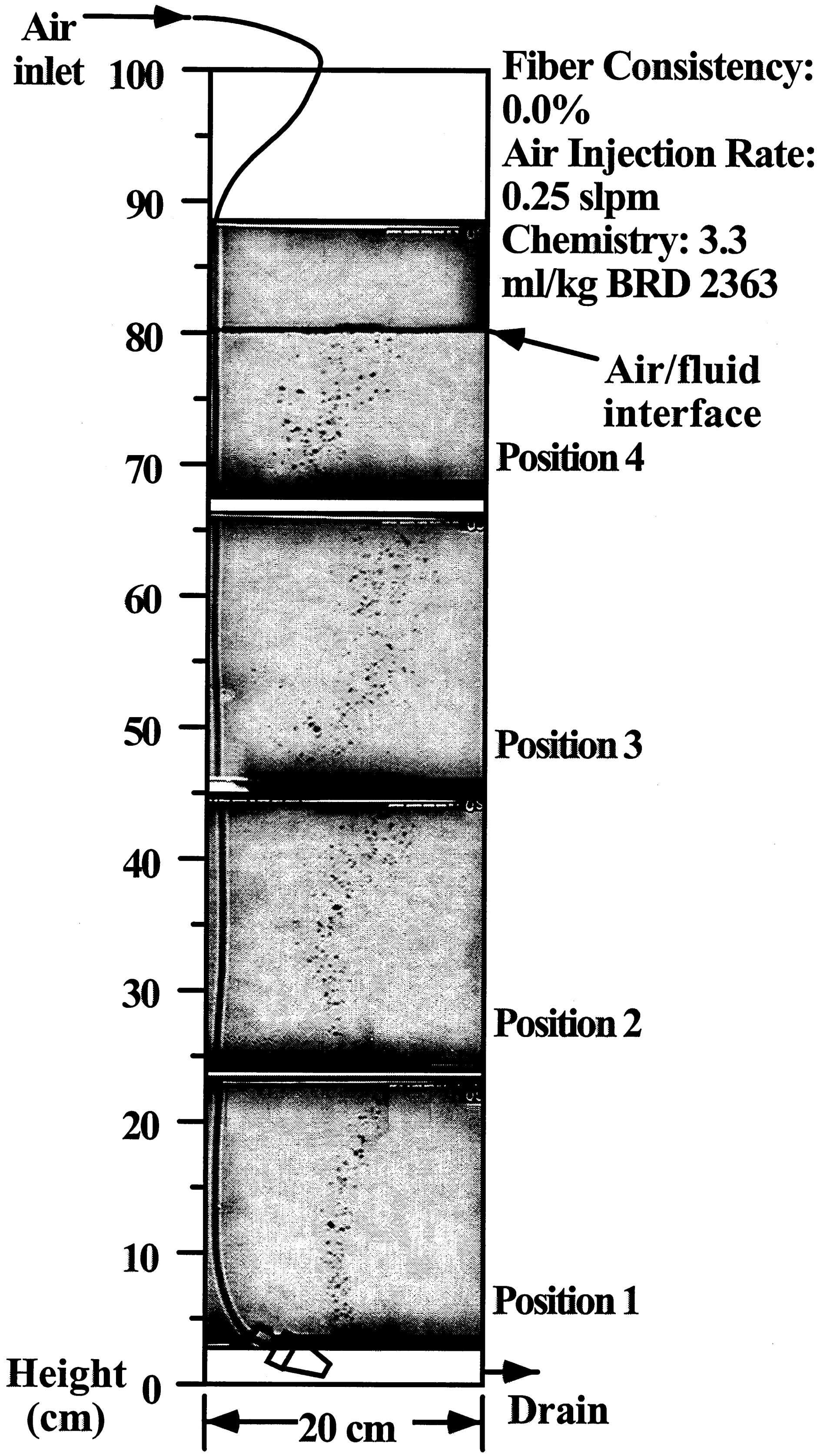

Figure 44: X-ray composite of air bubble flow patterns in an air/water system with 3.3 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

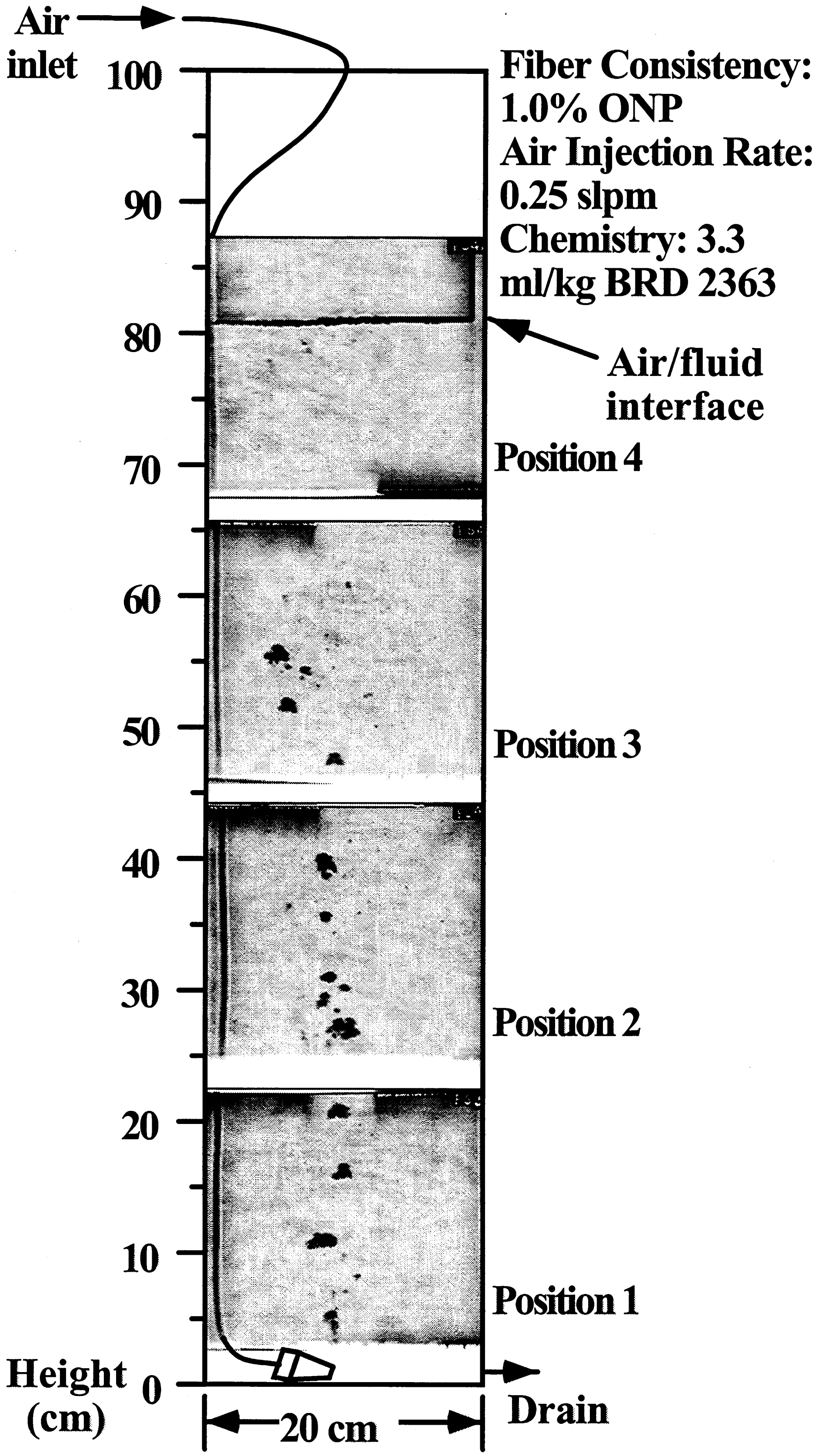

Figure 45: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with 3.3 ml/kg of BRD 2363 added to the system. Air at 0.25 slpm is being injected through a sparger with 40 μm openings placed on the column bottom.

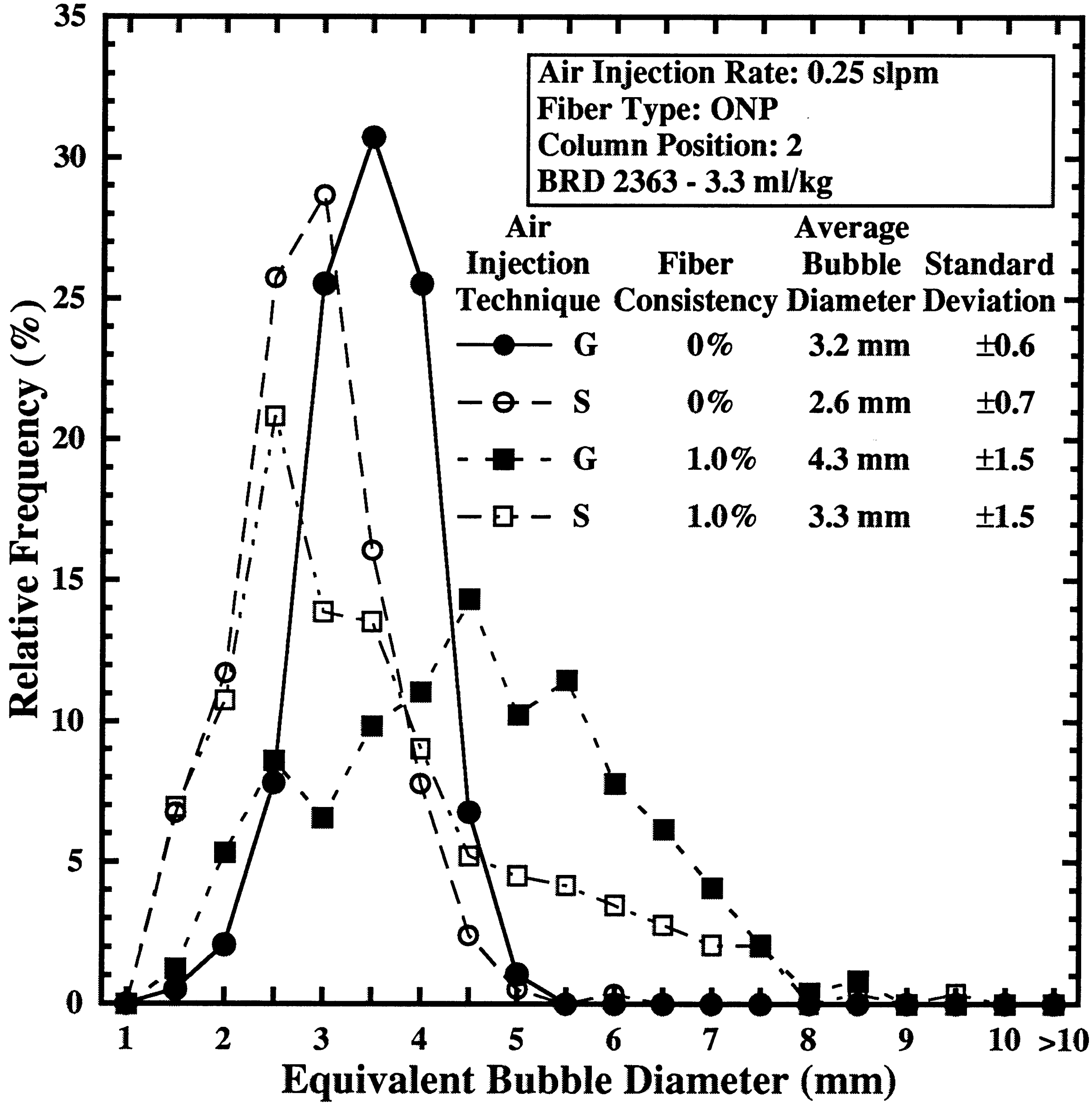

Figure 46: Bubble size distributions obtained in air/water and air/water/1% ONP systems with 3.3 ml/kg of BRD 2363 added to the system.

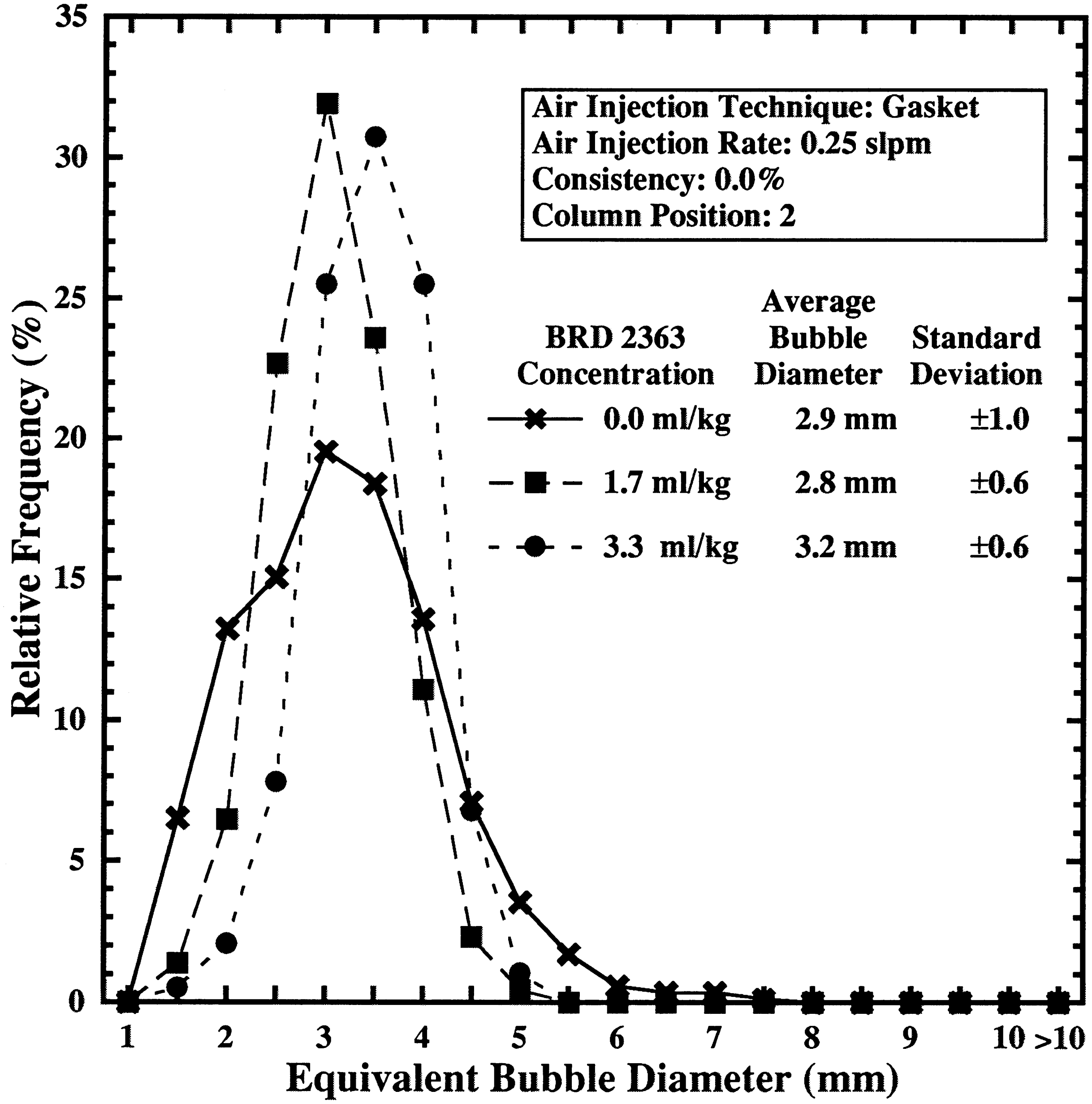

Figure 47: Effect of BRD 2363 concentration on the bubble size distribution for an air/water system with gasket air injection.

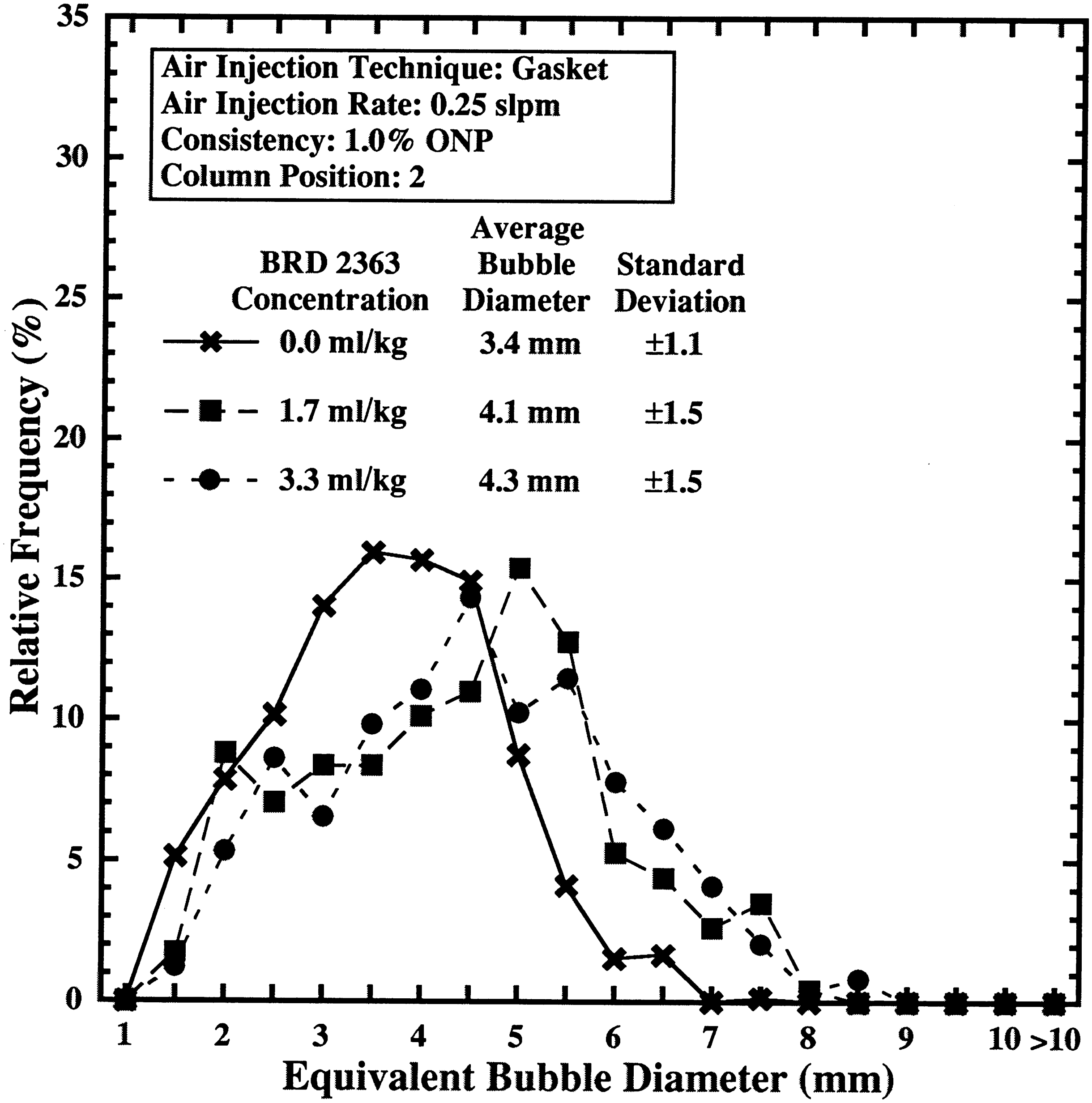

Figure 48: Effect of BRD 2363 concentration on the bubble size distribution for an air/water/1% ONP system with gasket air injection.

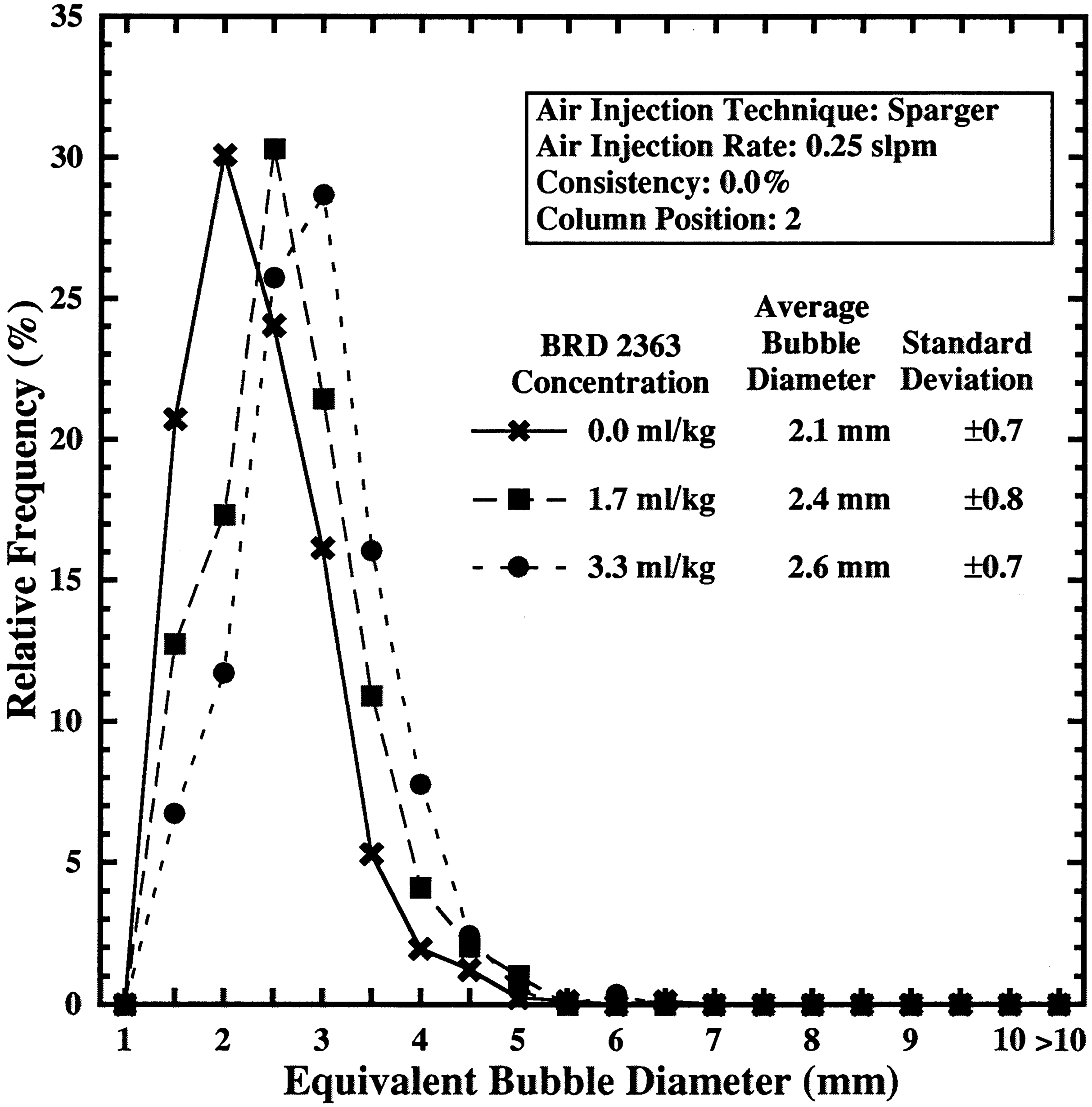

Figure 49: Effect of BRD 2363 concentration on the bubble size distribution for an air/water system with sparger air injection.

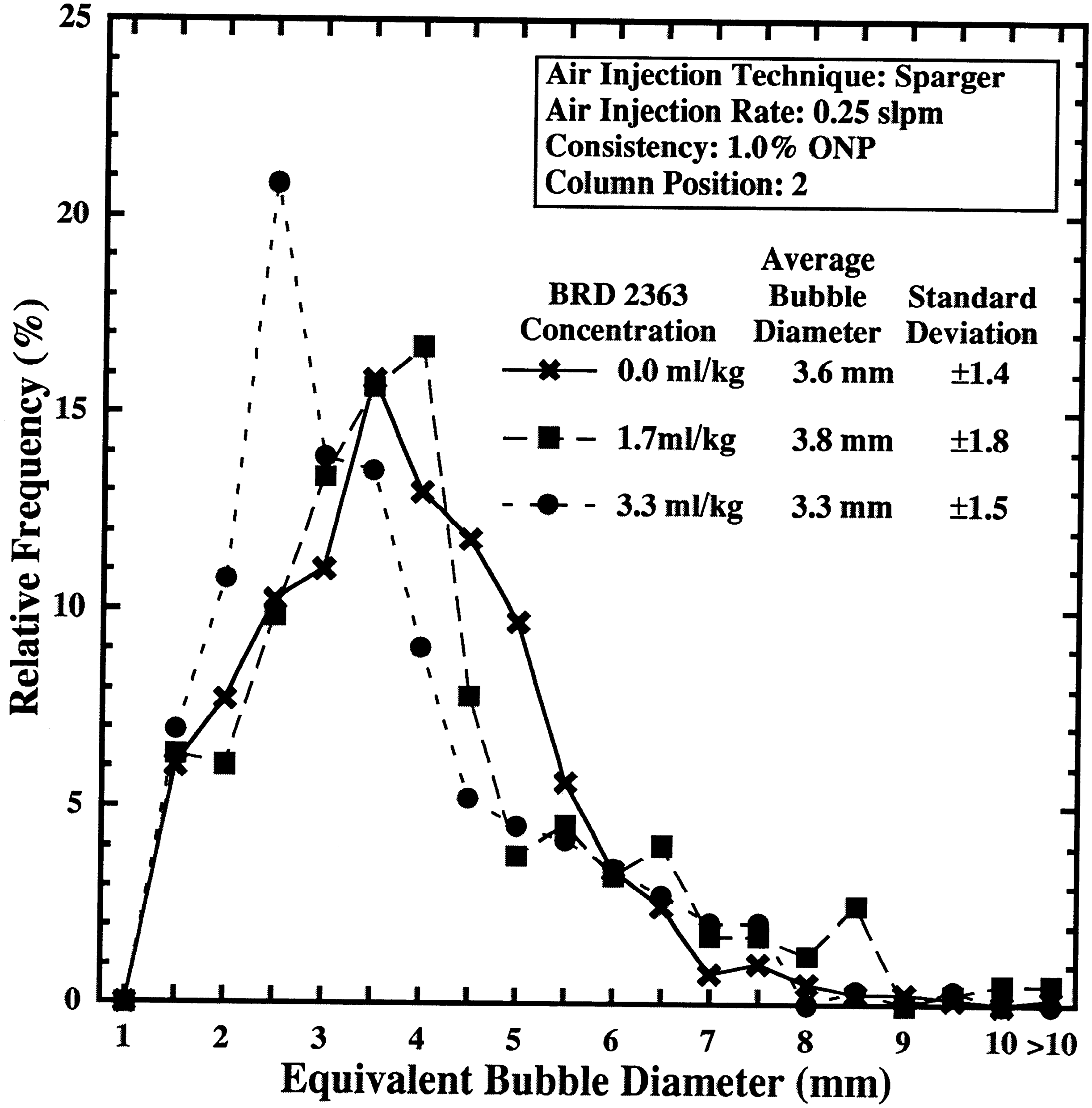

Figure 50: Effect of BRD 2363 concentration on the bubble size distribution for an air/water/1% ONP system with sparger air injection.

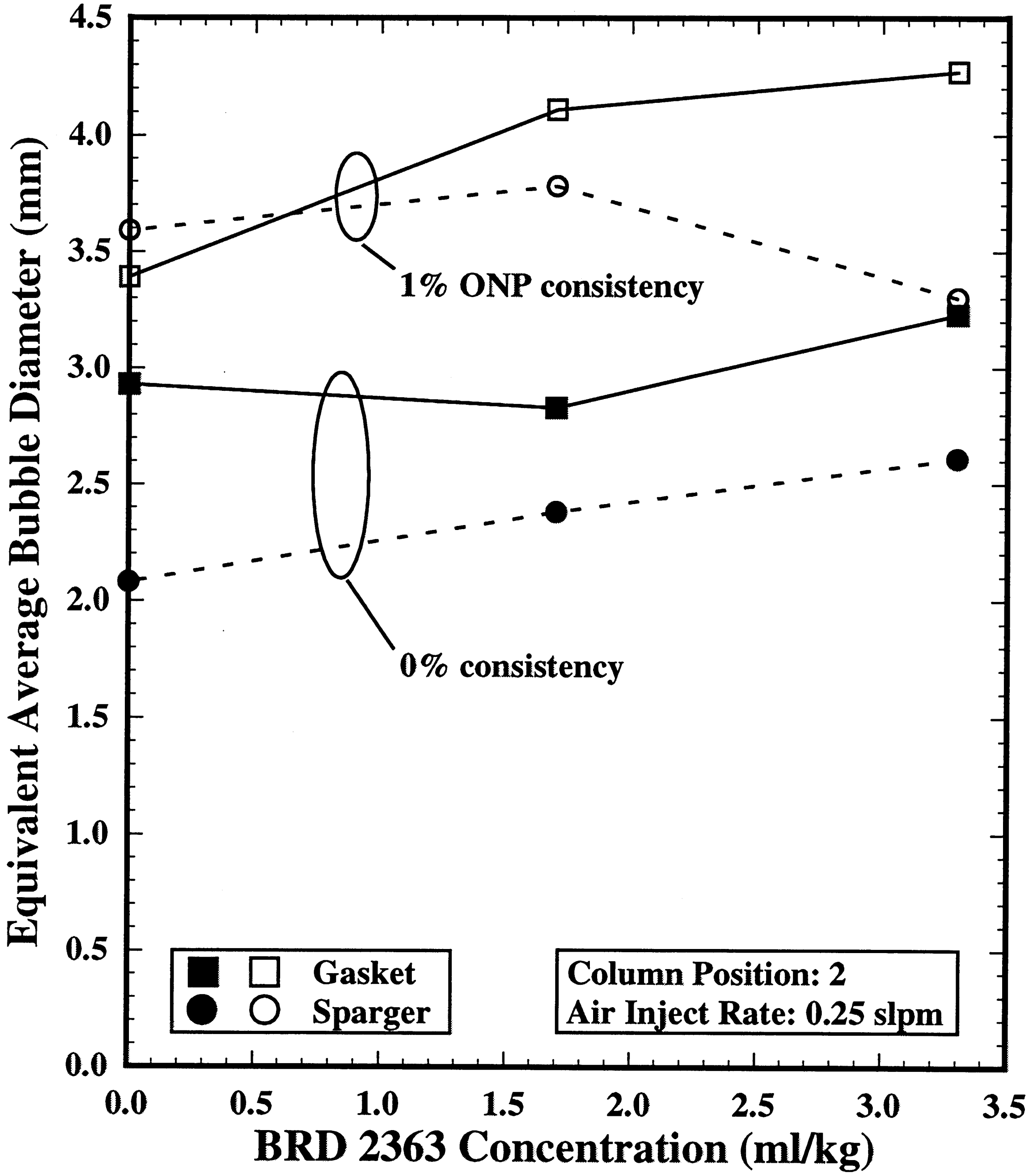

Figure 51: Effect of BRD 2363 concentration on the average bubble size.

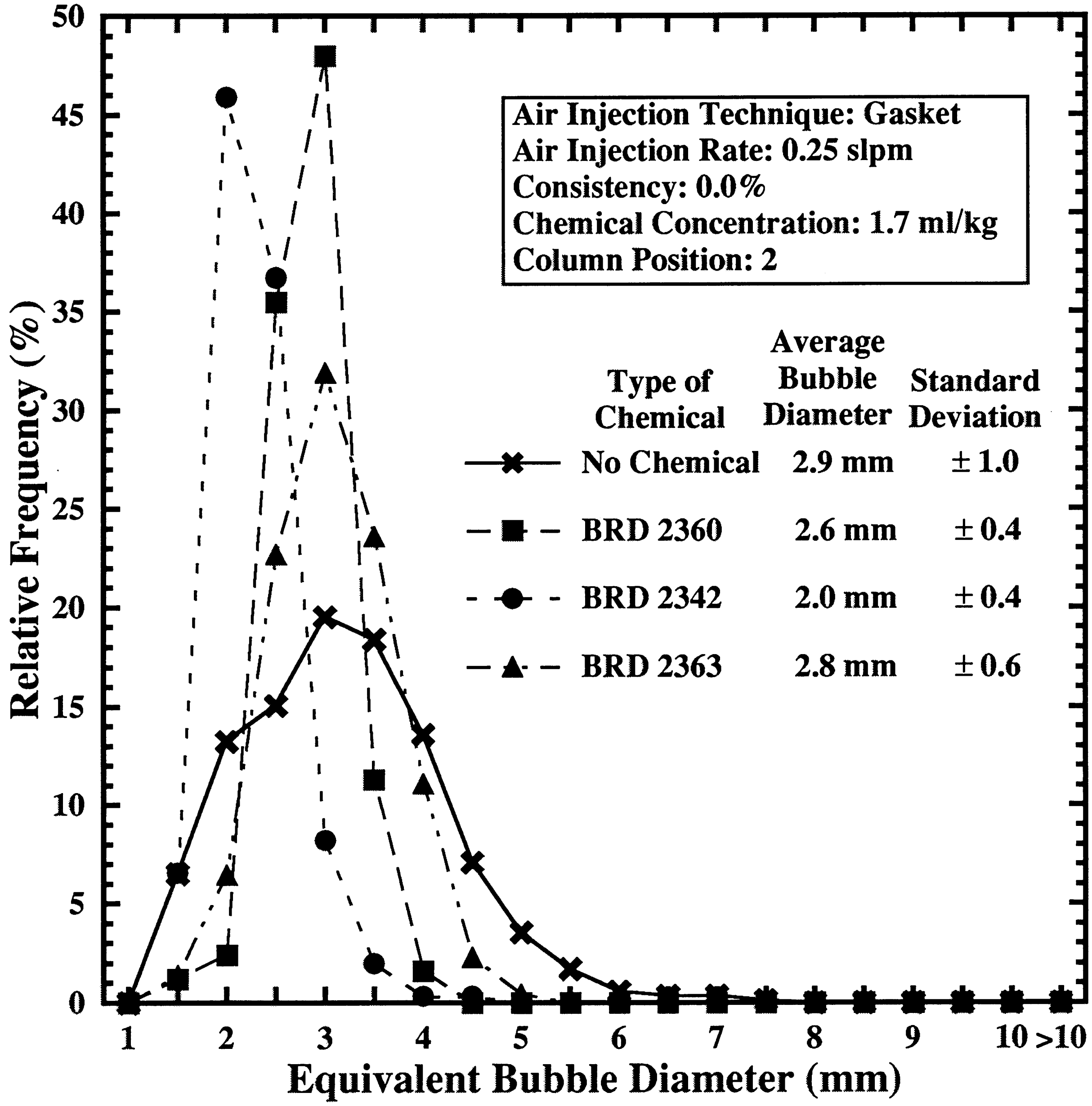

Figure 52: Effect of BRD type (concentration of 1.7 ml/kg) on the bubble size distribution for an air/water system with gasket air injection.

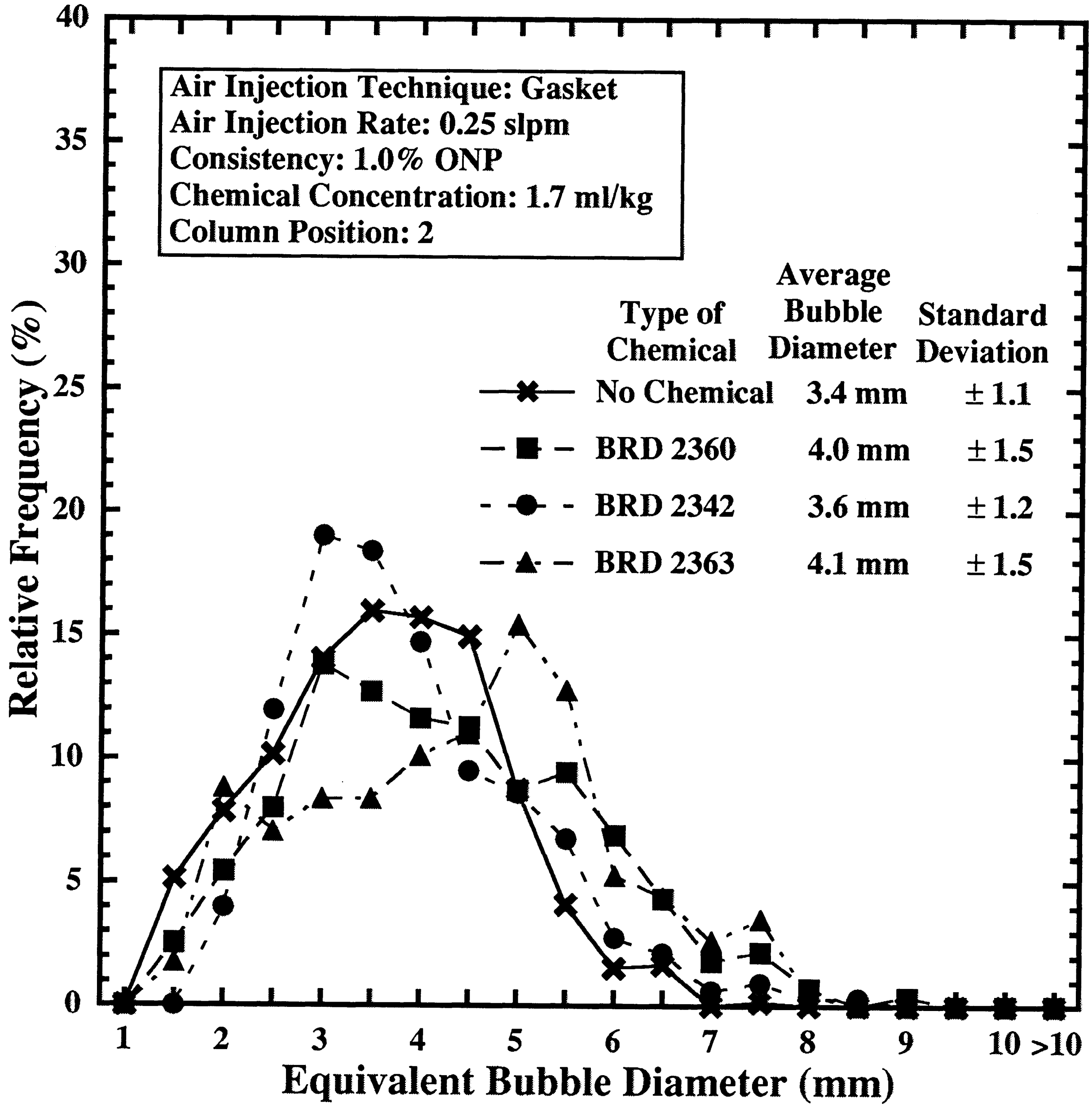

Figure 53: Effect of BRD type (concentration of 1.7 ml/kg) on the bubble size distribution for an air/water/1% ONP system with gasket air injection.

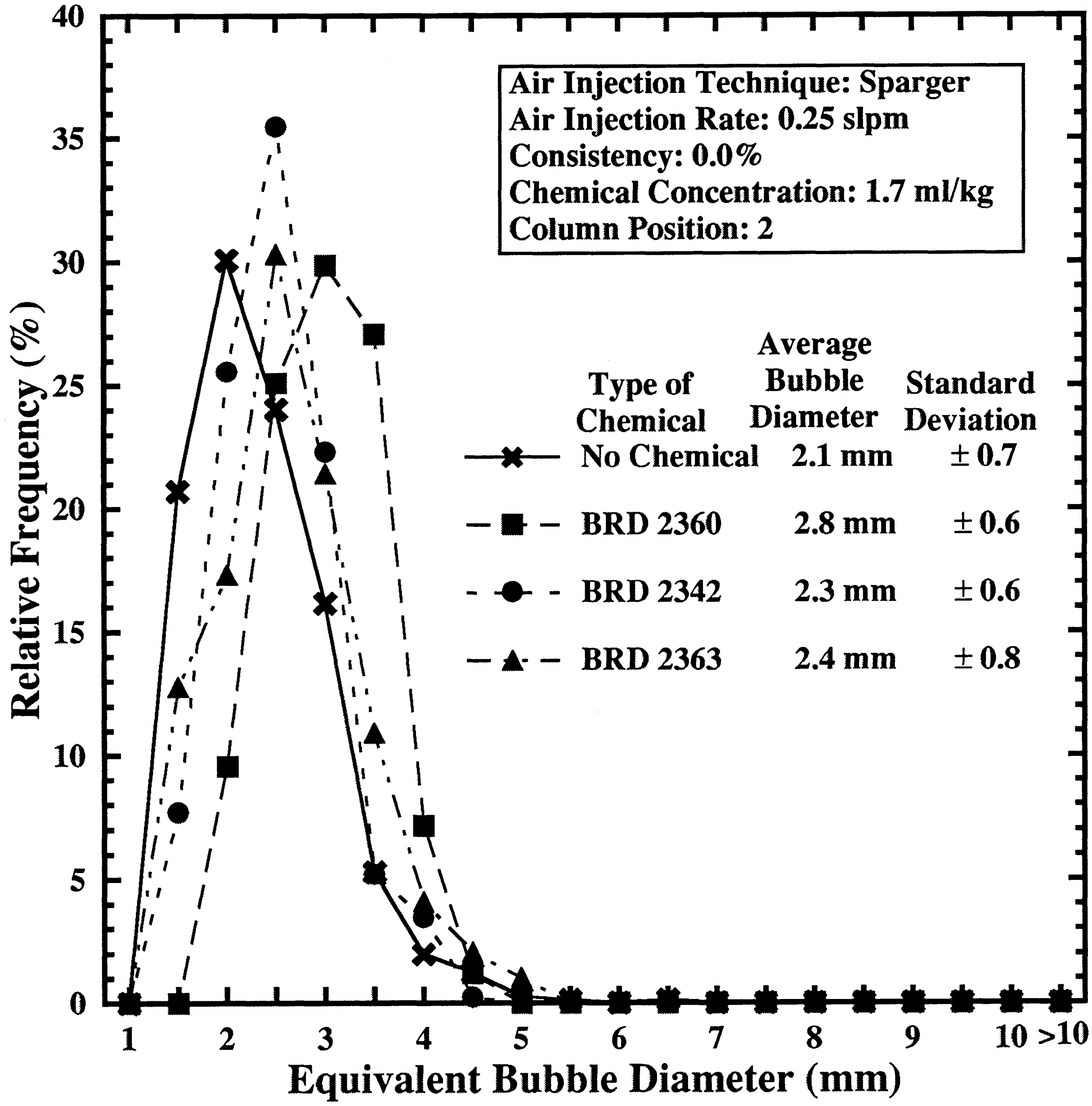

Figure 54: Effect of BRD type (concentration of 1.7 ml/kg) on the bubble size distribution for an air/water system with sparger air injection.

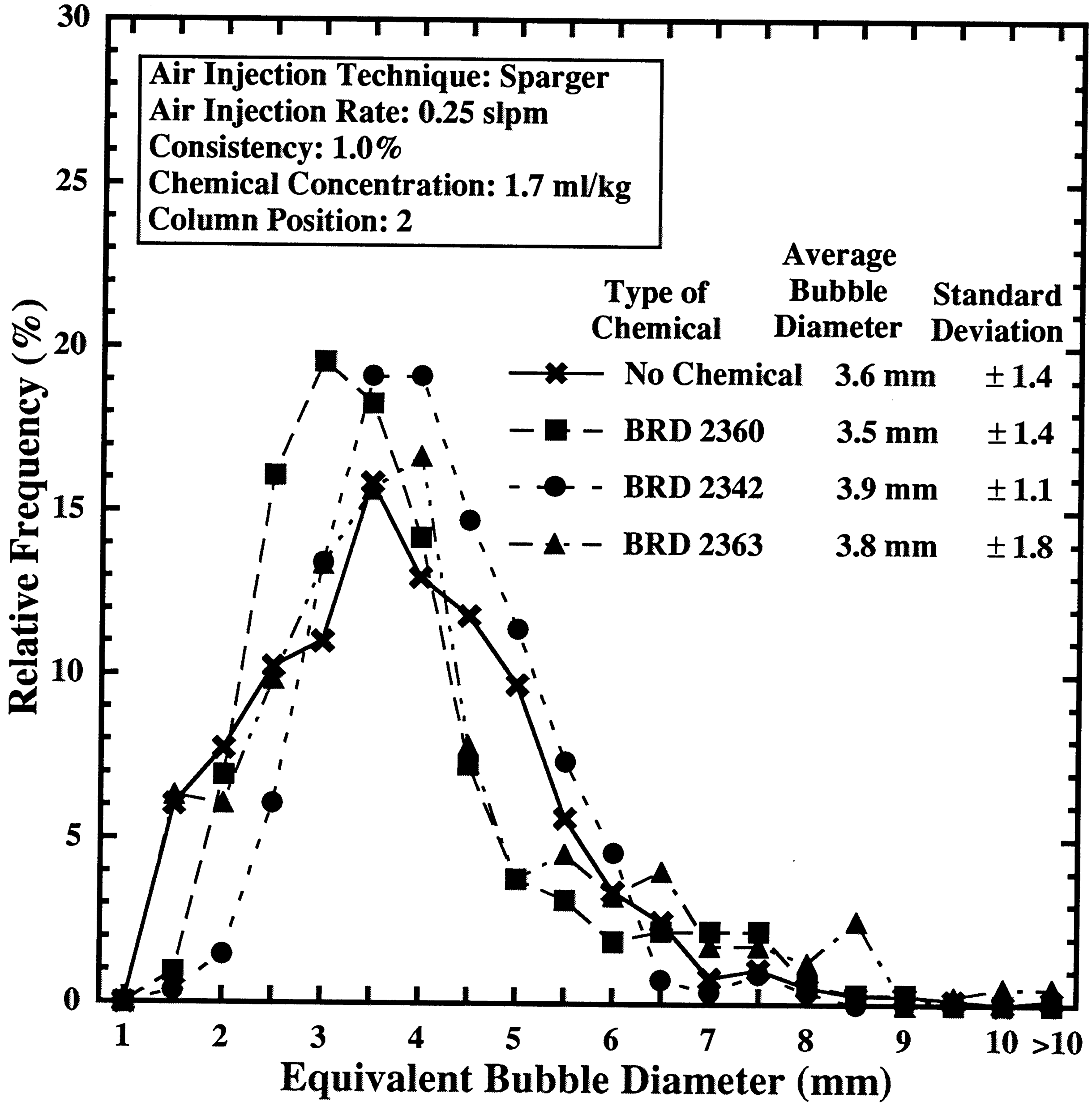

Figure 55: Effect of BRD type (concentration of 1.7 ml/kg) on the bubble size distribution for an air/water/1% ONP system with sparger air injection.

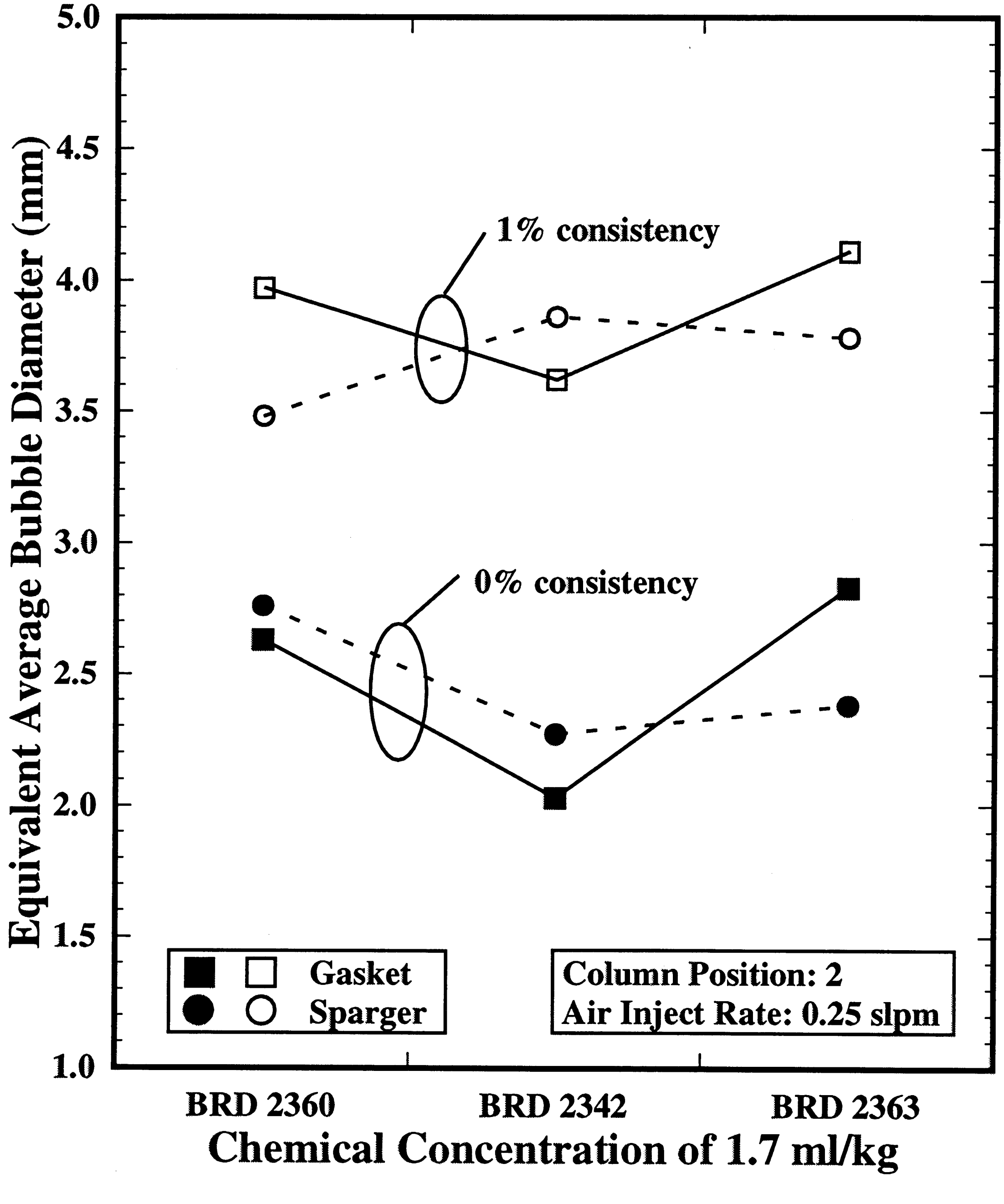

Figure 56: Effect of BRD type (concentration of 1.7 ml/kg) on the average bubble size.

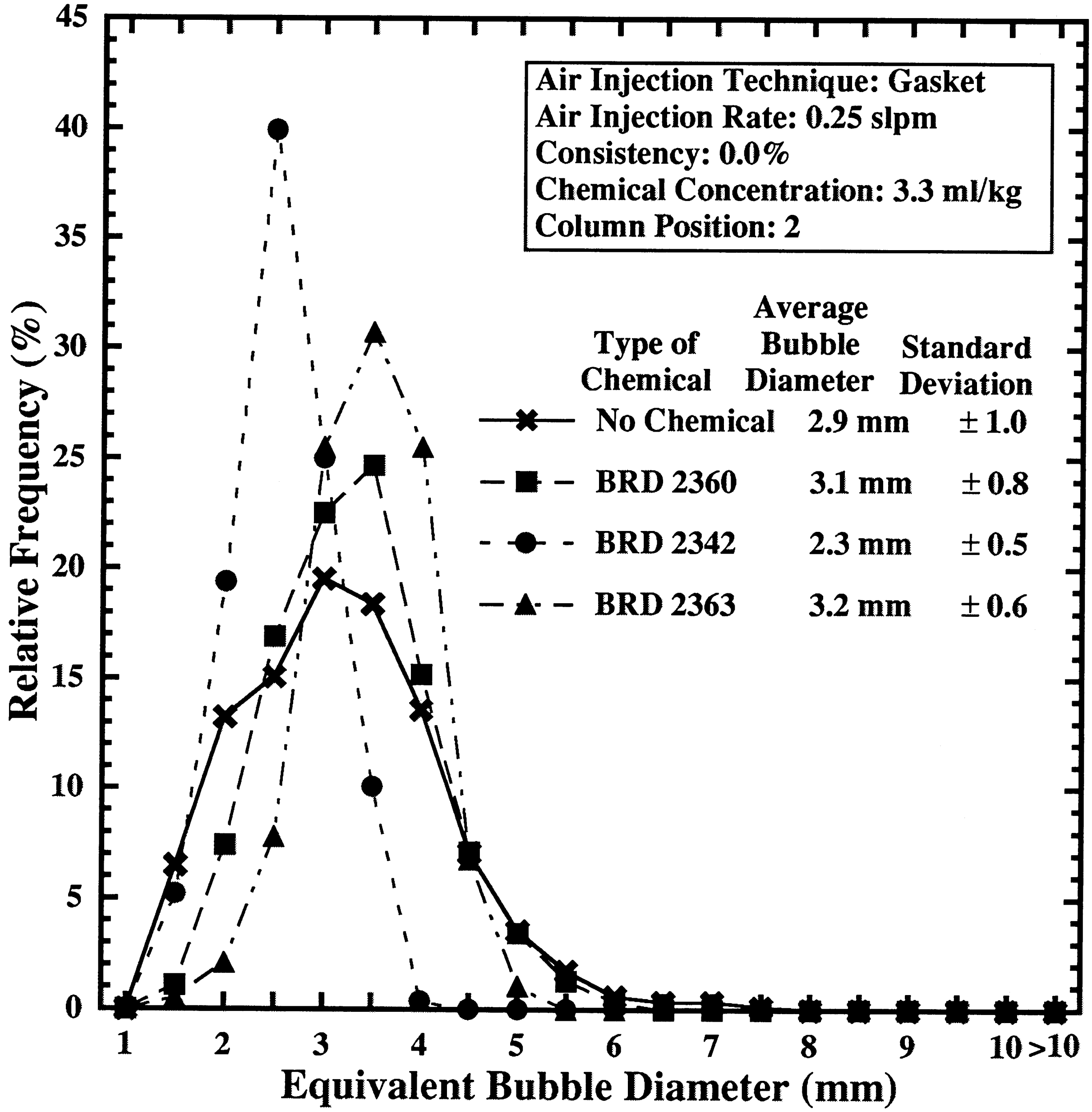

Figure 57: Effect of BRD type (concentration of 3.3 ml/kg) on the bubble size distribution for an air/water system with gasket air injection.

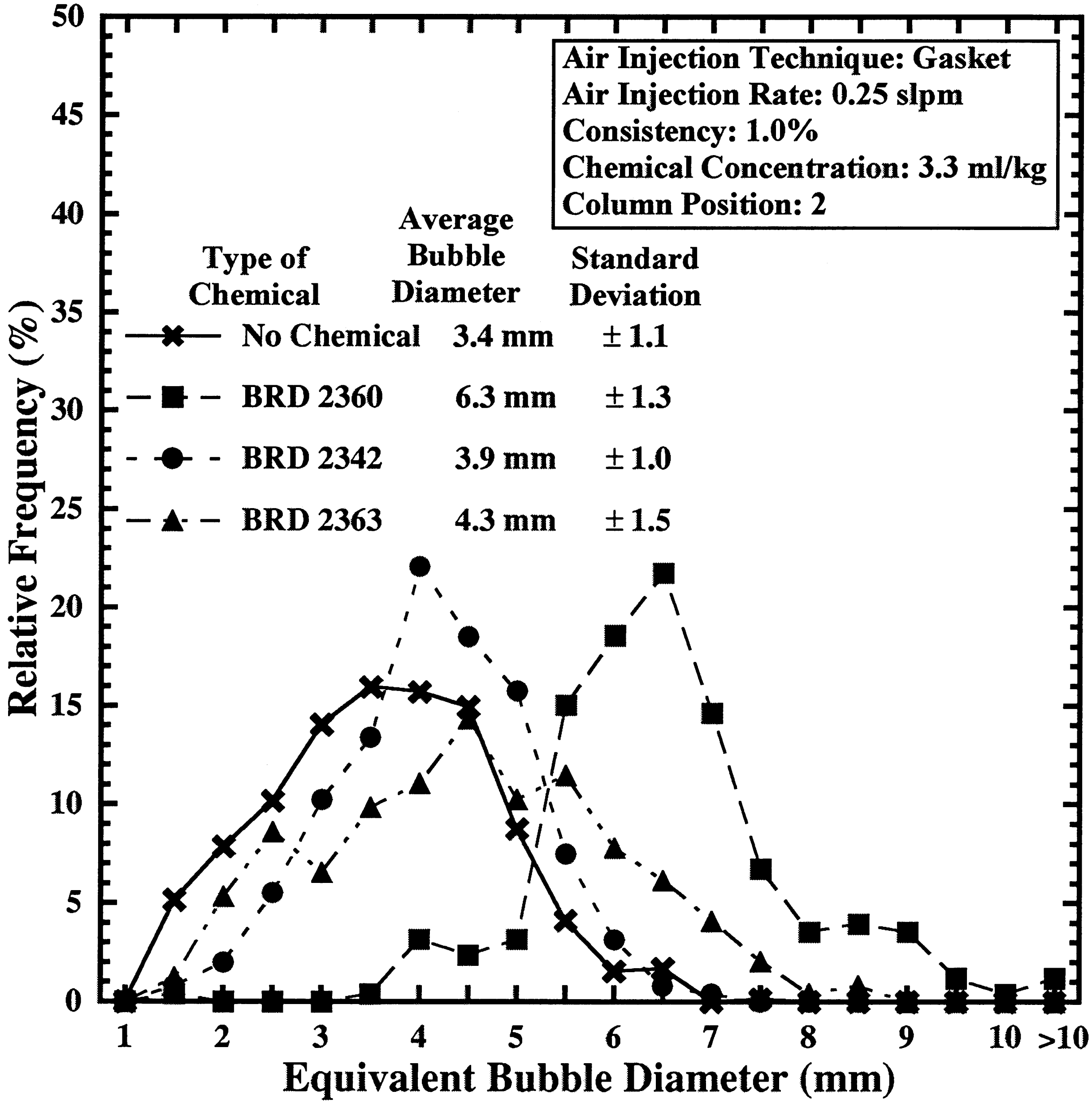

Figure 58: Effect of BRD type (concentration of 3.3 ml/kg) on the bubble size distribution for an air/water/1% ONP system with gasket air injection.

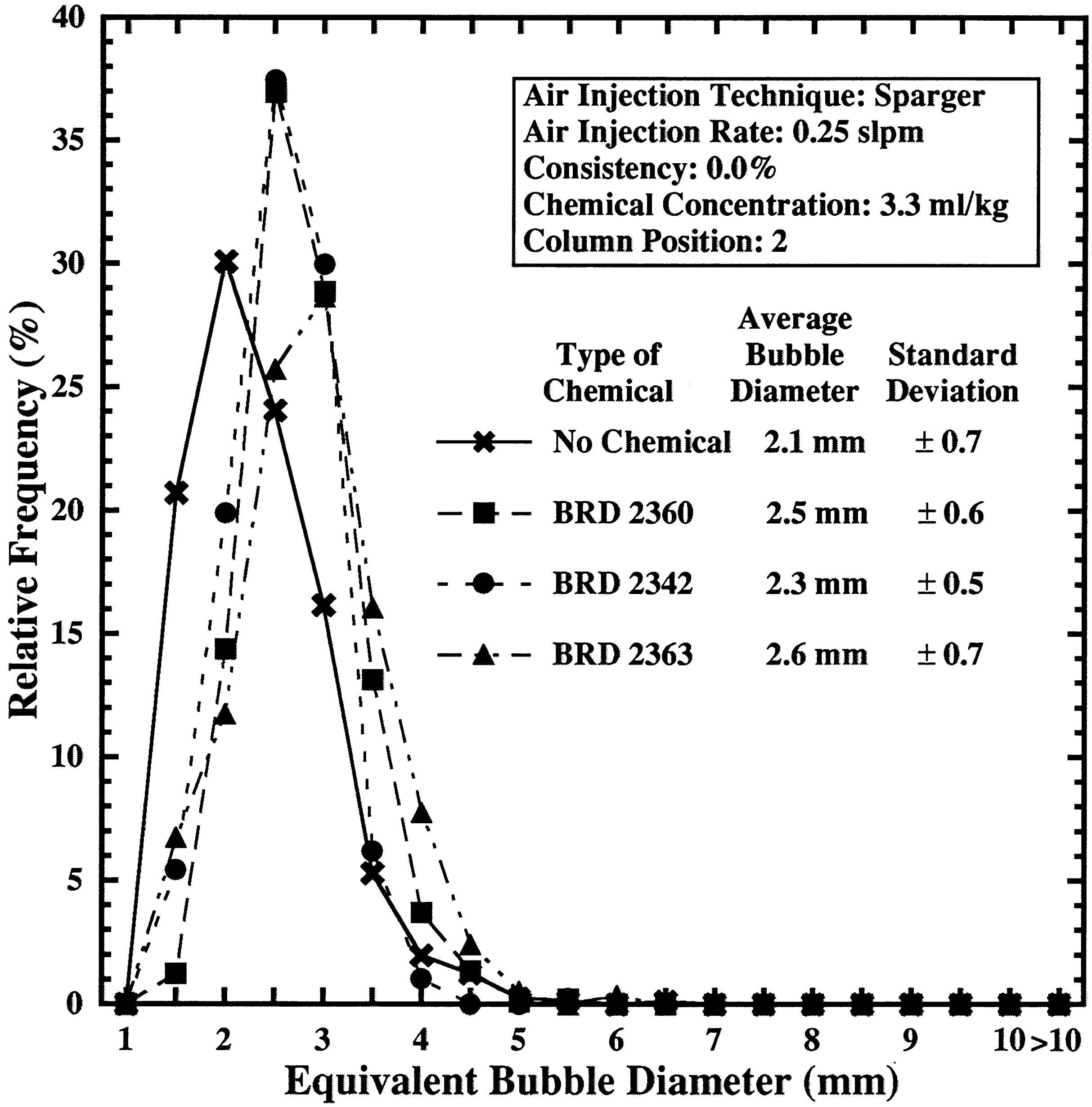

Figure 59: Effect of BRD type (concentration of 3.3 ml/kg) on the bubble size distribution for an air/water system with sparger air injection.

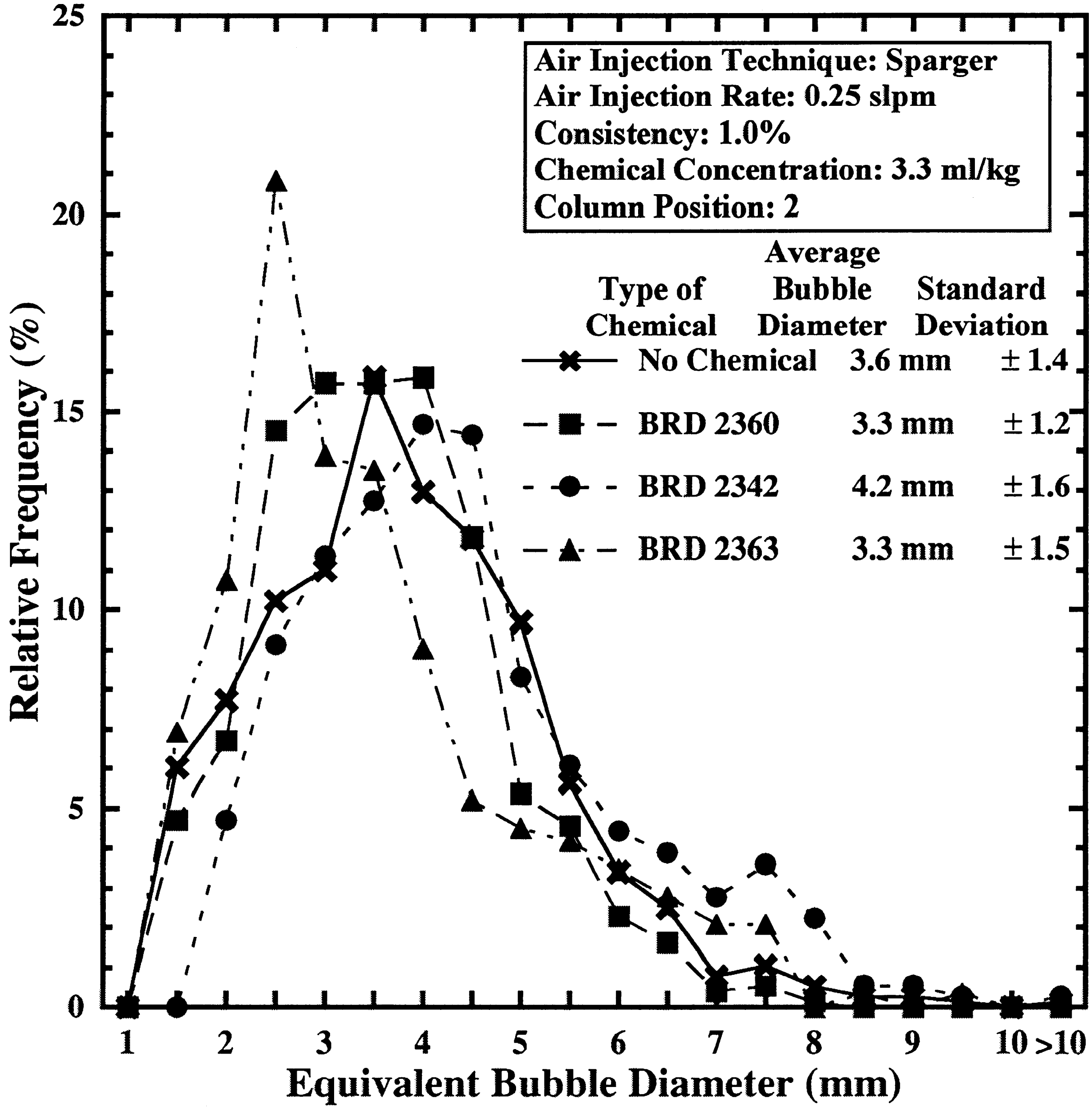

Figure 60: Effect of BRD type (concentration of 3.3 ml/kg) on the bubble size distribution for an air/water/1% ONP system with sparger air injection.

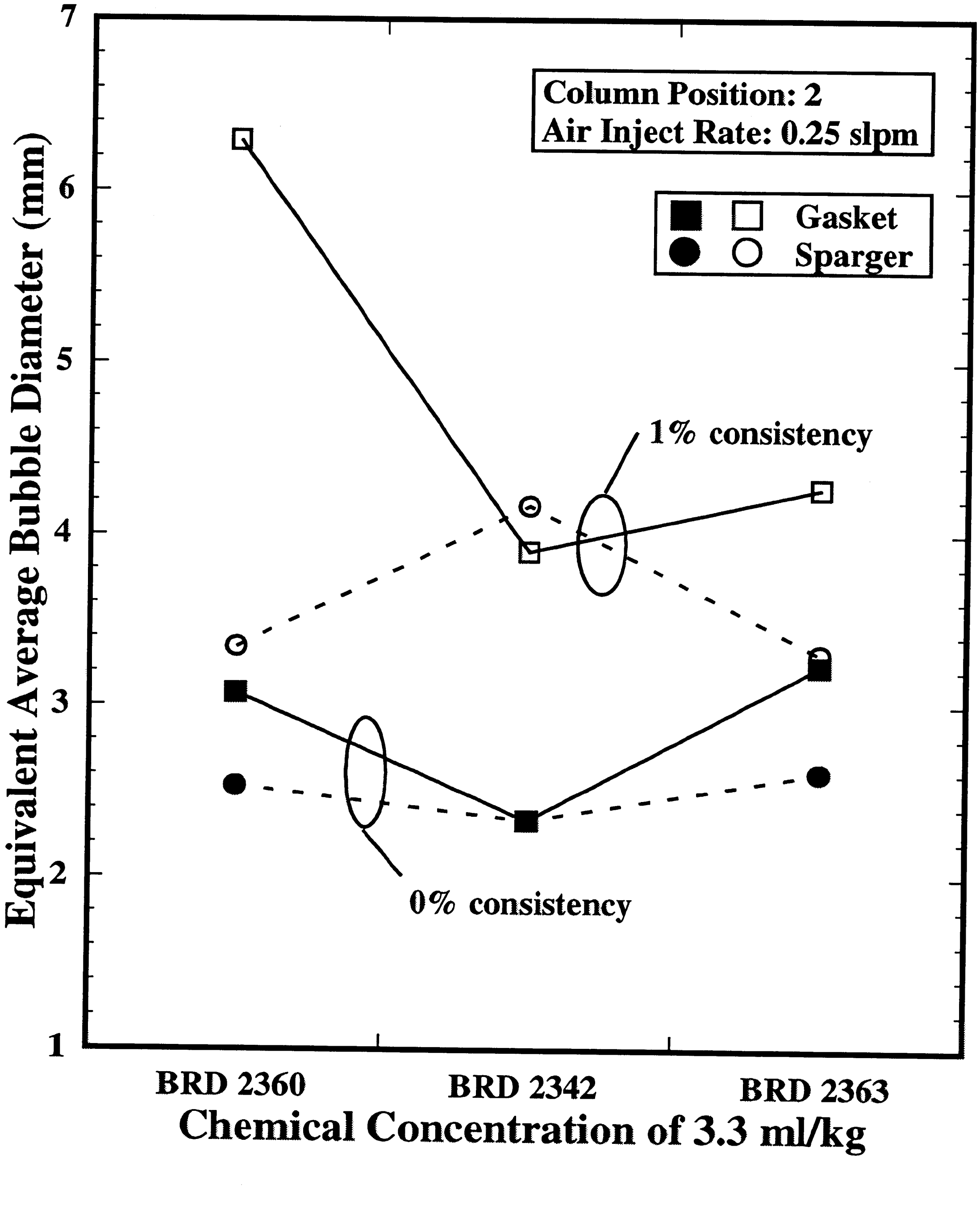

Figure 61: Effect of BRD type (concentration of 3.3 ml/kg) on the average bubble size.

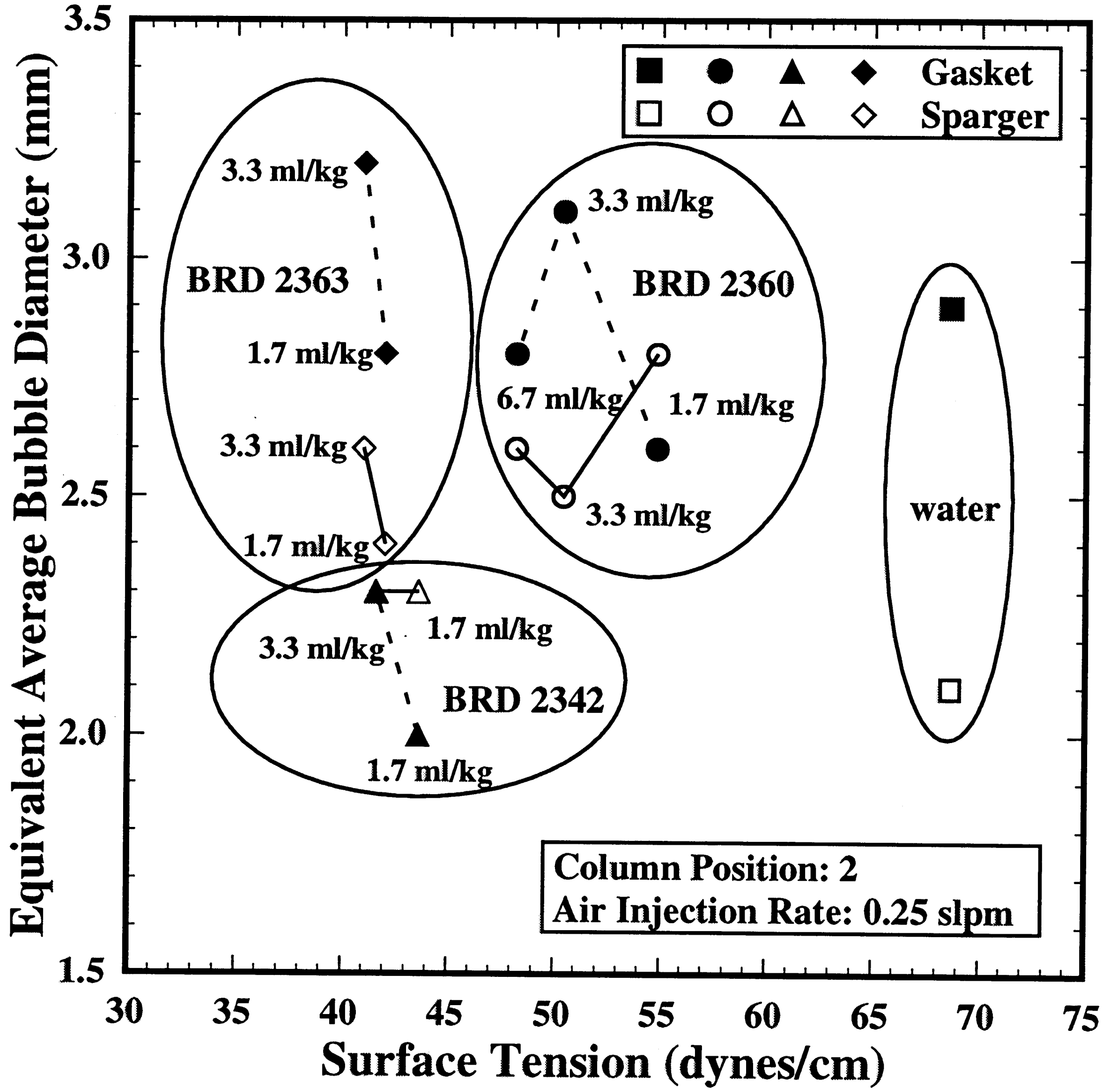

Figure 62: Effect of surface tension on the average bubble size.

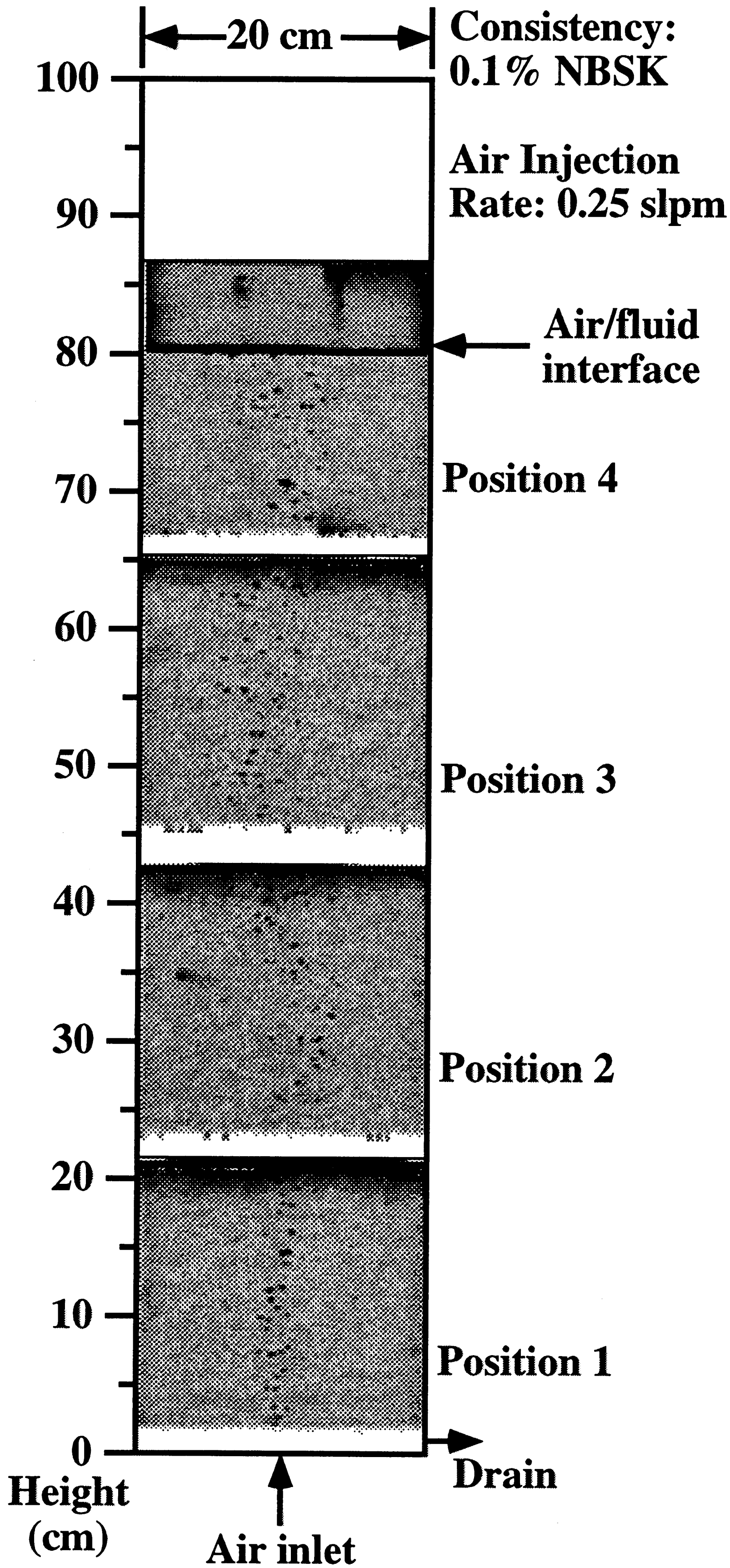

Figure 63: X-ray composite of air bubble flow patterns in an air/water/0.1% NBSK system with air injected at 0.25 slpm through a single-holed gasket located on the column bottom.

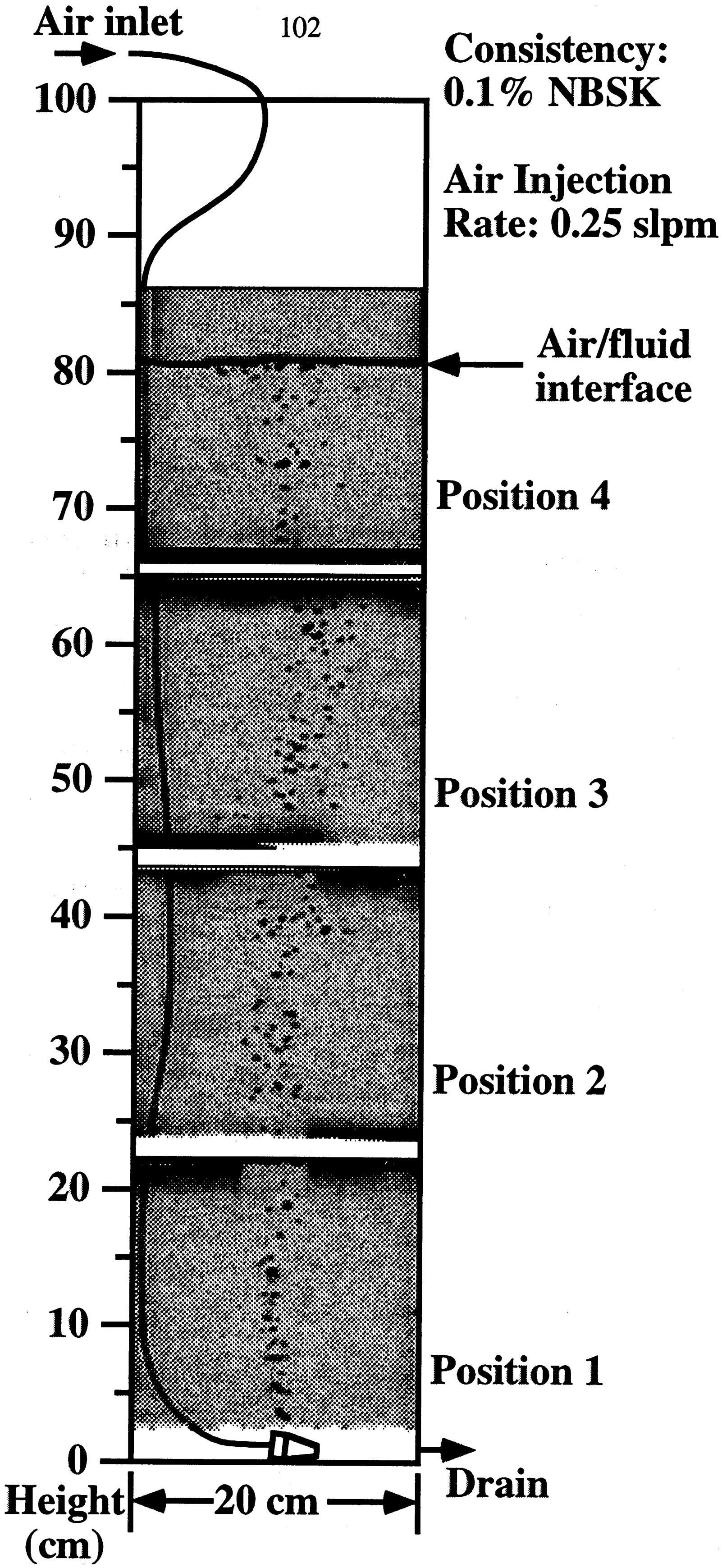

Figure 64: X-ray composite of air bubble flow patterns in an air/water/0.1% NBSK system with air injected at 0.25 slpm through a sparger with 40 μm openings placed on the column bottom.

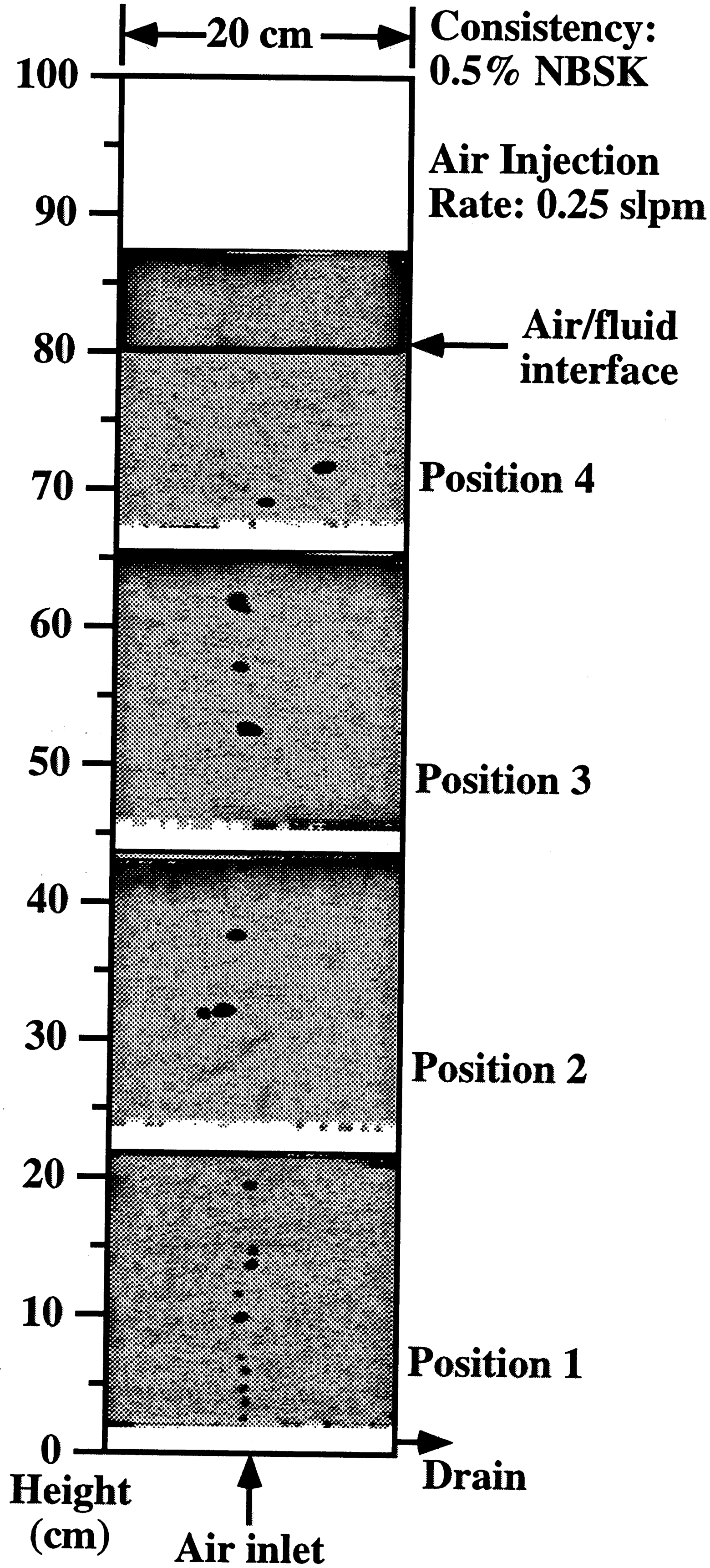

Figure 65: X-ray composite of air bubble flow patterns in an air/water/0.5% NBSK system with air injected at 0.25 slpm through a single-holed gasket located on the column bottom.

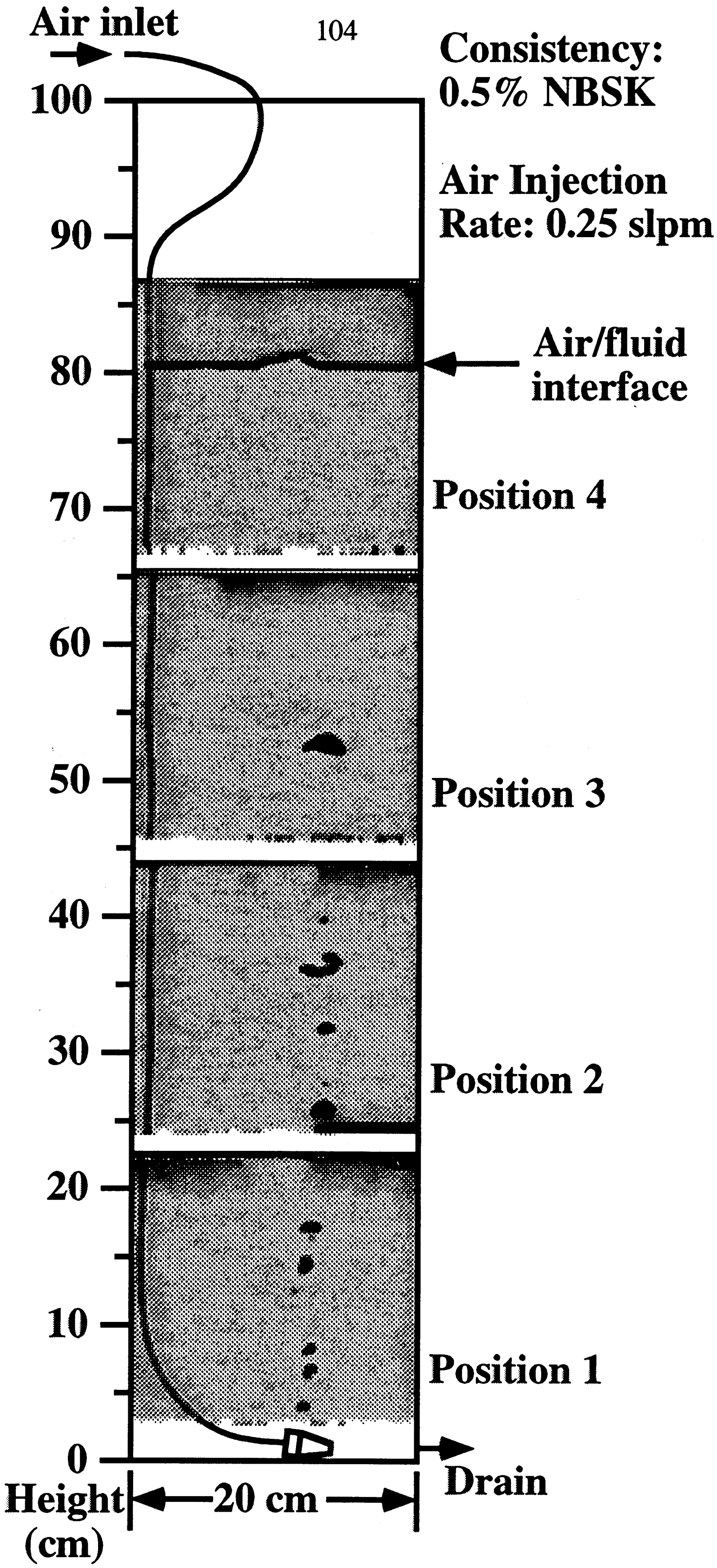

Figure 66: X-ray composite of air bubble flow patterns in an air/water/0.5% NBSK system with air injected at 0.25 slpm through a sparger with 40 μm openings placed on the column bottom.

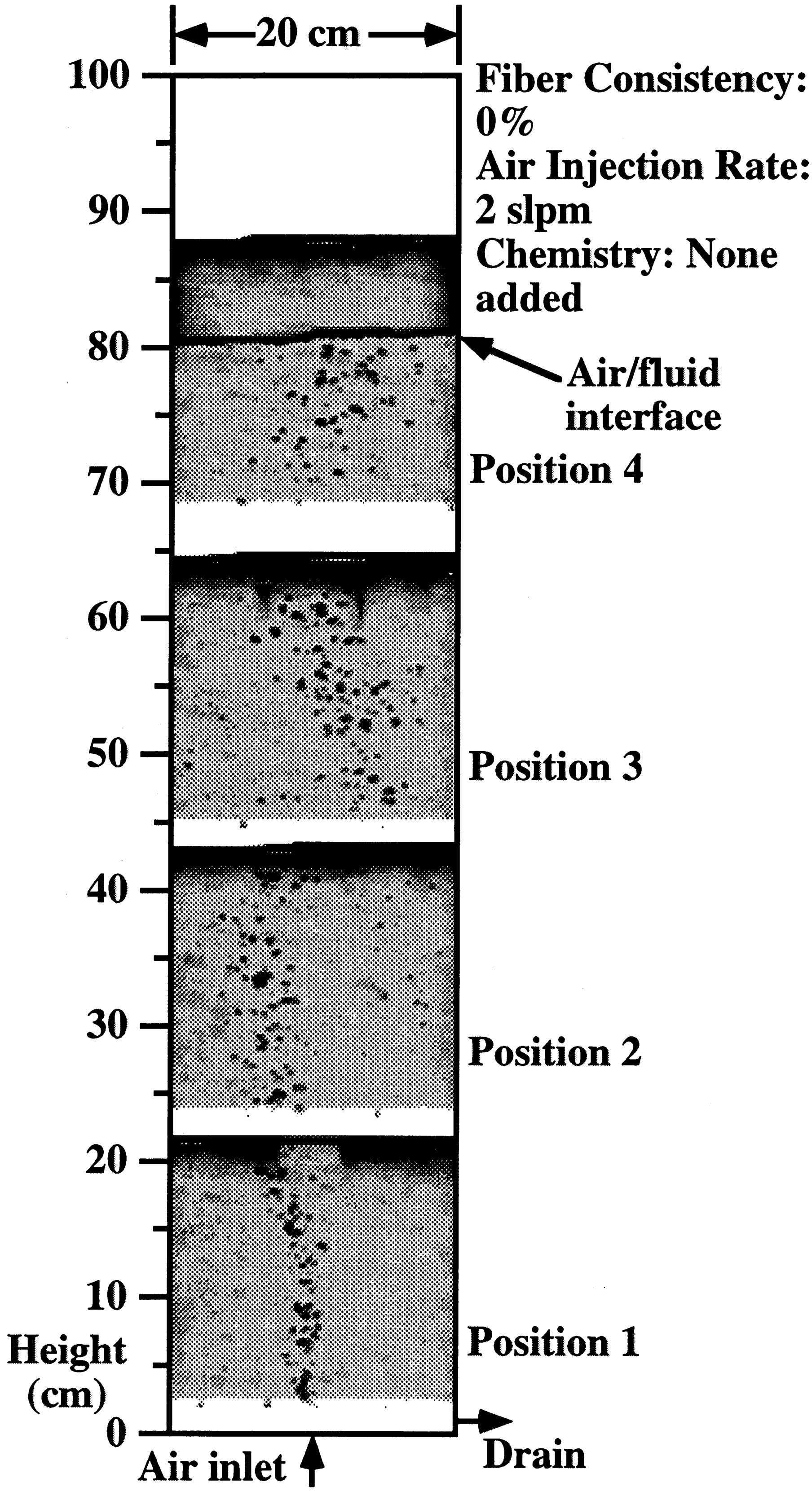

Figure 67: X-ray composite of air bubble flow patterns in an air/water system with air injected at 2 slpm through a single-holed gasket located on the column bottom.

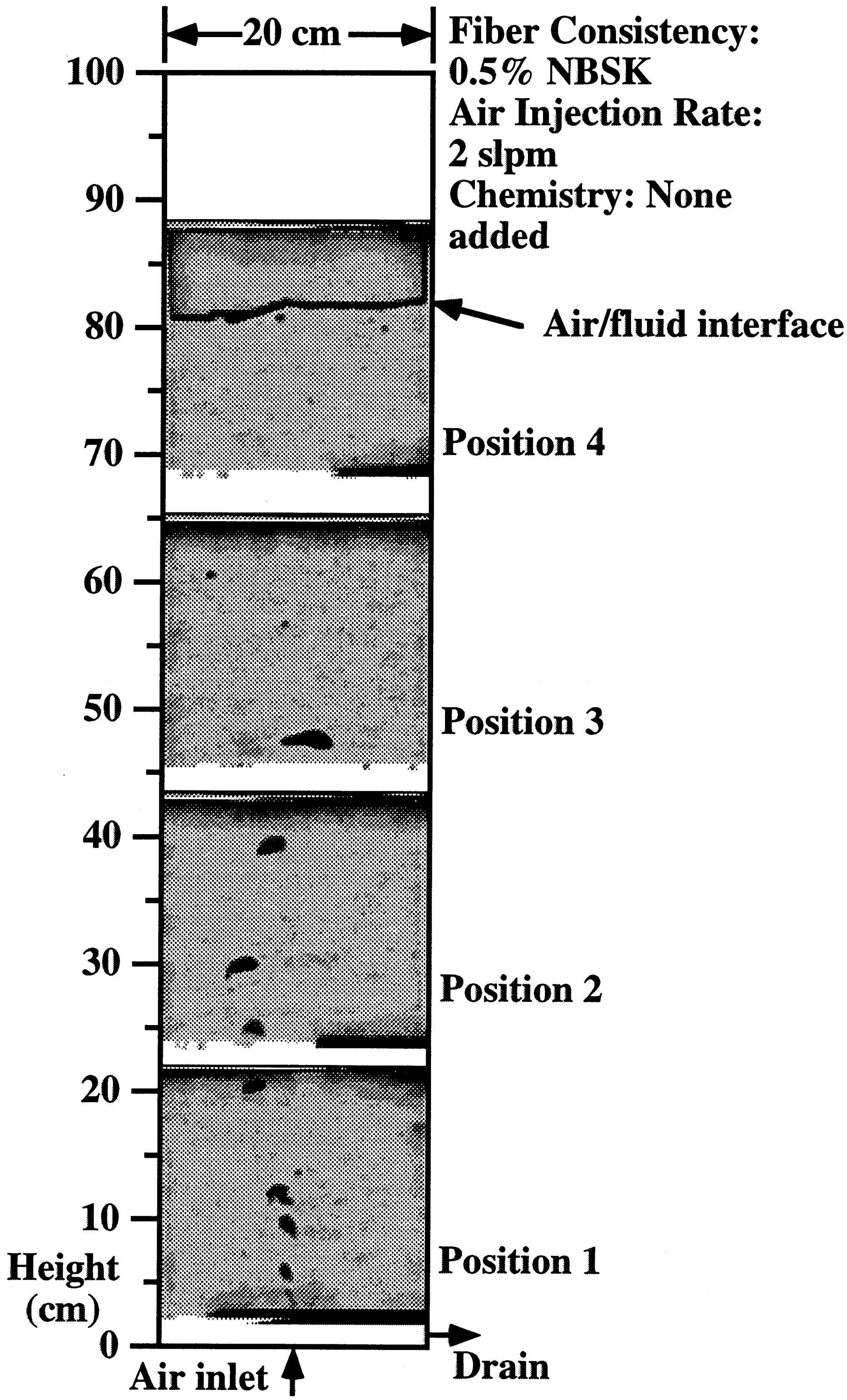

Figure 68: X-ray composite of air bubble flow patterns in an air/water/0.5% NBSK system with air injected at 2 slpm through a single-holed gasket located on the column bottom.

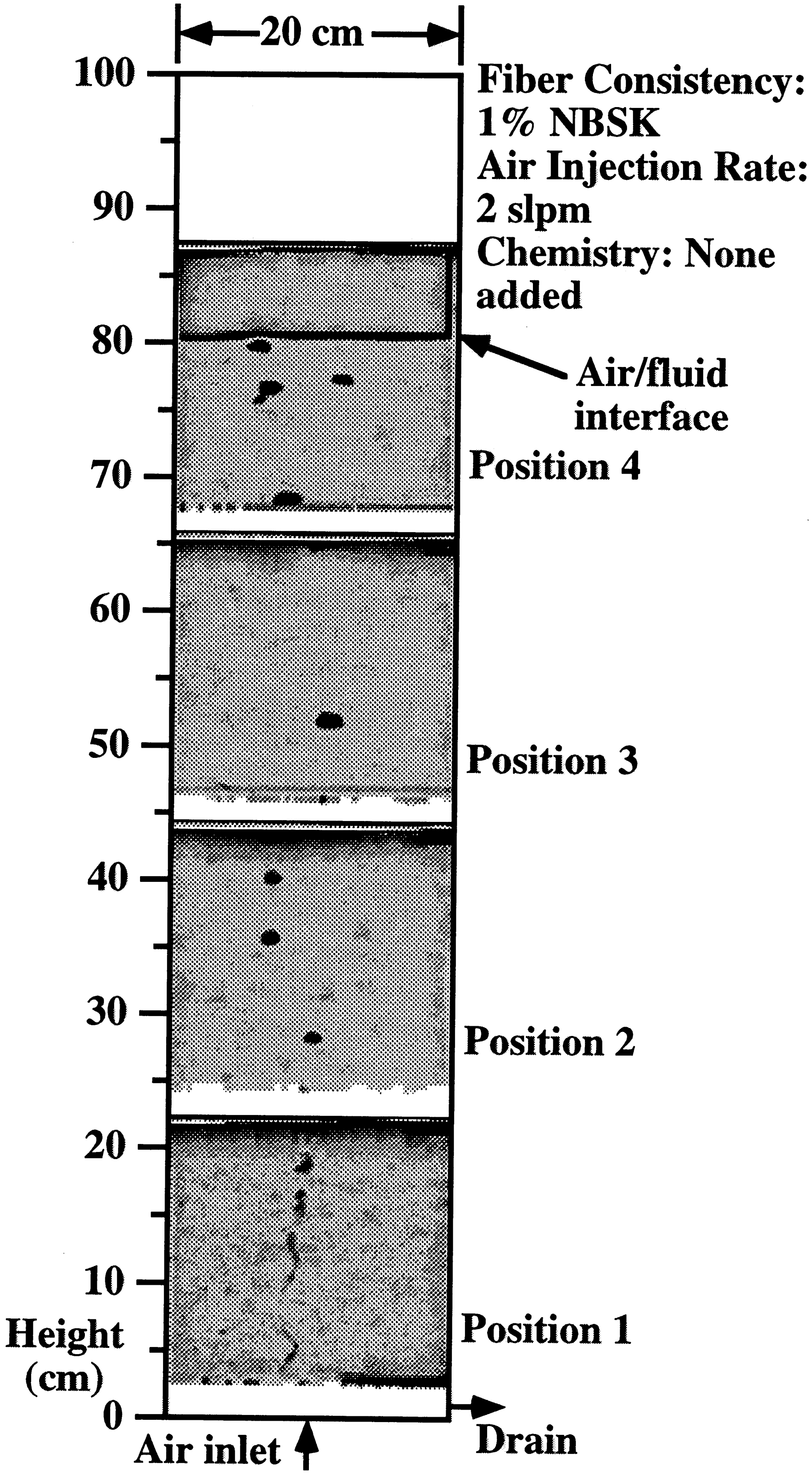

Figure 69: X-ray composite of air bubble flow patterns in an air/water/1% NBSK system with air injected at 2 slpm through a single-holed gasket located on the column bottom.

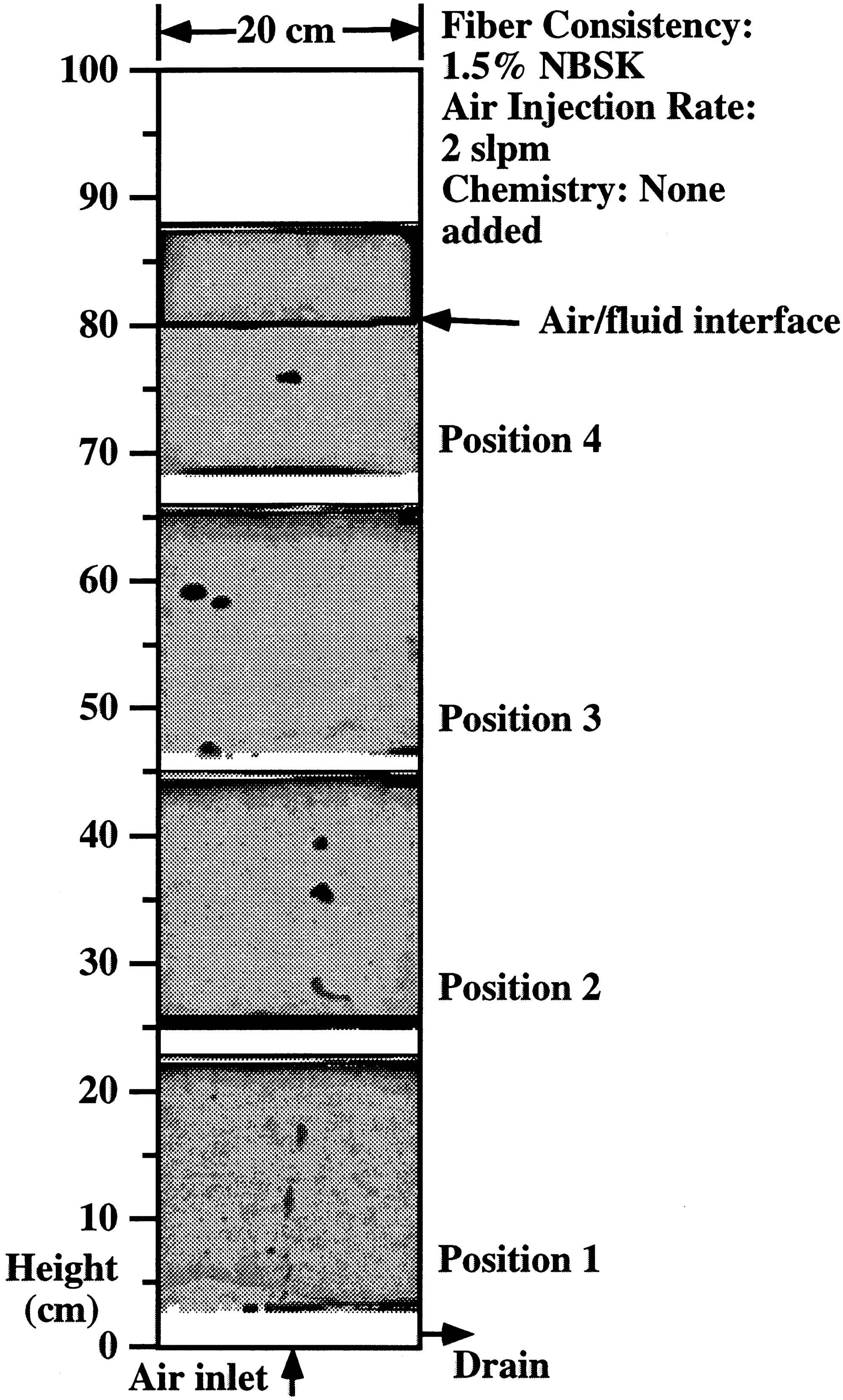

Figure 70: X-ray composite of air bubble flow patterns in an air/water/1.5% NBSK system with air injected at 2 slpm through a single-holed gasket located on the column bottom.

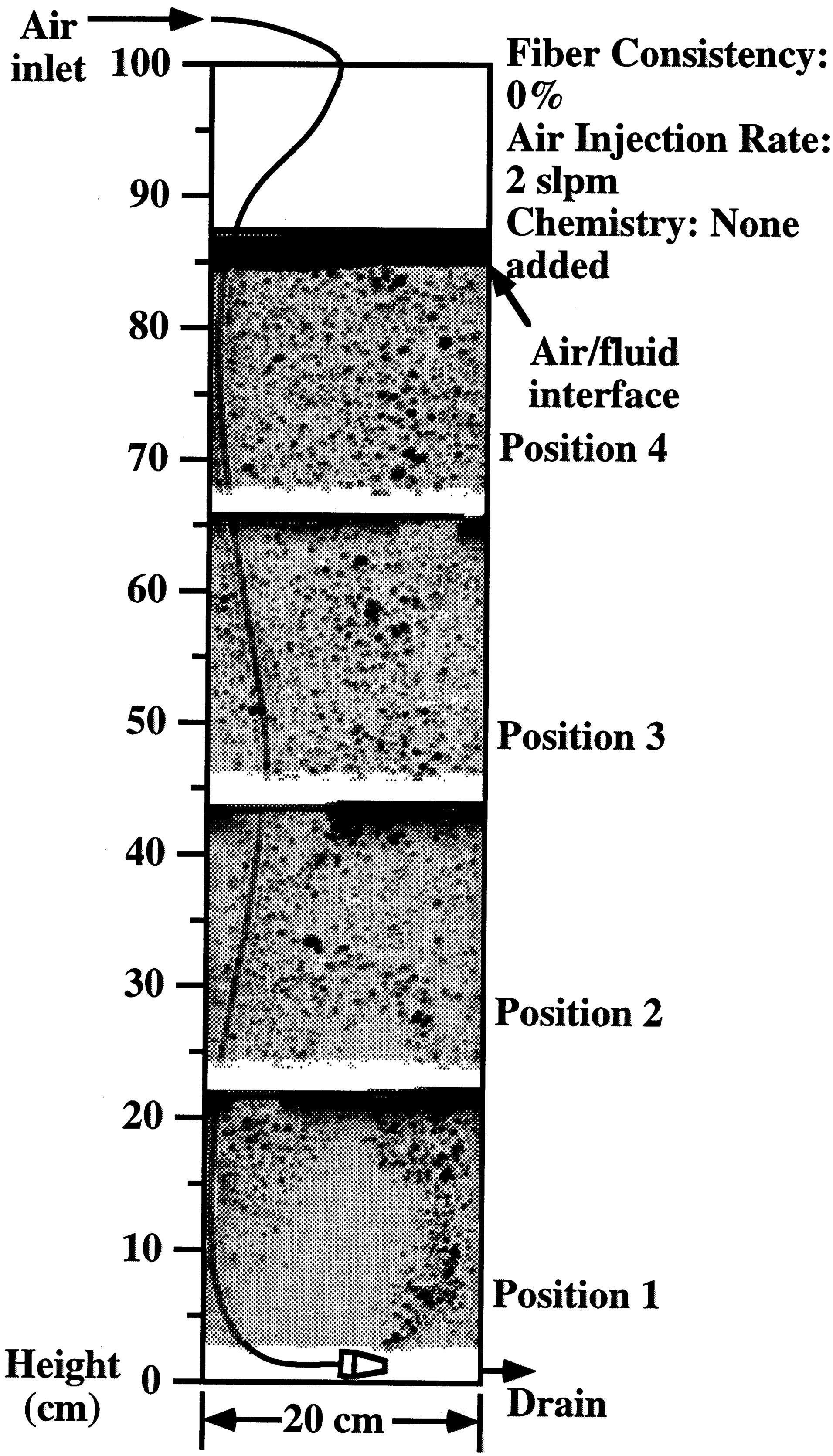

Figure 71: X-ray composite of air bubble flow patterns in an air/water system with air injected at 2 slpm through a sparger with 40 μm openings placed on the column bottom.

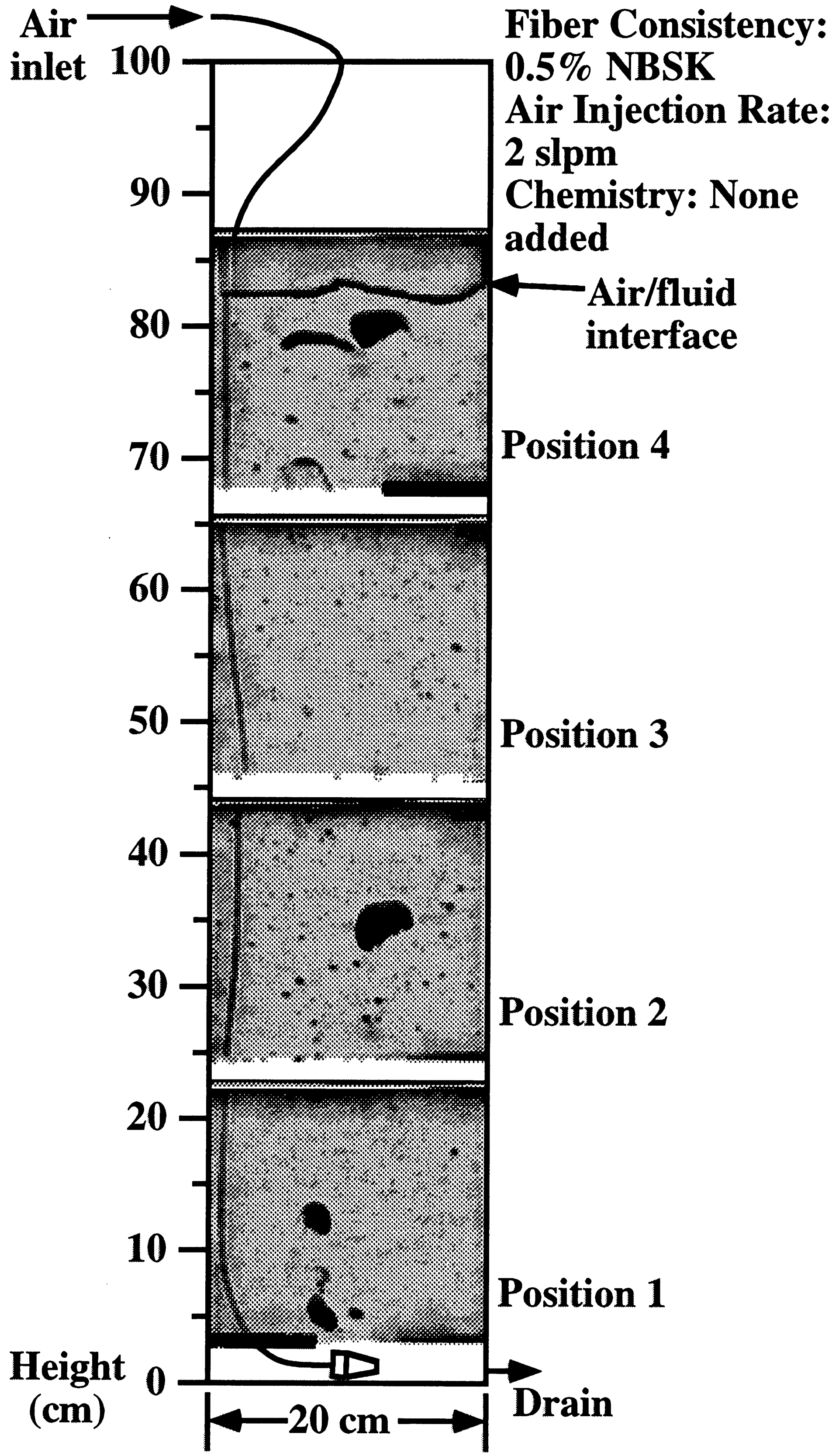

Figure 72: X-ray composite of air bubble flow patterns in an air/water/0.5% NBSK system with air injected at 2 slpm through a sparger with 40 μm openings placed on the column bottom.

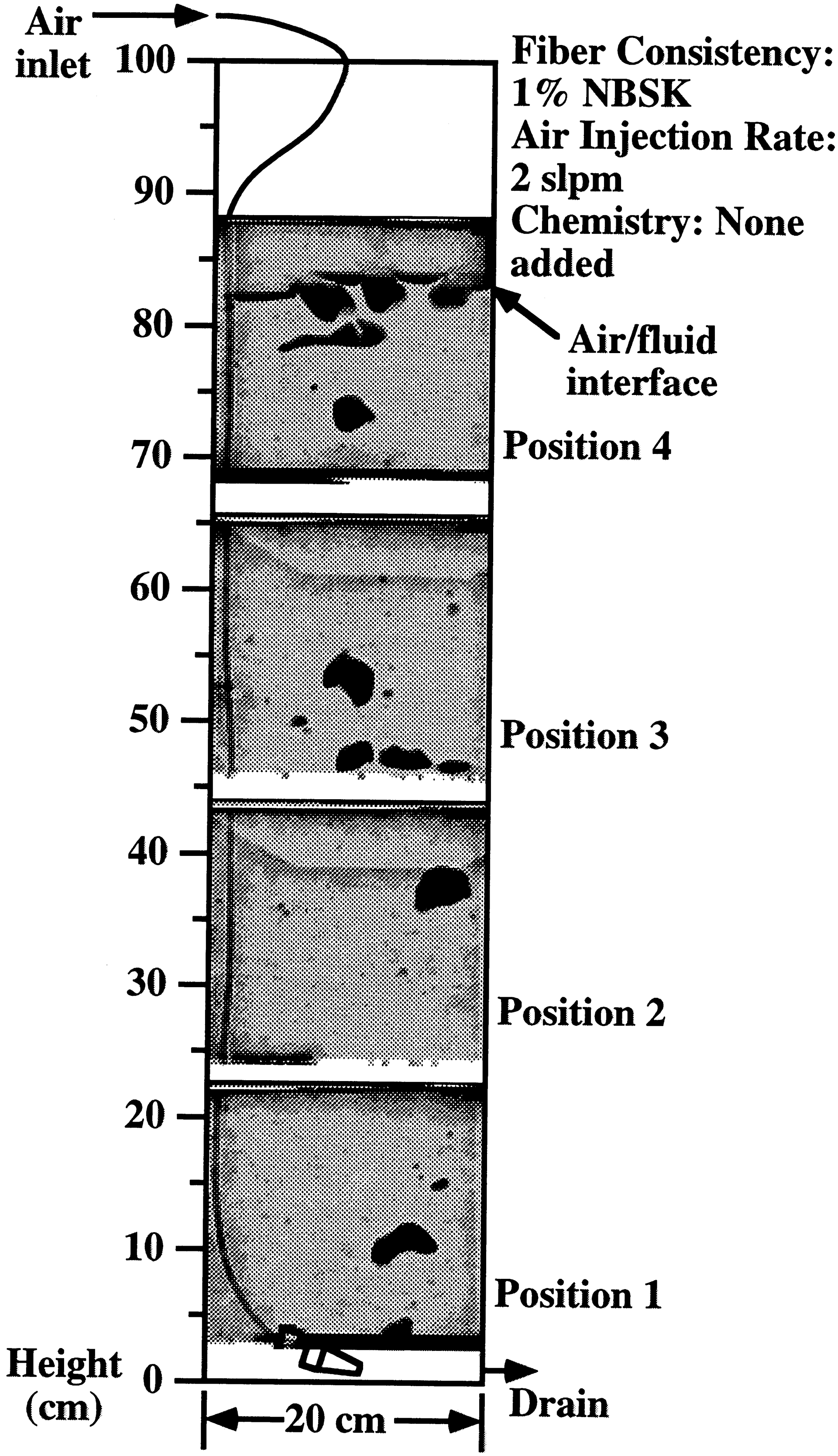

Figure 73: X-ray composite of air bubble flow patterns in an air/water/1% NBSK system with air injected at 2 slpm through a sparger with 40 μm openings placed on the column bottom.

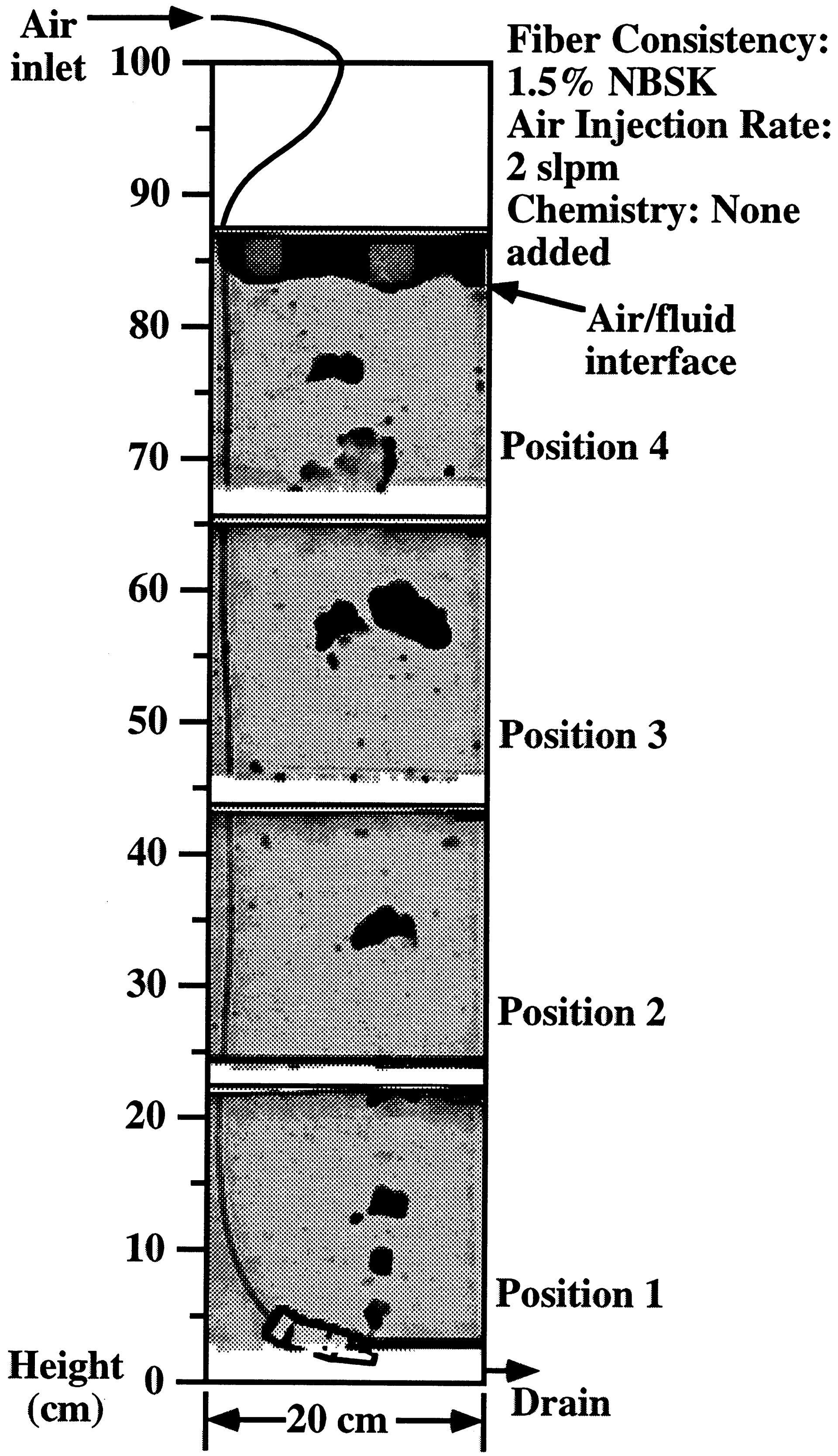

Figure 74: X-ray composite of air bubble flow patterns in an air/water/1.5% NBSK system with air injected at 2 slpm through a sparger with 40 μm openings placed on the column bottom.

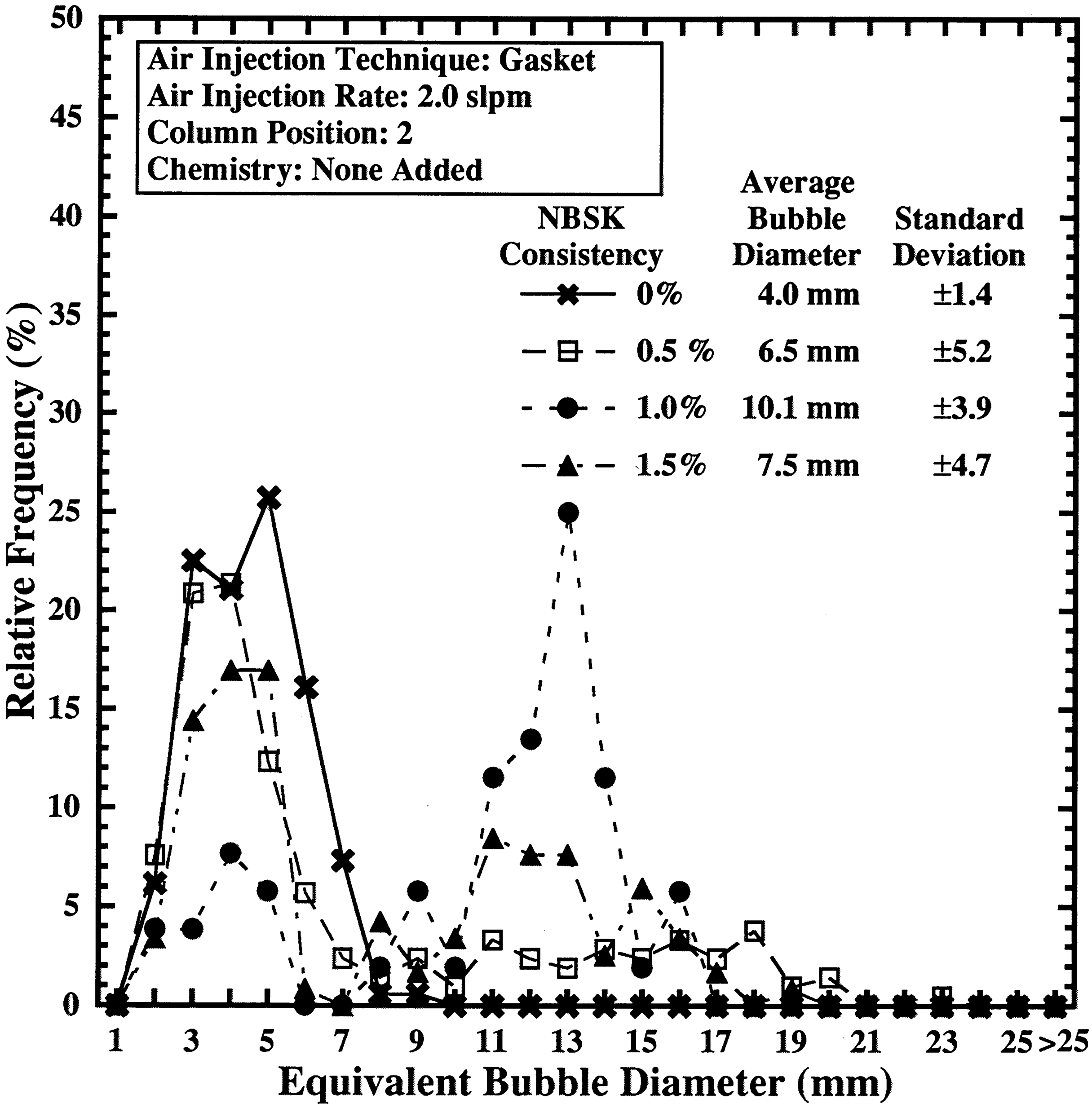

Figure 75: Bubble size distributions obtained with the gasket air injection technique for various NBSK consistencies.

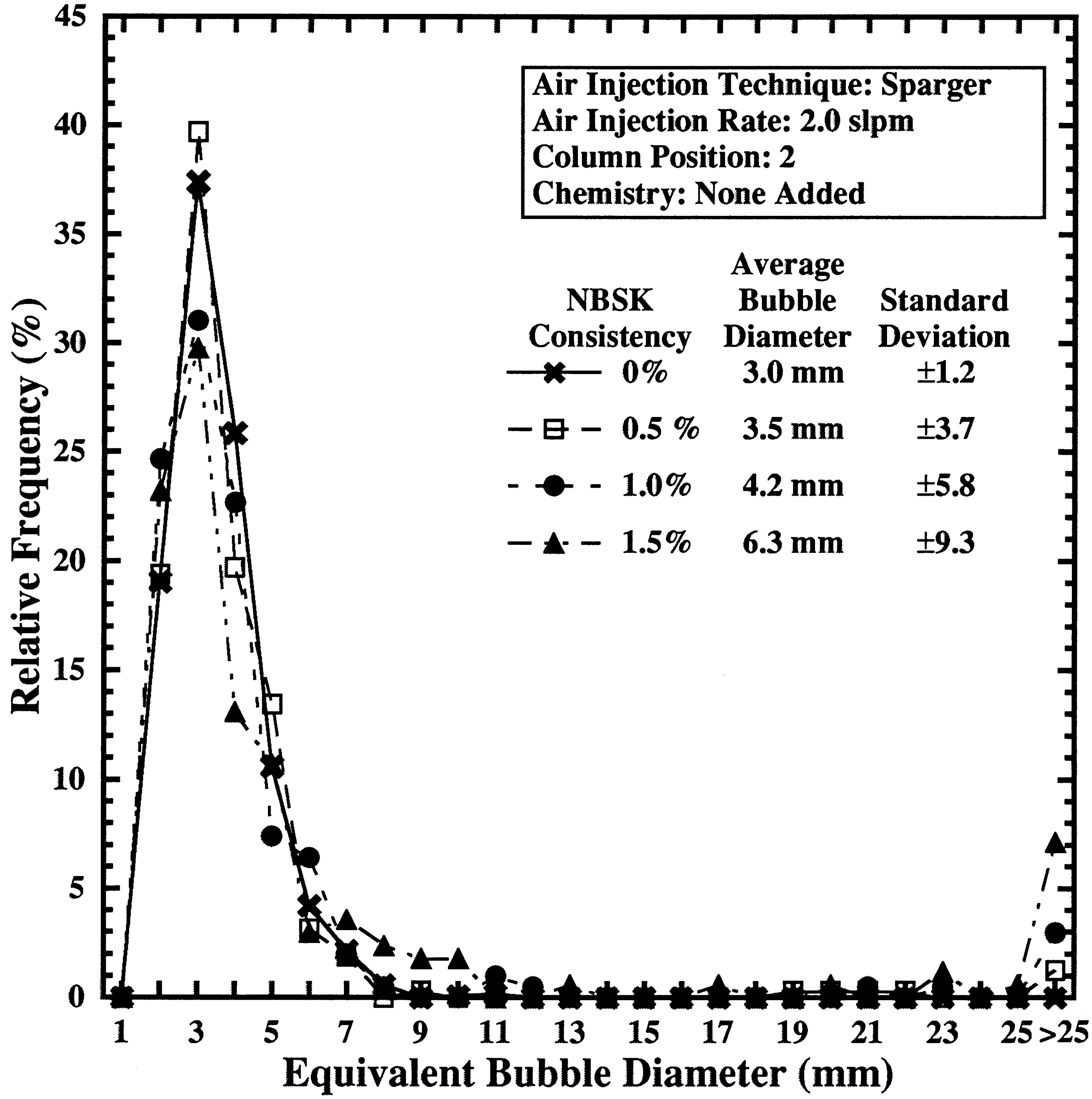

Figure 76: Bubble size distributions obtained with the sparger air injection technique for various NBSK consistencies.

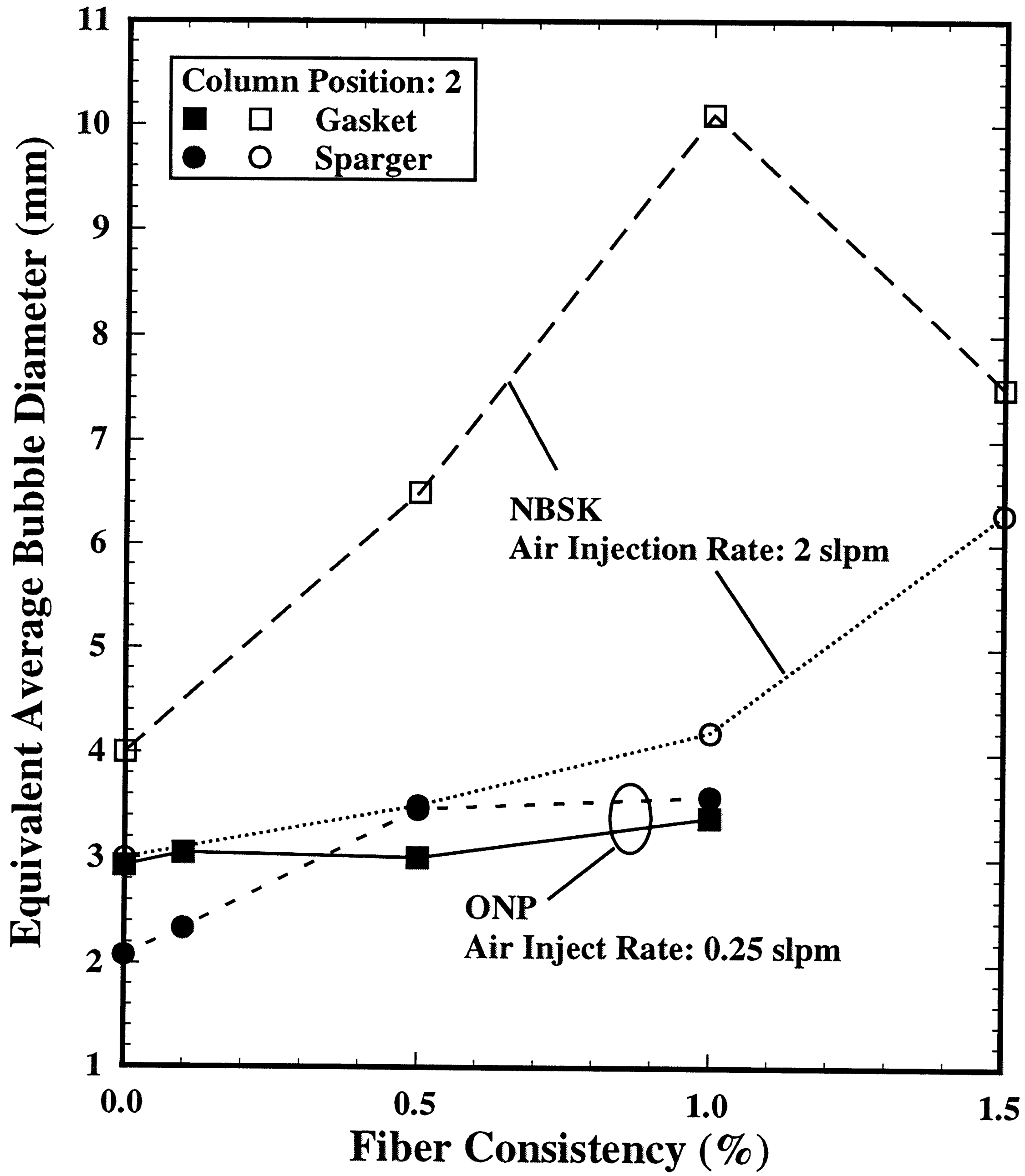

Figure 77: Effect of NBSK consistency on average bubble size.

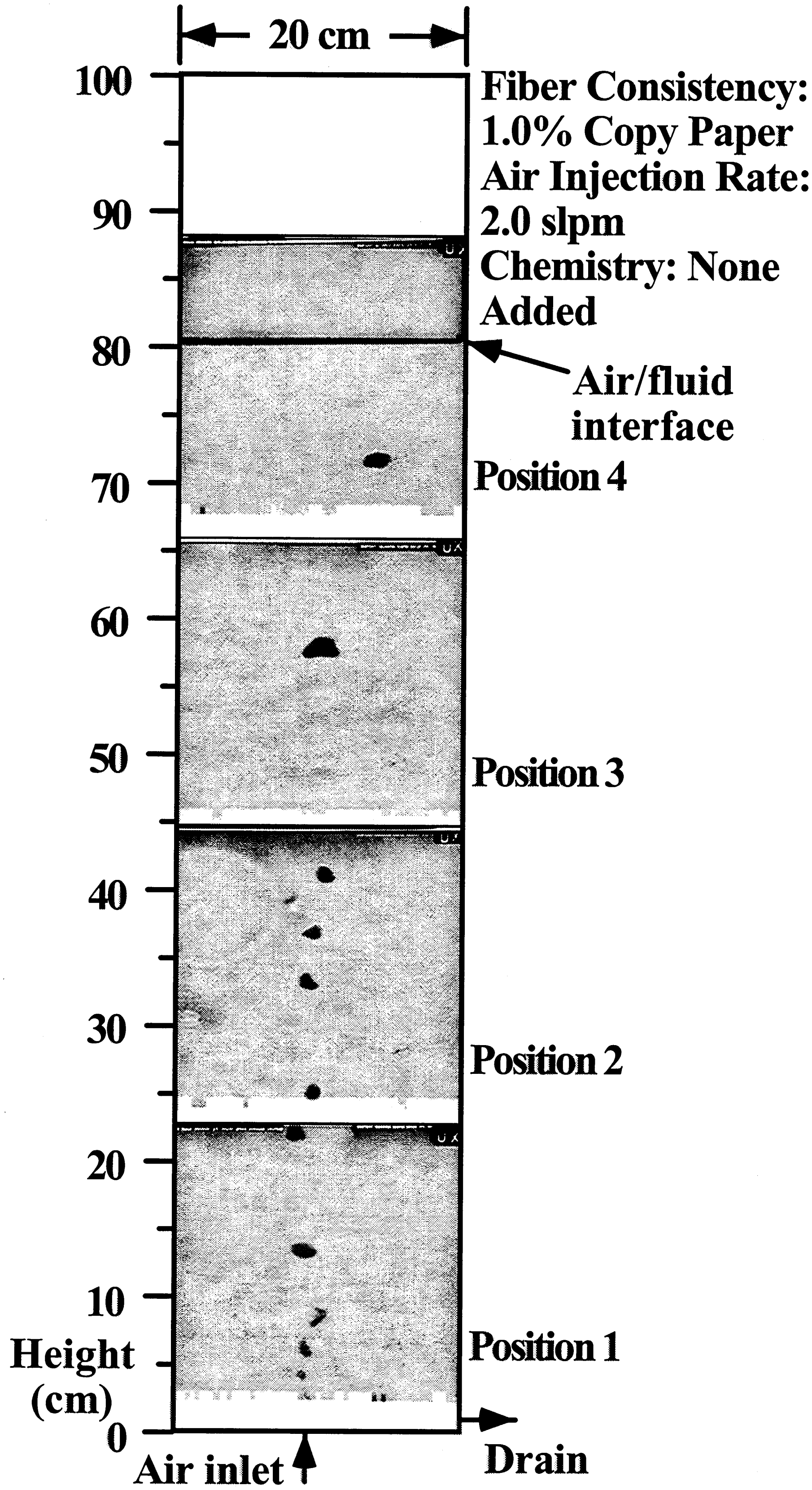

Figure 78: X-ray composite of air bubble flow patterns in an air/water/1% copy paper system with air injected at 2 slpm through a single-holed gasket located on the column bottom.

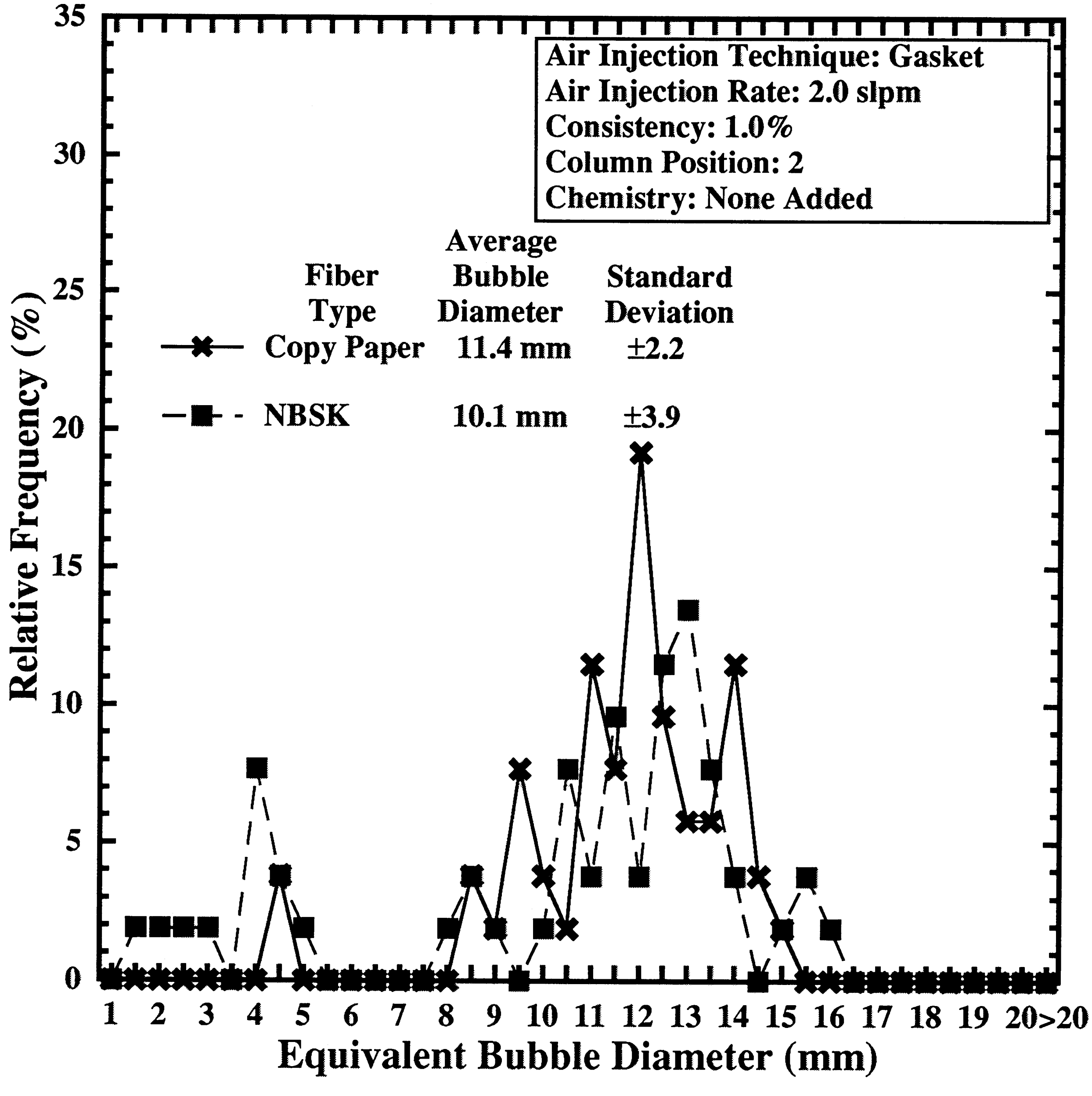

Figure 79: Bubble size distributions for 1% copy paper and 1% NBSK with the gasket air injection technique and 2 slpm.

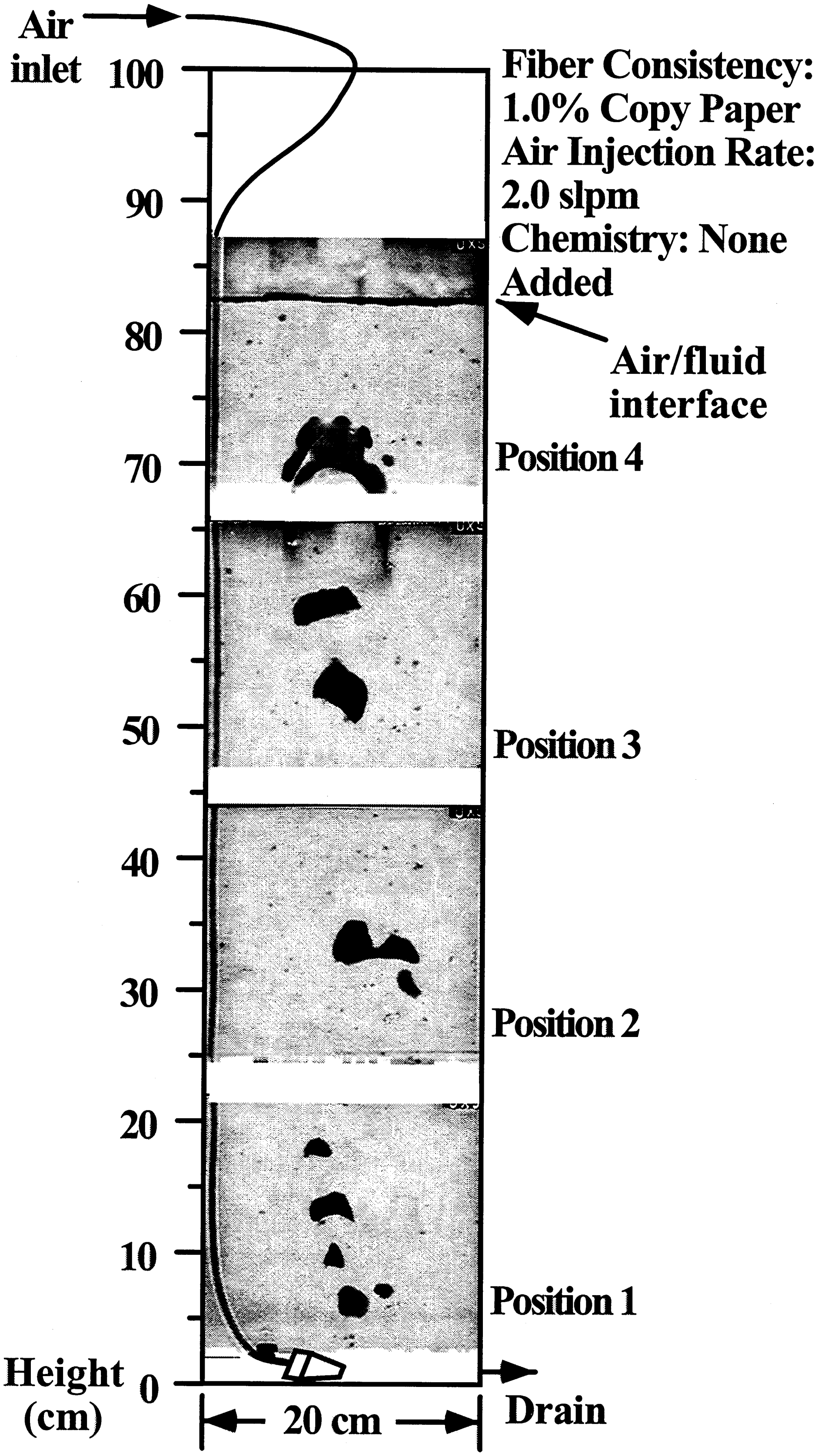

Figure 80: X-ray composite of air bubble flow patterns in an air/water/1% copy paper system with air injected at 2 slpm through a sparger with 40 μm openings placed on the column bottom.

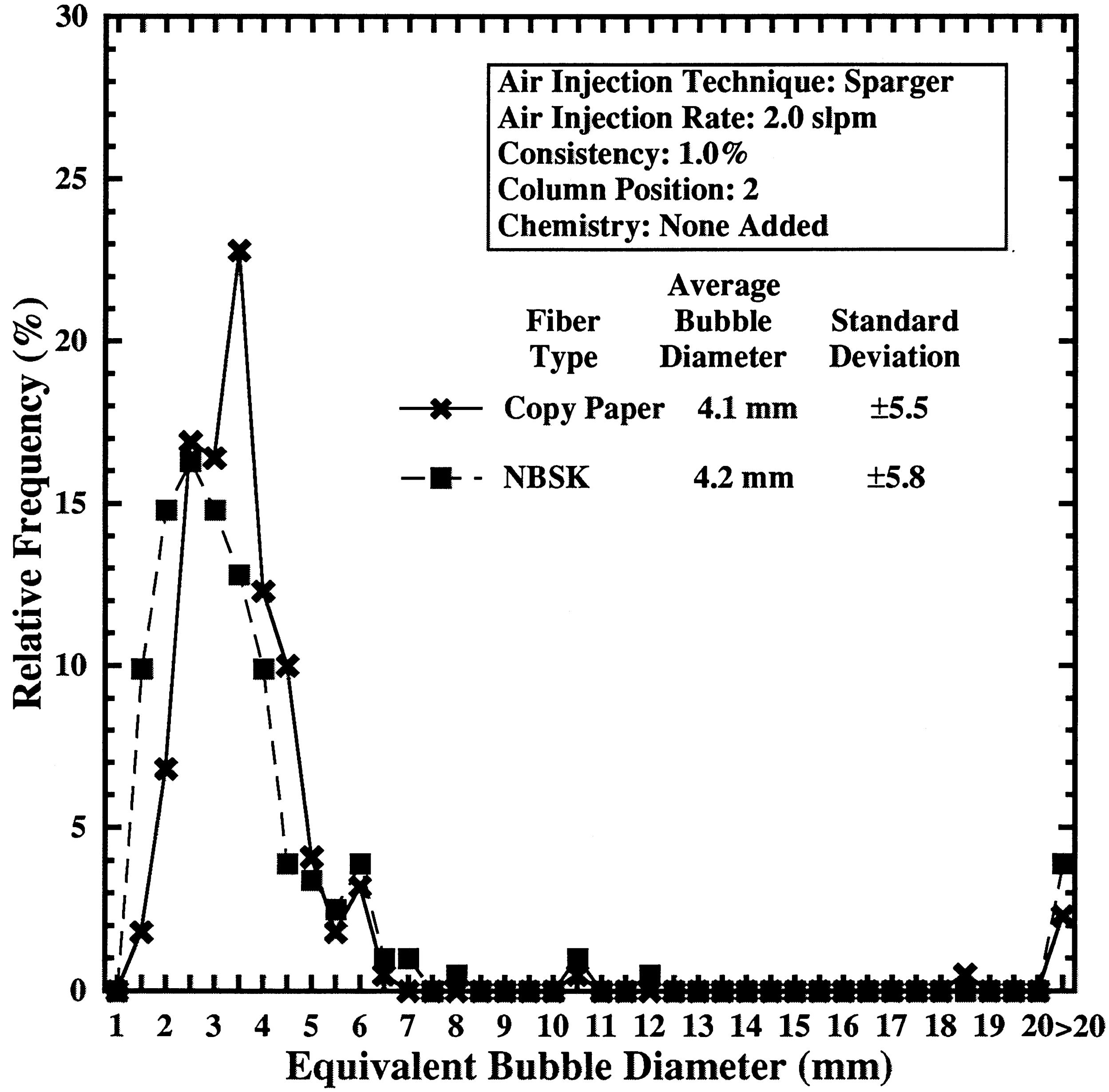

Figure 81: Bubble size distributions for 1% copy paper and 1% NBSK with the sparger air injection technique and 2 slpm.

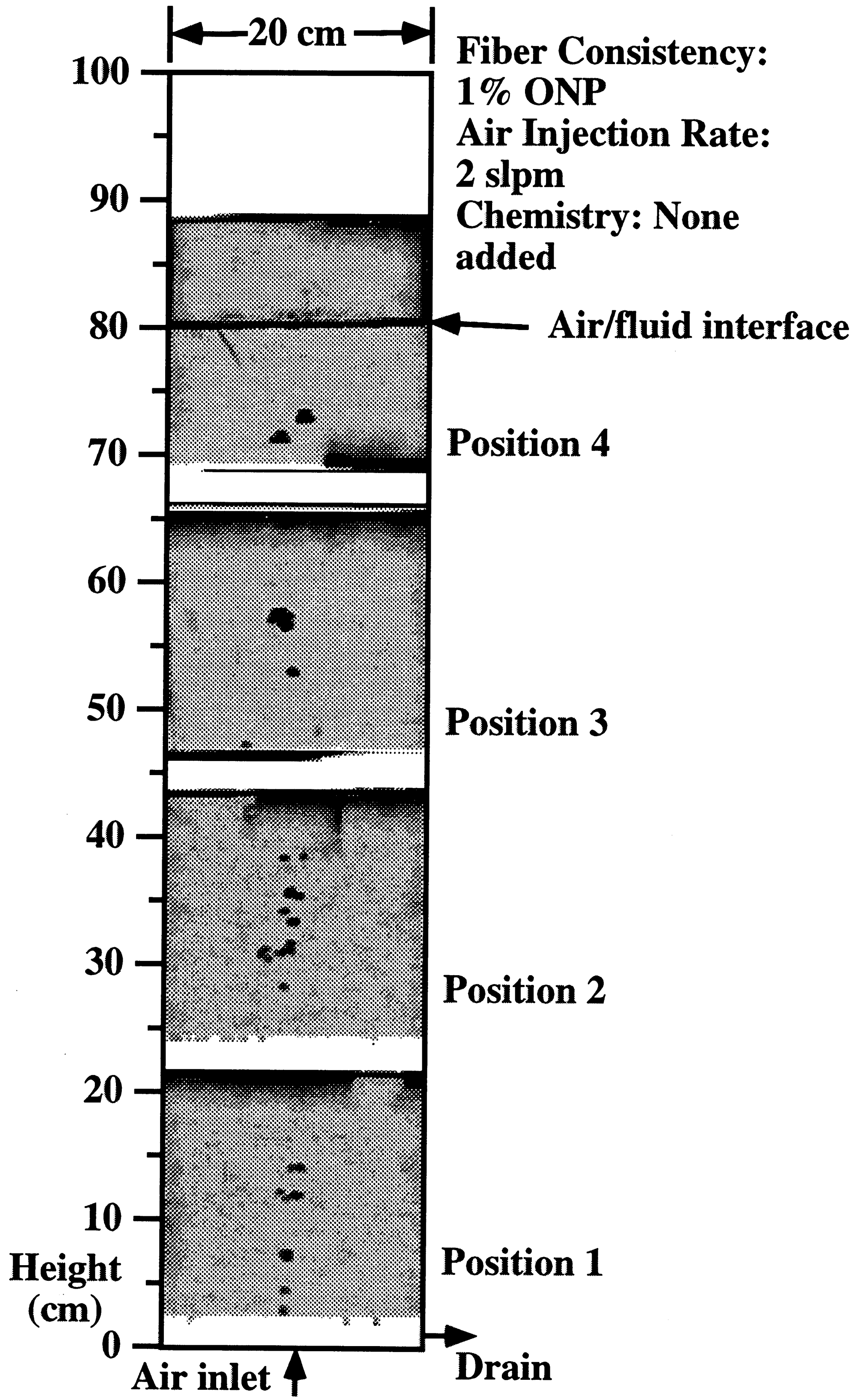

Figure 82: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with air injected at 2 slpm through a single-holed gasket located on the column bottom.

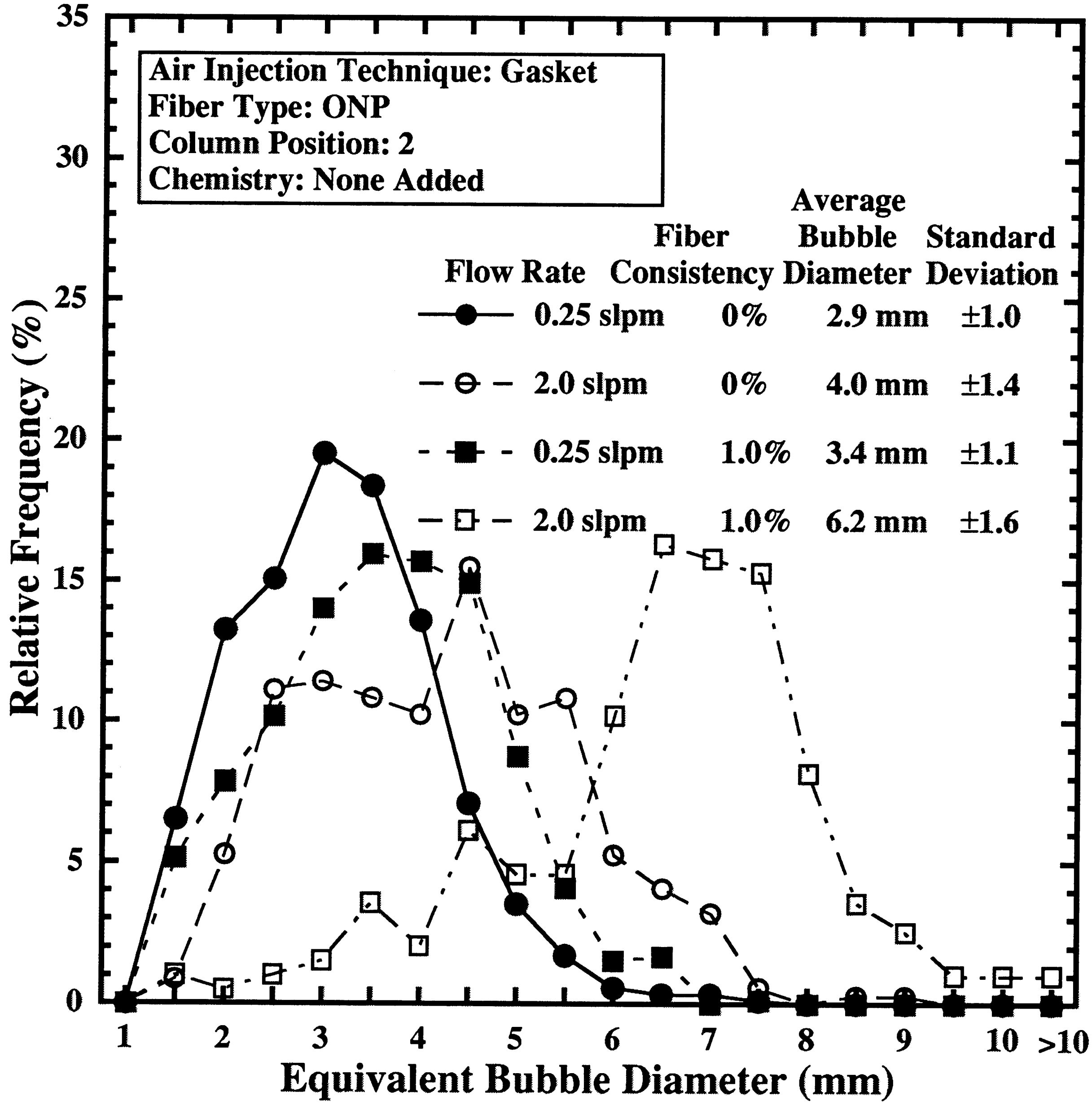

Figure 83: Bubble size distributions for the gasket air injection technique with different air flow rates.

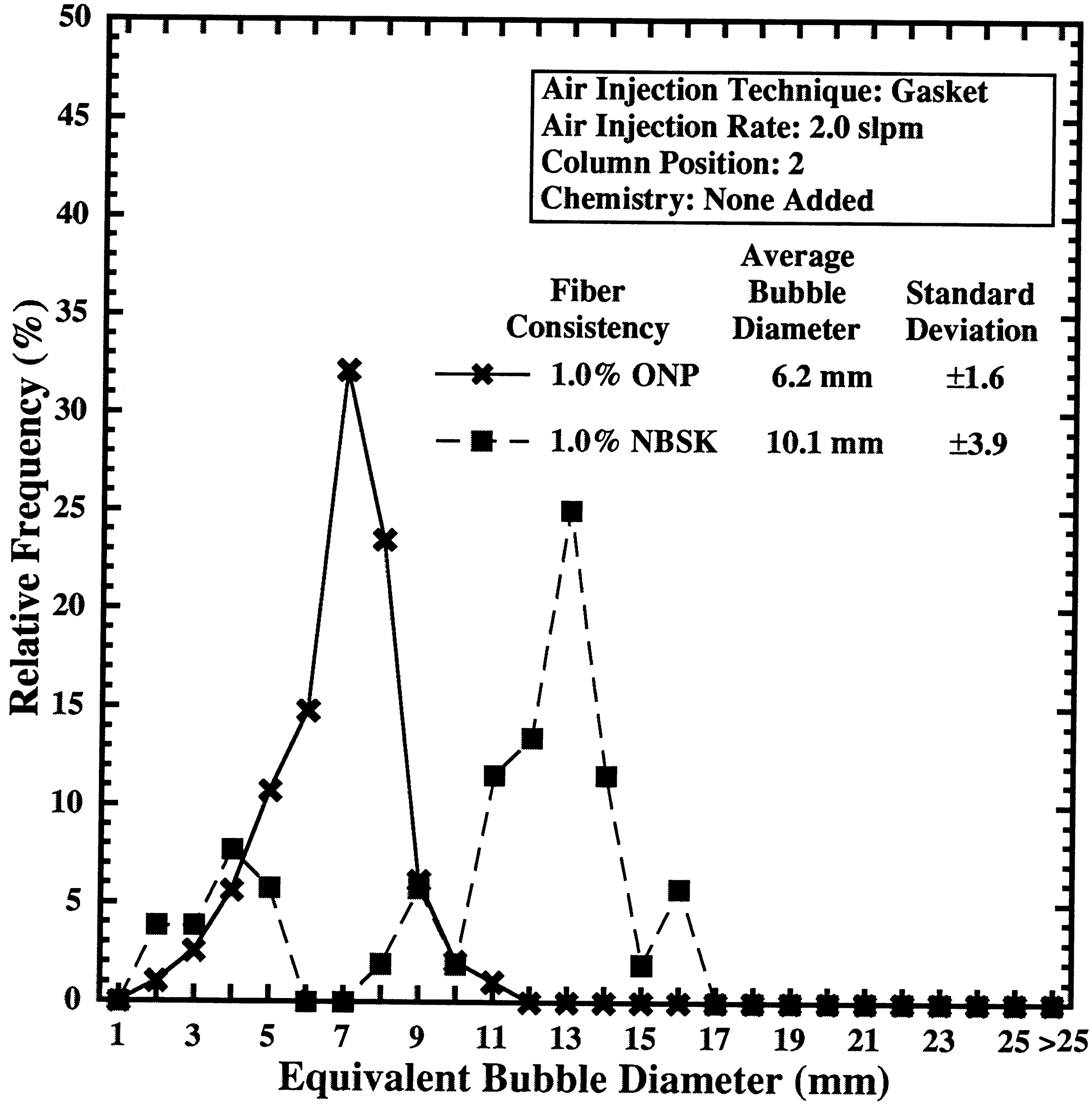

Figure 84: Bubble size distributions for 1% ONP and 1% NBSK with the gasket air injection technique and 2 slpm.

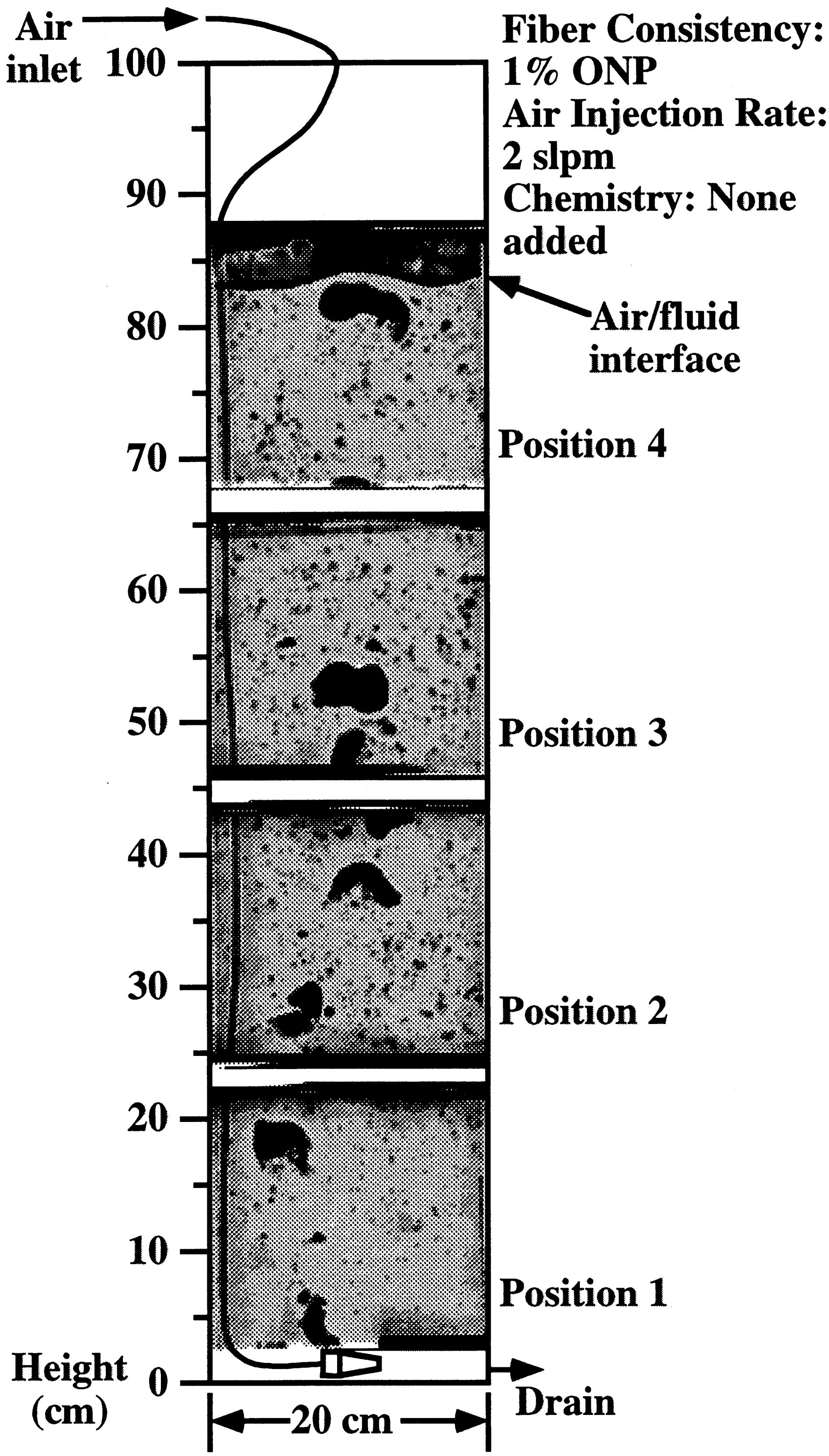

Figure 85: X-ray composite of air bubble flow patterns in an air/water/1% ONP system with air injected at 2 slpm through a sparger with 40 μm openings placed on the column bottom.

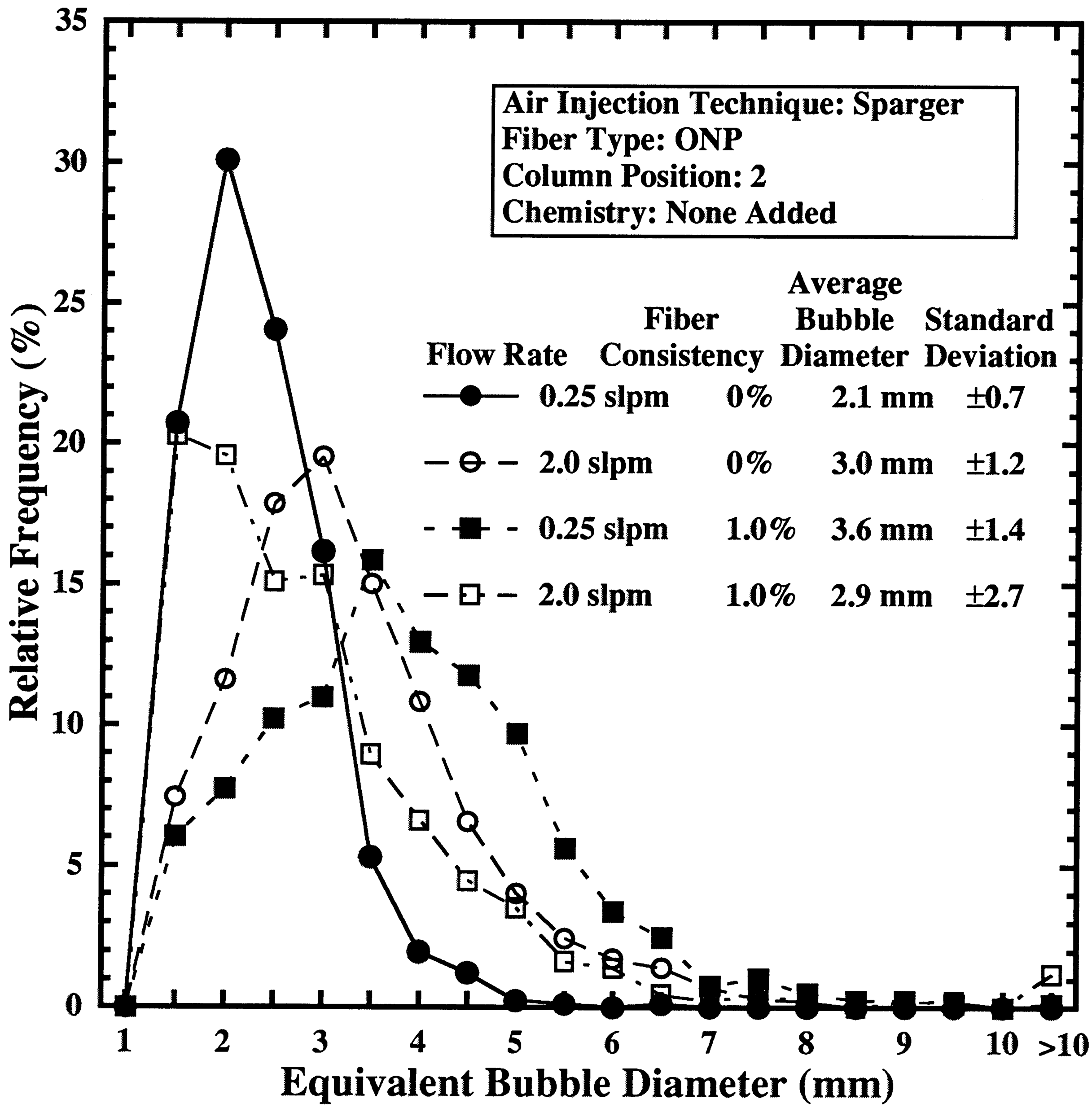

Figure 86: Bubble size distributions for the sparger air injection technique with different air flow rates.

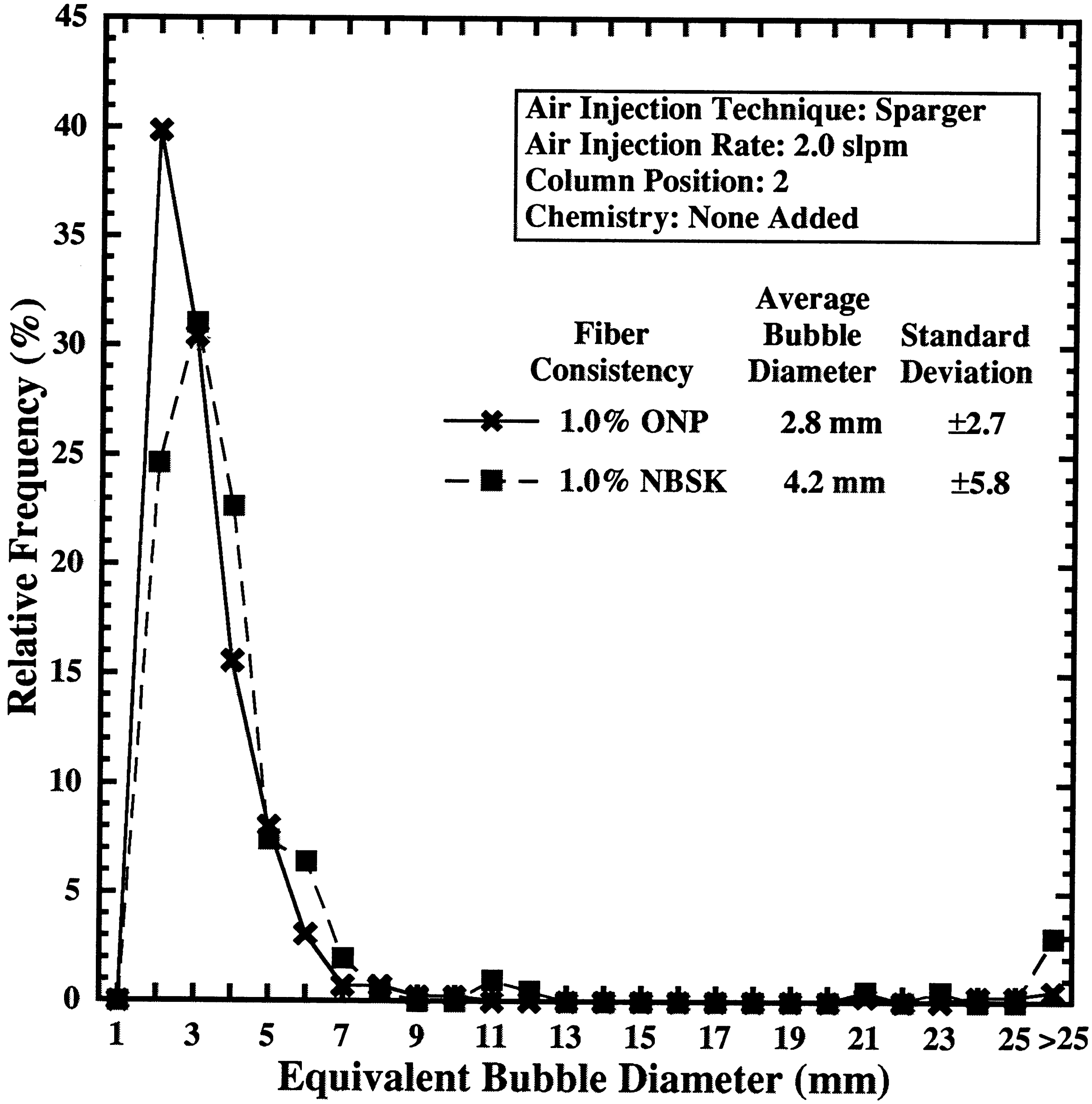

Figure 87: Bubble size distributions for 1% ONP and 1% NBSK with the sparger air injection technique and 2 slpm.

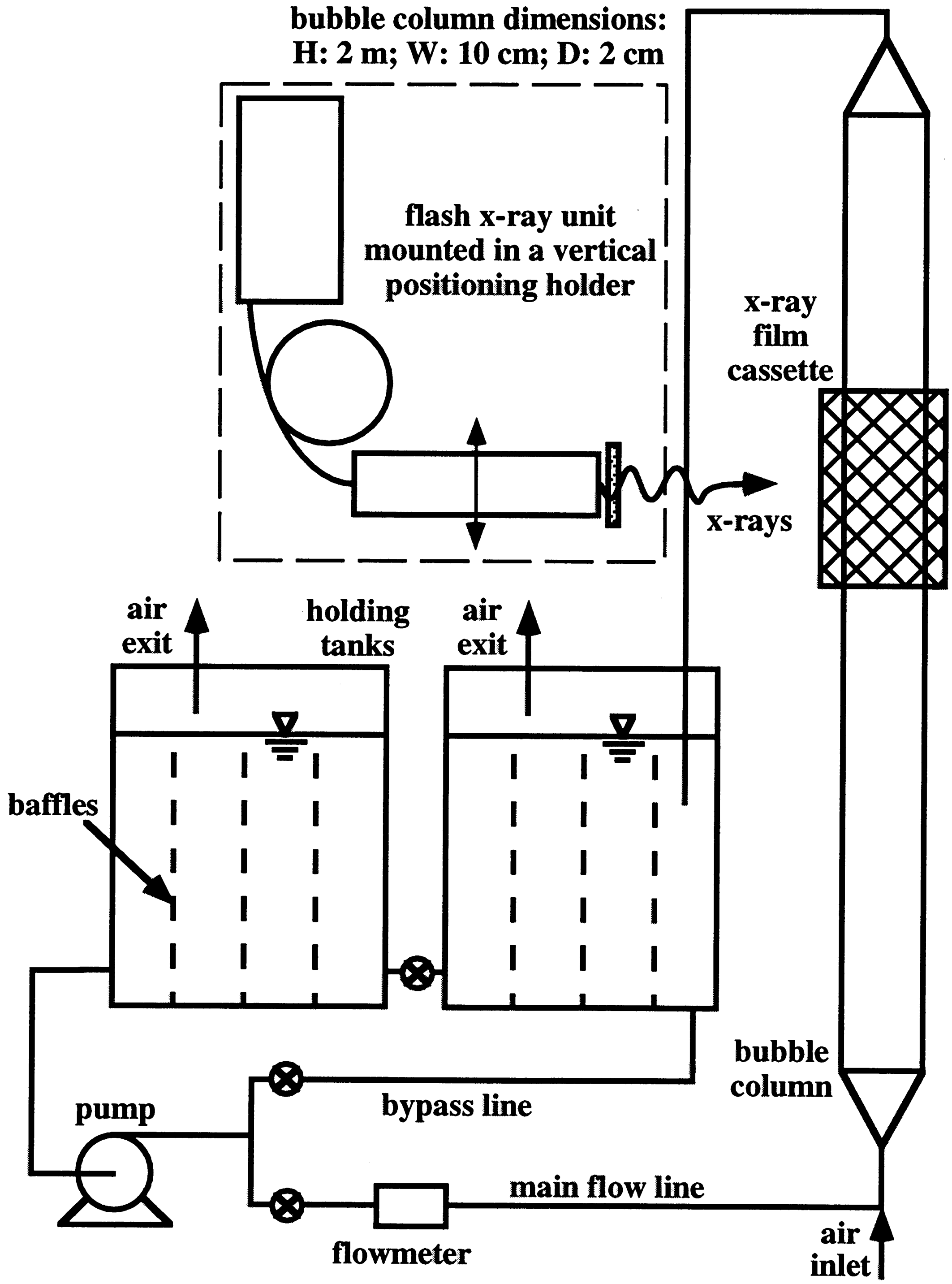

Figure 88: Schematic diagram of the new cocurrent flow loop to be used with the flash x-ray system.

APPENDIX A: EQUIVALENT BUBBLE DIAMETER MEASUREMENTS FOR ONP WITH VARIOUS ADDED CHEMISTRIES

This Appendix tabulates the equivalent bubble diameter measurements recorded from Position 2 x-rays obtained in an ONP suspension with the following chemistry conditions: Tables A1-A4 tabulate data taken with BRD 2360, a fatty acid; Tables A5-A7 summarize data from BRD 2342, a nonionic surfactant; and Tables A8-A10 include data from BRD 2363, a fatty acid/nonionic surfactant blend. All data presented in this Appendix were taken with a fixed air flow rate of 0.25 slpm.

Table A1: Summary of the equivalent bubble size distribution data for ONP with 1.7 ml/kg of BRD 2360 added to the system and an air flow rate of 0.25 slpm.

	BRD 2360 1.7 ml/kg (3 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	2.63	3.97	2.76	3.48
Median Equivalent Bubble Diameter (mm)	2.59	3.84	2.74	3.17
Minimum Equivalent Bubble Diameter (mm)	1.22	1.10	1.70	1.25
Maximum Equivalent Bubble Diameter (mm)	3.54	8.92	4.20	8.81
Standard Deviation (mm)	0.38	1.50	0.55	1.38
Variance (mm^2)	0.14	2.24	0.30	1.92
Bubble Population Size	248	275	251	317
Equivalent Sauter Mean Diameter (mm)	2.73	5.03	2.98	4.68
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	3	7	0	3
$1.5 < R_B \leq 2$	6	15	24	22
$2 < R_B \leq 2.5$	88	22	63	51
$2.5 < R_B \leq 3$	119	38	75	62
$3 < R_B \leq 3.5$	28	35	68	58
$3.5 < R_B \leq 4$	4	32	18	45
$4 < R_B \leq 4.5$	0	31	3	23
$4.5 < R_B \leq 5$	0	24	0	12
$5 < R_B \leq 5.5$	0	26	0	10
$5.5 < R_B \leq 6$	0	19	0	6
$6 < R_B \leq 6.5$	0	12	0	7
$6.5 < R_B \leq 7$	0	5	0	7
$7 < R_B \leq 7.5$	0	6	0	7
$7.5 < R_B \leq 8$	0	2	0	2
$8 < R_B \leq 8.5$	0	0	0	1
$8.5 < R_B \leq 9$	0	1	0	1
$9 < R_B \leq 9.5$	0	0	0	0
$9.5 < R_B \leq 10$	0	0	0	0
$R_B > 10$	0	0	0	0

Table A2: Summary of the equivalent bubble size distribution data for ONP with 3.3 ml/kg of BRD 2360 added to the system and an air flow rate of 0.25 slpm.

	BRD 2360 3.3 ml/kg (6 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	3.07	6.29	2.53	3.34
Median Equivalent Bubble Diameter (mm)	3.04	6.16	2.48	3.25
Minimum Equivalent Bubble Diameter (mm)	1.01	1.44	1.04	1.08
Maximum Equivalent Bubble Diameter (mm)	5.83	12.51	5.08	7.53
Standard Deviation (mm)	0.80	1.33	0.56	1.18
Variance (mm^2)	0.64	1.77	0.31	1.40
Bubble Population Size	928	253	890	744
Equivalent Sauter Mean Diameter (mm)	3.48	6.42	2.79	4.16
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	10	1	11	35
$1.5 < R_B \leq 2$	69	0	128	50
$2 < R_B \leq 2.5$	157	0	329	108
$2.5 < R_B \leq 3$	209	0	257	117
$3 < R_B \leq 3.5$	229	1	117	117
$3.5 < R_B \leq 4$	141	8	33	118
$4 < R_B \leq 4.5$	66	6	12	88
$4.5 < R_B \leq 5$	32	8	1	40
$5 < R_B \leq 5.5$	12	38	2	34
$5.5 < R_B \leq 6$	3	47	0	17
$6 < R_B \leq 6.5$	0	55	0	12
$6.5 < R_B \leq 7$	0	37	0	3
$7 < R_B \leq 7.5$	0	17	0	4
$7.5 < R_B \leq 8$	0	9	0	1
$8 < R_B \leq 8.5$	0	10	0	0
$8.5 < R_B \leq 9$	0	9	0	0
$9 < R_B \leq 9.5$	0	3	0	0
$9.5 < R_B \leq 10$	0	1	0	0
$R_B > 10$	0	3	0	0

Table A3: Summary of the equivalent bubble size distribution data for ONP with 6.7 ml/kg of BRD 2360 added to the system and an air flow rate of 0.25 slpm.

	BRD 2360 6.7 ml/kg (12 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	2.82	4.70	2.57	3.66
Median Equivalent Bubble Diameter (mm)	2.87	4.67	2.52	3.23
Minimum Equivalent Bubble Diameter (mm)	1.29	1.63	1.13	1.21
Maximum Equivalent Bubble Diameter (mm)	4.96	10.59	4.43	8.52
Standard Deviation (mm)	0.62	1.42	0.58	1.56
Variance (mm^2)	0.38	2.03	0.34	2.43
Bubble Population Size	303	221	400	327
Equivalent Sauter Mean Diameter (mm)	3.07	5.55	2.83	4.97
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	6	0	6	8
$1.5 < R_B \leq 2$	29	4	62	24
$2 < R_B \leq 2.5$	46	7	125	54
$2.5 < R_B \leq 3$	96	16	120	56
$3 < R_B \leq 3.5$	85	18	55	42
$3.5 < R_B \leq 4$	37	27	26	31
$4 < R_B \leq 4.5$	3	27	6	25
$4.5 < R_B \leq 5$	1	33	0	19
$5 < R_B \leq 5.5$	0	25	0	14
$5.5 < R_B \leq 6$	0	23	0	21
$6 < R_B \leq 6.5$	0	21	0	13
$6.5 < R_B \leq 7$	0	11	0	8
$7 < R_B \leq 7.5$	0	6	0	7
$7.5 < R_B \leq 8$	0	1	0	4
$8 < R_B \leq 8.5$	0	0	0	0
$8.5 < R_B \leq 9$	0	0	0	1
$9 < R_B \leq 9.5$	0	0	0	0
$9.5 < R_B \leq 10$	0	0	0	0
$R_B > 10$	0	2	0	0

Table A4: Equivalent bubble diameter data sorted by size for ONP with BRD 2360 added to the system and an air flow rate of 0.25 slpm.

	BRD 2360 1.7 ml/kg (3 lbs/ton)				BRD 2360 3.3 ml/kg (6 lbs/ton)				BRD 2360 6.7 ml/kg (12 lbs/ton)			
	Gasket		Sparger		Gasket		Sparger		Gasket		Sparger	
Consistency	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP
Bubble Count	Equivalent Bubble Diameter (mm)											
1	1.22	1.10	1.70	1.25	1.01	1.44	1.04	1.08	1.29	1.63	1.13	1.21
2	1.41	1.17	1.74	1.31	1.23	3.16	1.13	1.10	1.30	1.78	1.28	1.23
3	1.41	1.17	1.80	1.46	1.24	3.64	1.14	1.10	1.39	1.87	1.34	1.25
4	1.66	1.19	1.80	1.55	1.29	3.67	1.24	1.11	1.40	1.96	1.34	1.32
5	1.80	1.22	1.81	1.56	1.37	3.73	1.28	1.14	1.40	2.25	1.44	1.36
6	1.85	1.27	1.82	1.57	1.37	3.79	1.30	1.15	1.42	2.35	1.47	1.39
7	1.93	1.31	1.83	1.64	1.38	3.84	1.30	1.15	1.51	2.36	1.53	1.42
8	1.94	1.55	1.83	1.65	1.42	3.87	1.43	1.16	1.53	2.36	1.53	1.44
9	1.99	1.58	1.83	1.71	1.44	3.92	1.44	1.16	1.53	2.37	1.58	1.53
10	2.03	1.64	1.84	1.72	1.46	3.95	1.48	1.19	1.55	2.43	1.59	1.59
11	2.03	1.64	1.89	1.77	1.54	4.17	1.49	1.20	1.58	2.45	1.60	1.60
12	2.04	1.67	1.90	1.81	1.55	4.23	1.52	1.21	1.59	2.52	1.60	1.62
13	2.15	1.67	1.91	1.81	1.57	4.37	1.53	1.22	1.60	2.52	1.61	1.65
14	2.15	1.70	1.91	1.81	1.57	4.37	1.53	1.22	1.60	2.56	1.62	1.73
15	2.15	1.75	1.92	1.82	1.57	4.40	1.54	1.23	1.62	2.64	1.63	1.74
16	2.16	1.75	1.93	1.83	1.57	4.50	1.55	1.23	1.68	2.64	1.64	1.76
17	2.17	1.89	1.94	1.85	1.58	4.55	1.55	1.27	1.68	2.64	1.64	1.77
18	2.17	1.90	1.98	1.88	1.58	4.61	1.55	1.33	1.71	2.67	1.65	1.77
19	2.19	1.95	1.98	1.93	1.59	4.69	1.57	1.33	1.75	2.68	1.66	1.79
20	2.19	1.96	1.99	1.93	1.59	4.78	1.58	1.33	1.76	2.71	1.67	1.79
21	2.20	1.98	1.99	1.94	1.62	4.81	1.58	1.34	1.77	2.73	1.68	1.82
22	2.20	1.99	1.99	1.95	1.63	4.82	1.59	1.36	1.77	2.78	1.69	1.83
23	2.20	2.01	2.00	1.96	1.66	4.91	1.60	1.37	1.79	2.84	1.70	1.84
24	2.21	2.01	2.00	1.96	1.66	4.93	1.63	1.38	1.85	2.89	1.71	1.87
25	2.23	2.04	2.00	2.00	1.68	5.01	1.63	1.38	1.85	2.91	1.71	1.88
26	2.25	2.05	2.01	2.01	1.69	5.01	1.64	1.39	1.87	2.92	1.72	1.92
27	2.25	2.08	2.01	2.01	1.72	5.01	1.64	1.40	1.87	2.97	1.73	1.92
28	2.25	2.09	2.03	2.03	1.72	5.01	1.64	1.40	1.87	3.03	1.76	1.92
29	2.25	2.12	2.04	2.03	1.72	5.02	1.64	1.45	1.88	3.03	1.77	1.93
30	2.25	2.13	2.04	2.04	1.74	5.02	1.65	1.45	1.89	3.03	1.77	1.94
31	2.26	2.18	2.04	2.05	1.75	5.03	1.65	1.46	1.89	3.07	1.79	1.94
32	2.26	2.18	2.05	2.06	1.75	5.03	1.65	1.46	1.92	3.14	1.79	1.95
33	2.26	2.24	2.05	2.12	1.75	5.10	1.65	1.49	1.93	3.15	1.80	2.02
34	2.27	2.25	2.07	2.14	1.75	5.10	1.67	1.50	1.95	3.19	1.80	2.02
35	2.27	2.26	2.08	2.15	1.76	5.11	1.68	1.50	1.99	3.29	1.81	2.04
36	2.29	2.32	2.11	2.15	1.76	5.16	1.69	1.52	2.01	3.30	1.81	2.05
37	2.29	2.33	2.12	2.18	1.77	5.20	1.71	1.55	2.02	3.33	1.84	2.05
38	2.31	2.36	2.13	2.18	1.77	5.22	1.71	1.55	2.03	3.36	1.85	2.05
39	2.31	2.37	2.14	2.19	1.77	5.23	1.72	1.55	2.04	3.37	1.85	2.06
40	2.31	2.39	2.14	2.20	1.78	5.23	1.74	1.56	2.06	3.40	1.85	2.07
41	2.31	2.39	2.14	2.20	1.79	5.23	1.74	1.56	2.06	3.41	1.86	2.08
42	2.31	2.46	2.14	2.22	1.82	5.26	1.74	1.59	2.06	3.42	1.86	2.08
43	2.32	2.47	2.14	2.22	1.82	5.26	1.74	1.61	2.07	3.43	1.86	2.09
44	2.32	2.49	2.17	2.24	1.86	5.30	1.74	1.61	2.07	3.44	1.87	2.12
45	2.32	2.51	2.18	2.25	1.86	5.31	1.75	1.61	2.08	3.48	1.87	2.13
46	2.32	2.57	2.18	2.26	1.86	5.32	1.75	1.63	2.09	3.52	1.87	2.15
47	2.33	2.60	2.20	2.27	1.86	5.37	1.75	1.64	2.10	3.55	1.87	2.17
48	2.34	2.60	2.21	2.27	1.87	5.39	1.75	1.64	2.11	3.55	1.88	2.17
49	2.34	2.60	2.22	2.29	1.88	5.40	1.76	1.65	2.13	3.55	1.88	2.17
50	2.34	2.61	2.23	2.31	1.88	5.42	1.76	1.65	2.15	3.56	1.88	2.17
51	2.34	2.62	2.24	2.31	1.89	5.43	1.77	1.65	2.19	3.57	1.89	2.18
52	2.35	2.67	2.24	2.32	1.89	5.44	1.77	1.69	2.20	3.63	1.90	2.18
53	2.35	2.67	2.26	2.32	1.90	5.45	1.78	1.70	2.22	3.64	1.91	2.18
54	2.35	2.68	2.28	2.32	1.90	5.45	1.78	1.71	2.23	3.68	1.91	2.19
55	2.36	2.69	2.29	2.33	1.90	5.46	1.79	1.72	2.25	3.69	1.92	2.22
56	2.36	2.69	2.29	2.33	1.91	5.46	1.80	1.72	2.25	3.73	1.93	2.25
57	2.36	2.70	2.31	2.33	1.91	5.46	1.80	1.73	2.26	3.75	1.94	2.25
58	2.37	2.70	2.31	2.33	1.92	5.46	1.80	1.73	2.27	3.78	1.94	2.26
59	2.37	2.70	2.31	2.35	1.93	5.47	1.80	1.74	2.27	3.80	1.94	2.27
60	2.37	2.71	2.33	2.36	1.93	5.47	1.81	1.75	2.28	3.80	1.94	2.27
61	2.38	2.72	2.34	2.36	1.93	5.48	1.81	1.77	2.28	3.80	1.95	2.27
62	2.38	2.73	2.35	2.36	1.94	5.49	1.82	1.78	2.30	3.81	1.95	2.28

Table A4: cont.

63	2.38	2.74	2.36	2.37	1.94	5.52	1.82	1.78	2.31	3.82	1.96	2.30
64	2.38	2.78	2.37	2.37	1.95	5.58	1.83	1.79	2.31	3.83	1.97	2.31
65	2.38	2.78	2.37	2.40	1.95	5.64	1.83	1.80	2.32	3.83	1.98	2.32
66	2.39	2.79	2.37	2.40	1.95	5.65	1.83	1.81	2.34	3.85	1.98	2.32
67	2.39	2.79	2.37	2.42	1.95	5.65	1.84	1.82	2.35	3.88	2.00	2.33
68	2.39	2.81	2.38	2.43	1.95	5.65	1.84	1.83	2.37	3.94	2.00	2.34
69	2.40	2.83	2.39	2.44	1.95	5.65	1.84	1.85	2.39	3.95	2.00	2.36
70	2.40	2.84	2.41	2.44	1.96	5.65	1.84	1.85	2.41	3.98	2.00	2.38
71	2.40	2.85	2.42	2.44	1.96	5.65	1.85	1.85	2.41	3.98	2.02	2.38
72	2.41	2.85	2.42	2.45	1.96	5.66	1.85	1.86	2.41	4.00	2.03	2.38
73	2.41	2.89	2.43	2.46	1.96	5.66	1.86	1.90	2.41	4.00	2.03	2.40
74	2.42	2.92	2.43	2.48	1.96	5.66	1.86	1.91	2.43	4.04	2.03	2.41
75	2.42	2.95	2.43	2.49	1.96	5.66	1.86	1.91	2.43	4.07	2.03	2.42
76	2.43	2.96	2.44	2.50	1.99	5.66	1.86	1.92	2.46	4.08	2.04	2.43
77	2.43	2.97	2.44	2.52	1.99	5.66	1.86	1.92	2.46	4.14	2.04	2.44
78	2.43	2.97	2.44	2.53	1.99	5.67	1.86	1.93	2.49	4.14	2.05	2.44
79	2.43	2.98	2.45	2.53	2.00	5.68	1.87	1.97	2.50	4.15	2.06	2.45
80	2.43	2.99	2.45	2.53	2.00	5.69	1.87	1.97	2.50	4.15	2.06	2.45
81	2.44	2.99	2.46	2.55	2.00	5.69	1.87	1.97	2.50	4.16	2.07	2.46
82	2.45	3.00	2.46	2.56	2.01	5.69	1.87	1.97	2.50	4.17	2.08	2.46
83	2.45	3.00	2.47	2.56	2.01	5.73	1.87	1.98	2.50	4.18	2.10	2.46
84	2.46	3.01	2.48	2.57	2.01	5.74	1.88	1.99	2.51	4.21	2.10	2.47
85	2.47	3.02	2.49	2.57	2.01	5.74	1.89	1.99	2.51	4.24	2.12	2.48
86	2.48	3.05	2.49	2.57	2.01	5.76	1.89	2.00	2.51	4.24	2.12	2.49
87	2.48	3.05	2.50	2.58	2.02	5.76	1.90	2.01	2.51	4.28	2.13	2.50
88	2.48	3.05	2.51	2.60	2.02	5.76	1.90	2.01	2.51	4.31	2.13	2.50
89	2.48	3.06	2.51	2.61	2.02	5.77	1.90	2.02	2.52	4.32	2.14	2.50
90	2.49	3.08	2.51	2.61	2.03	5.80	1.91	2.02	2.54	4.33	2.14	2.52
91	2.49	3.09	2.52	2.62	2.04	5.82	1.91	2.04	2.54	4.36	2.14	2.54
92	2.49	3.09	2.53	2.63	2.04	5.82	1.91	2.05	2.54	4.36	2.15	2.55
93	2.49	3.13	2.53	2.64	2.04	5.83	1.91	2.06	2.56	4.39	2.15	2.55
94	2.50	3.18	2.54	2.65	2.04	5.84	1.91	2.07	2.57	4.39	2.16	2.56
95	2.50	3.22	2.54	2.67	2.05	5.85	1.91	2.07	2.57	4.39	2.16	2.56
96	2.50	3.22	2.54	2.67	2.06	5.87	1.92	2.07	2.57	4.41	2.16	2.56
97	2.50	3.23	2.55	2.67	2.06	5.87	1.92	2.08	2.58	4.41	2.17	2.57
98	2.51	3.24	2.56	2.68	2.07	5.89	1.92	2.09	2.58	4.45	2.17	2.59
99	2.51	3.25	2.57	2.69	2.07	5.89	1.92	2.09	2.58	4.47	2.17	2.60
100	2.51	3.25	2.57	2.70	2.07	5.89	1.93	2.09	2.58	4.50	2.18	2.60
101	2.52	3.26	2.58	2.70	2.07	5.92	1.93	2.09	2.58	4.50	2.19	2.60
102	2.52	3.26	2.59	2.71	2.08	5.92	1.93	2.10	2.59	4.52	2.19	2.61
103	2.53	3.28	2.61	2.72	2.09	5.93	1.93	2.10	2.60	4.57	2.20	2.61
104	2.53	3.28	2.62	2.72	2.09	5.94	1.94	2.10	2.60	4.58	2.20	2.61
105	2.54	3.28	2.63	2.73	2.09	5.94	1.94	2.12	2.60	4.59	2.20	2.62
106	2.54	3.28	2.63	2.73	2.11	5.99	1.94	2.12	2.61	4.59	2.21	2.63
107	2.55	3.28	2.63	2.73	2.11	6.00	1.94	2.13	2.62	4.61	2.21	2.63
108	2.55	3.30	2.64	2.74	2.11	6.00	1.95	2.13	2.62	4.63	2.21	2.64
109	2.56	3.31	2.64	2.75	2.12	6.00	1.95	2.13	2.64	4.67	2.21	2.64
110	2.56	3.33	2.64	2.76	2.12	6.01	1.95	2.13	2.64	4.67	2.21	2.65
111	2.56	3.36	2.64	2.78	2.12	6.01	1.95	2.14	2.65	4.67	2.22	2.66
112	2.56	3.36	2.64	2.79	2.12	6.01	1.95	2.14	2.65	4.68	2.23	2.67
113	2.56	3.39	2.65	2.79	2.13	6.02	1.95	2.14	2.66	4.73	2.23	2.68
114	2.56	3.39	2.67	2.81	2.13	6.02	1.96	2.14	2.66	4.73	2.24	2.74
115	2.57	3.47	2.67	2.81	2.13	6.03	1.96	2.14	2.66	4.75	2.24	2.75
116	2.57	3.49	2.67	2.82	2.14	6.04	1.96	2.14	2.67	4.78	2.24	2.75
117	2.57	3.50	2.67	2.83	2.15	6.05	1.96	2.15	2.67	4.80	2.24	2.78
118	2.58	3.50	2.70	2.84	2.17	6.07	1.96	2.16	2.68	4.81	2.24	2.82
119	2.58	3.52	2.70	2.84	2.17	6.13	1.96	2.18	2.70	4.86	2.24	2.82
120	2.58	3.54	2.70	2.85	2.17	6.13	1.96	2.18	2.72	4.87	2.24	2.83
121	2.58	3.56	2.72	2.85	2.17	6.13	1.96	2.18	2.72	4.88	2.25	2.83
122	2.58	3.57	2.72	2.85	2.17	6.13	1.96	2.18	2.73	4.88	2.26	2.84
123	2.58	3.61	2.72	2.86	2.17	6.14	1.97	2.18	2.74	4.89	2.27	2.84
124	2.59	3.63	2.72	2.87	2.17	6.15	1.97	2.19	2.74	4.92	2.28	2.85
125	2.59	3.63	2.73	2.88	2.18	6.15	1.97	2.19	2.74	4.94	2.28	2.86
126	2.60	3.65	2.74	2.89	2.18	6.15	1.97	2.21	2.75	4.95	2.28	2.87
127	2.60	3.66	2.74	2.89	2.18	6.16	1.97	2.21	2.75	4.97	2.28	2.87
128	2.60	3.69	2.76	2.91	2.19	6.16	1.98	2.21	2.75	4.98	2.28	2.88
129	2.61	3.69	2.76	2.91	2.19	6.16	1.98	2.21	2.75	4.99	2.29	2.89
130	2.62	3.71	2.76	2.91	2.20	6.18	1.98	2.21	2.76	4.99	2.29	2.89

Table A4: cont.

131	2.63	3.73	2.76	2.91	2.20	6.18	1.98	2.22	2.76	5.00	2.29	2.89
132	2.63	3.74	2.77	2.93	2.21	6.21	1.99	2.22	2.76	5.00	2.31	2.90
133	2.64	3.76	2.79	2.93	2.21	6.22	1.99	2.23	2.76	5.00	2.31	2.90
134	2.65	3.76	2.80	2.95	2.21	6.23	1.99	2.25	2.76	5.01	2.31	2.91
135	2.66	3.76	2.80	2.96	2.21	6.23	2.00	2.27	2.76	5.02	2.31	2.91
136	2.67	3.77	2.83	2.96	2.22	6.23	2.00	2.27	2.76	5.03	2.32	2.92
137	2.68	3.79	2.84	3.00	2.22	6.23	2.00	2.28	2.79	5.04	2.32	2.93
138	2.68	3.84	2.85	3.00	2.22	6.26	2.00	2.28	2.79	5.04	2.33	2.93
139	2.69	3.84	2.85	3.01	2.22	6.26	2.00	2.28	2.79	5.04	2.34	2.94
140	2.69	3.86	2.86	3.02	2.23	6.27	2.01	2.28	2.80	5.04	2.34	2.94
141	2.69	3.88	2.86	3.02	2.23	6.28	2.01	2.29	2.81	5.05	2.34	2.94
142	2.69	3.91	2.87	3.03	2.23	6.29	2.01	2.29	2.81	5.08	2.34	2.95
143	2.70	3.91	2.88	3.03	2.25	6.29	2.01	2.30	2.82	5.15	2.34	3.00
144	2.70	3.91	2.88	3.03	2.25	6.30	2.02	2.31	2.84	5.17	2.35	3.01
145	2.70	3.92	2.88	3.03	2.26	6.30	2.02	2.31	2.84	5.17	2.35	3.01
146	2.71	3.93	2.89	3.06	2.26	6.34	2.02	2.32	2.85	5.21	2.36	3.03
147	2.71	3.96	2.90	3.06	2.27	6.34	2.02	2.32	2.85	5.22	2.36	3.06
148	2.71	3.97	2.90	3.10	2.27	6.35	2.02	2.32	2.85	5.26	2.36	3.07
149	2.71	3.98	2.90	3.11	2.27	6.37	2.02	2.33	2.86	5.27	2.37	3.08
150	2.71	4.00	2.91	3.12	2.27	6.37	2.03	2.33	2.86	5.28	2.37	3.10
151	2.72	4.01	2.93	3.12	2.27	6.38	2.04	2.33	2.86	5.28	2.37	3.10
152	2.72	4.04	2.93	3.14	2.27	6.39	2.04	2.33	2.87	5.30	2.38	3.11
153	2.73	4.05	2.94	3.14	2.28	6.40	2.04	2.34	2.88	5.32	2.38	3.13
154	2.73	4.09	2.95	3.15	2.28	6.40	2.04	2.34	2.88	5.44	2.38	3.14
155	2.74	4.11	2.95	3.15	2.28	6.40	2.04	2.35	2.88	5.45	2.38	3.15
156	2.74	4.12	2.95	3.16	2.28	6.41	2.04	2.35	2.88	5.47	2.39	3.17
157	2.74	4.13	2.96	3.16	2.28	6.42	2.05	2.35	2.89	5.50	2.39	3.18
158	2.74	4.13	2.96	3.16	2.29	6.42	2.05	2.35	2.91	5.51	2.40	3.18
159	2.74	4.14	2.96	3.17	2.29	6.43	2.05	2.37	2.93	5.51	2.40	3.20
160	2.75	4.15	2.99	3.18	2.30	6.44	2.05	2.37	2.93	5.52	2.40	3.21
161	2.75	4.15	3.00	3.18	2.30	6.46	2.05	2.37	2.93	5.52	2.41	3.21
162	2.75	4.16	3.00	3.19	2.30	6.47	2.06	2.38	2.93	5.54	2.41	3.23
163	2.75	4.16	3.00	3.19	2.31	6.47	2.06	2.38	2.94	5.56	2.41	3.23
164	2.76	4.20	3.01	3.20	2.31	6.49	2.06	2.39	2.94	5.56	2.41	3.23
165	2.76	4.20	3.01	3.21	2.31	6.52	2.06	2.39	2.94	5.56	2.42	3.24
166	2.76	4.22	3.02	3.23	2.31	6.54	2.07	2.39	2.94	5.58	2.43	3.26
167	2.76	4.24	3.02	3.25	2.31	6.54	2.07	2.39	2.96	5.59	2.43	3.27
168	2.76	4.29	3.03	3.25	2.31	6.57	2.07	2.40	2.97	5.62	2.43	3.27
169	2.77	4.29	3.03	3.25	2.32	6.59	2.07	2.40	2.97	5.63	2.43	3.32
170	2.77	4.31	3.03	3.26	2.33	6.60	2.07	2.40	2.97	5.73	2.43	3.34
171	2.78	4.34	3.04	3.26	2.33	6.60	2.08	2.40	2.98	5.76	2.43	3.34
172	2.78	4.36	3.04	3.28	2.33	6.62	2.08	2.40	2.98	5.77	2.43	3.35
173	2.78	4.37	3.05	3.29	2.33	6.64	2.08	2.41	2.99	5.86	2.43	3.38
174	2.79	4.40	3.05	3.29	2.33	6.67	2.08	2.41	2.99	5.88	2.44	3.38
175	2.79	4.41	3.05	3.30	2.33	6.68	2.08	2.41	2.99	5.89	2.44	3.39
176	2.80	4.44	3.05	3.32	2.34	6.68	2.08	2.42	3.00	5.90	2.44	3.39
177	2.80	4.46	3.06	3.34	2.34	6.70	2.08	2.42	3.00	5.92	2.45	3.40
178	2.80	4.47	3.08	3.34	2.35	6.71	2.08	2.42	3.00	5.94	2.45	3.40
179	2.81	4.48	3.10	3.35	2.35	6.74	2.08	2.44	3.01	5.98	2.45	3.41
180	2.81	4.49	3.11	3.35	2.35	6.75	2.08	2.44	3.01	6.00	2.46	3.41
181	2.82	4.51	3.12	3.36	2.36	6.76	2.09	2.45	3.01	6.03	2.46	3.44
182	2.82	4.59	3.12	3.37	2.36	6.77	2.09	2.45	3.01	6.06	2.46	3.44
183	2.82	4.62	3.13	3.38	2.37	6.78	2.09	2.46	3.01	6.07	2.46	3.47
184	2.83	4.65	3.13	3.39	2.37	6.80	2.09	2.46	3.01	6.11	2.46	3.49
185	2.83	4.65	3.13	3.39	2.37	6.81	2.10	2.46	3.01	6.13	2.46	3.50
186	2.83	4.68	3.14	3.39	2.37	6.83	2.10	2.46	3.02	6.14	2.48	3.54
187	2.84	4.71	3.14	3.42	2.38	6.83	2.10	2.47	3.02	6.15	2.48	3.55
188	2.84	4.72	3.15	3.45	2.39	6.84	2.11	2.47	3.02	6.17	2.49	3.56
189	2.84	4.72	3.20	3.46	2.39	6.85	2.11	2.48	3.04	6.19	2.49	3.58
190	2.84	4.72	3.21	3.48	2.40	6.90	2.11	2.49	3.04	6.20	2.49	3.58
191	2.84	4.73	3.21	3.49	2.40	6.94	2.11	2.49	3.04	6.22	2.49	3.58
192	2.85	4.78	3.22	3.49	2.40	6.94	2.11	2.50	3.05	6.23	2.49	3.60
193	2.86	4.78	3.23	3.49	2.40	6.94	2.11	2.50	3.06	6.27	2.50	3.68
194	2.87	4.78	3.23	3.49	2.41	6.94	2.11	2.50	3.07	6.39	2.50	3.68
195	2.87	4.79	3.23	3.49	2.41	6.94	2.11	2.50	3.08	6.41	2.51	3.71
196	2.89	4.80	3.24	3.50	2.42	6.96	2.12	2.50	3.09	6.46	2.51	3.74
197	2.89	4.82	3.25	3.51	2.42	6.97	2.12	2.51	3.09	6.46	2.51	3.75
198	2.90	4.83	3.26	3.52	2.42	6.99	2.12	2.51	3.09	6.46	2.51	3.78

Table A4: cont.

199	2.91	4.84	3.27	3.52	2.43	6.99	2.13	2.52	3.10	6.47	2.52	3.79
200	2.93	4.87	3.27	3.53	2.43	7.00	2.13	2.52	3.10	6.48	2.52	3.79
201	2.93	4.88	3.28	3.54	2.43	7.00	2.13	2.53	3.11	6.50	2.52	3.80
202	2.93	4.93	3.28	3.54	2.44	7.01	2.13	2.53	3.11	6.52	2.52	3.82
203	2.94	4.95	3.29	3.57	2.44	7.05	2.14	2.53	3.11	6.56	2.52	3.84
204	2.94	4.98	3.29	3.60	2.44	7.14	2.14	2.53	3.11	6.60	2.52	3.84
205	2.94	5.03	3.29	3.62	2.44	7.15	2.14	2.54	3.12	6.60	2.53	3.85
206	2.94	5.03	3.29	3.62	2.44	7.16	2.14	2.54	3.13	6.60	2.53	3.86
207	2.94	5.06	3.30	3.62	2.44	7.17	2.14	2.55	3.13	6.61	2.54	3.86
208	2.94	5.11	3.30	3.63	2.45	7.19	2.14	2.55	3.14	6.74	2.54	3.89
209	2.95	5.13	3.30	3.63	2.45	7.20	2.14	2.56	3.15	6.89	2.54	3.90
210	2.95	5.14	3.31	3.65	2.45	7.21	2.15	2.56	3.16	6.91	2.54	3.92
211	2.96	5.14	3.32	3.66	2.45	7.23	2.15	2.58	3.16	6.95	2.54	3.92
212	2.98	5.18	3.35	3.68	2.45	7.29	2.15	2.58	3.16	6.98	2.55	3.92
213	2.99	5.20	3.35	3.69	2.46	7.35	2.15	2.59	3.17	7.03	2.56	3.93
214	2.99	5.21	3.36	3.70	2.46	7.35	2.15	2.60	3.19	7.18	2.56	3.97
215	2.99	5.23	3.37	3.72	2.46	7.35	2.15	2.60	3.21	7.19	2.56	3.99
216	3.00	5.24	3.39	3.72	2.46	7.35	2.16	2.61	3.22	7.21	2.56	4.01
217	3.02	5.25	3.40	3.73	2.46	7.42	2.16	2.61	3.22	7.27	2.57	4.04
218	3.05	5.28	3.42	3.73	2.47	7.44	2.16	2.61	3.22	7.29	2.57	4.06
219	3.06	5.28	3.42	3.73	2.47	7.61	2.16	2.61	3.23	7.54	2.57	4.14
220	3.07	5.38	3.42	3.74	2.47	7.63	2.16	2.62	3.24	10.59	2.58	4.15
221	3.09	5.39	3.42	3.75	2.47	7.66	2.17	2.62	3.24	10.59	2.59	4.16
222	3.09	5.43	3.42	3.75	2.47	7.70	2.17	2.62	3.24		2.59	4.22
223	3.12	5.43	3.44	3.76	2.48	7.73	2.17	2.62	3.24		2.59	4.23
224	3.12	5.43	3.44	3.79	2.48	7.77	2.17	2.63	3.24		2.60	4.24
225	3.14	5.43	3.45	3.79	2.48	7.79	2.17	2.63	3.24		2.60	4.27
226	3.14	5.44	3.45	3.81	2.48	7.83	2.17	2.63	3.25		2.61	4.27
227	3.14	5.45	3.46	3.82	2.48	7.98	2.18	2.64	3.26		2.61	4.29
228	3.15	5.46	3.47	3.83	2.48	8.04	2.18	2.64	3.26		2.62	4.29
229	3.15	5.46	3.48	3.83	2.48	8.08	2.18	2.64	3.27		2.62	4.29
230	3.17	5.47	3.48	3.84	2.49	8.14	2.18	2.65	3.29		2.62	4.30
231	3.18	5.60	3.54	3.86	2.49	8.24	2.18	2.65	3.30		2.62	4.32
232	3.26	5.60	3.54	3.86	2.49	8.28	2.18	2.65	3.30		2.63	4.34
233	3.26	5.61	3.56	3.88	2.49	8.41	2.18	2.65	3.30		2.63	4.35
234	3.27	5.67	3.56	3.88	2.49	8.43	2.18	2.66	3.30		2.63	4.35
235	3.30	5.67	3.57	3.92	2.49	8.43	2.18	2.66	3.31		2.63	4.35
236	3.33	5.71	3.59	3.92	2.49	8.43	2.19	2.67	3.31		2.63	4.36
237	3.40	5.72	3.62	3.95	2.51	8.43	2.19	2.67	3.31		2.64	4.40
238	3.41	5.73	3.64	3.96	2.51	8.57	2.19	2.68	3.32		2.64	4.40
239	3.43	5.74	3.74	3.97	2.51	8.59	2.19	2.68	3.32		2.64	4.42
240	3.47	5.76	3.75	3.99	2.52	8.70	2.19	2.70	3.32		2.65	4.47
241	3.47	5.76	3.75	4.00	2.53	8.72	2.19	2.71	3.32		2.65	4.53
242	3.47	5.76	3.75	4.02	2.53	8.84	2.19	2.71	3.32		2.65	4.54
243	3.48	5.76	3.78	4.04	2.54	8.86	2.19	2.72	3.33		2.65	4.56
244	3.49	5.83	3.79	4.04	2.54	8.87	2.19	2.73	3.33		2.65	4.58
245	3.53	5.93	3.83	4.05	2.54	8.88	2.20	2.74	3.34		2.65	4.61
246	3.53	5.94	3.89	4.06	2.54	8.88	2.20	2.74	3.35		2.66	4.62
247	3.53	5.95	3.96	4.10	2.54	9.06	2.21	2.74	3.35		2.66	4.65
248	3.54	5.96	3.96	4.11	2.55	9.17	2.21	2.74	3.36		2.66	4.70
249		5.99	4.06	4.12	2.55	9.43	2.21	2.74	3.37		2.67	4.70
250		6.01	4.19	4.12	2.55	9.91	2.21	2.75	3.38		2.67	4.77
251		6.02	4.20	4.13	2.55	11.18	2.21	2.76	3.38		2.67	4.77
252		6.03		4.16	2.55	11.18	2.21	2.76	3.39		2.68	4.78
253		6.08		4.20	2.56	12.51	2.21	2.76	3.39		2.69	4.79
254		6.12		4.22	2.56		2.21	2.77	3.40		2.69	4.79
255		6.22		4.24	2.56		2.21	2.77	3.41		2.69	4.84
256		6.25		4.24	2.56		2.22	2.78	3.41		2.70	4.86
257		6.31		4.31	2.57		2.22	2.78	3.43		2.70	4.91
258		6.32		4.35	2.58		2.22	2.78	3.46		2.70	4.95
259		6.34		4.35	2.58		2.22	2.79	3.47		2.71	4.96
260		6.35		4.36	2.58		2.22	2.79	3.48		2.71	5.04
261		6.44		4.37	2.59		2.22	2.79	3.48		2.72	5.04
262		6.58		4.38	2.59		2.22	2.79	3.48		2.72	5.05
263		6.61		4.41	2.59		2.22	2.79	3.50		2.73	5.06
264		6.76		4.45	2.59		2.22	2.79	3.50		2.73	5.06
265		6.81		4.52	2.59		2.23	2.79	3.51		2.73	5.07
266		6.98		4.54	2.60		2.23	2.79	3.53		2.74	5.10

Table A4: cont.

267		7.06		4.58	2.60		2.23	2.80	3.54		2.74	5.10
268		7.17		4.61	2.60		2.23	2.81	3.54		2.74	5.12
269		7.33		4.75	2.60		2.23	2.81	3.54		2.76	5.22
270		7.36		4.84	2.61		2.23	2.82	3.56		2.78	5.22
271		7.47		4.86	2.61		2.23	2.82	3.57		2.78	5.23
272		7.47		4.88	2.61		2.23	2.83	3.60		2.78	5.33
273		7.64		4.89	2.61		2.23	2.83	3.60		2.79	5.48
274		7.67		4.90	2.62		2.23	2.84	3.60		2.79	5.54
275		8.92		4.99	2.62		2.23	2.84	3.60		2.81	5.54
276				4.99	2.62		2.24	2.84	3.60		2.81	5.58
277				5.08	2.62		2.24	2.85	3.61		2.82	5.58
278				5.13	2.62		2.24	2.86	3.61		2.82	5.68
279				5.16	2.63		2.24	2.87	3.63		2.82	5.72
280				5.18	2.63		2.24	2.88	3.63		2.82	5.73
281				5.24	2.63		2.24	2.88	3.64		2.83	5.74
282				5.25	2.63		2.25	2.88	3.64		2.83	5.74
283				5.28	2.63		2.25	2.88	3.64		2.83	5.75
284				5.35	2.64		2.25	2.88	3.64		2.84	5.81
285				5.46	2.64		2.25	2.89	3.65		2.84	5.82
286				5.47	2.65		2.25	2.89	3.67		2.85	5.84
287				5.61	2.65		2.25	2.89	3.67		2.85	5.88
288				5.73	2.66		2.25	2.89	3.69		2.86	5.91
289				5.78	2.66		2.26	2.90	3.70		2.86	5.92
290				5.80	2.66		2.26	2.91	3.71		2.87	5.93
291				5.84	2.67		2.26	2.91	3.71		2.87	5.94
292				5.85	2.67		2.26	2.92	3.71		2.87	5.96
293				6.01	2.67		2.26	2.93	3.73		2.88	5.99
294				6.07	2.67		2.26	2.94	3.76		2.89	6.00
295				6.09	2.67		2.26	2.94	3.80		2.89	6.01
296				6.19	2.67		2.26	2.94	3.84		2.89	6.05
297				6.24	2.67		2.26	2.94	3.90		2.89	6.08
298				6.32	2.68		2.27	2.95	3.91		2.90	6.09
299				6.35	2.68		2.27	2.95	4.00		2.90	6.12
300				6.60	2.68		2.27	2.96	4.09		2.92	6.15
301				6.70	2.68		2.27	2.96	4.11		2.92	6.16
302				6.73	2.69		2.27	2.96	4.14		2.93	6.24
303				6.77	2.69		2.27	2.97	4.96		2.94	6.33
304				6.80	2.69		2.27	2.97			2.94	6.36
305				6.86	2.69		2.27	2.97			2.94	6.38
306				6.97	2.69		2.27	2.97			2.95	6.42
307				7.01	2.69		2.28	2.98			2.95	6.47
308				7.27	2.70		2.28	2.98			2.96	6.52
309				7.30	2.70		2.28	2.99			2.97	6.53
310				7.30	2.70		2.28	3.00			2.97	6.54
311				7.38	2.70		2.28	3.00			2.98	6.65
312				7.40	2.71		2.28	3.00			2.99	6.72
313				7.41	2.71		2.28	3.03			2.99	6.81
314				7.52	2.71		2.28	3.04			3.00	6.82
315				7.85	2.72		2.28	3.04			3.00	6.99
316				8.21	2.72		2.28	3.04			3.01	7.14
317				8.81	2.72		2.28	3.05			3.01	7.20
318					2.72		2.28	3.05			3.01	7.21
319					2.72		2.28	3.06			3.01	7.26
320					2.73		2.29	3.07			3.02	7.38
321					2.74		2.29	3.07			3.03	7.38
322					2.74		2.29	3.09			3.03	7.43
323					2.74		2.29	3.09			3.04	7.59
324					2.74		2.29	3.10			3.05	7.68
325					2.74		2.29	3.10			3.05	7.69
326					2.74		2.30	3.10			3.07	7.74
327					2.74		2.30	3.10			3.07	8.52
328					2.74		2.30	3.10			3.07	
329					2.75		2.30	3.11			3.07	
330					2.75		2.31	3.11			3.08	
331					2.75		2.31	3.12			3.09	
332					2.75		2.31	3.12			3.09	
333					2.75		2.31	3.13			3.10	
334					2.75		2.31	3.13			3.12	

Table A4: cont.

335					2.76		2.31	3.13			3.12	
336					2.76		2.32	3.14			3.12	
337					2.76		2.32	3.14			3.13	
338					2.76		2.32	3.14			3.14	
339					2.76		2.32	3.14			3.17	
340					2.77		2.32	3.14			3.17	
341					2.77		2.32	3.14			3.17	
342					2.77		2.32	3.15			3.18	
343					2.78		2.32	3.15			3.19	
344					2.78		2.33	3.15			3.19	
345					2.78		2.33	3.15			3.20	
346					2.78		2.33	3.15			3.20	
347					2.78		2.33	3.15			3.21	
348					2.78		2.33	3.16			3.22	
349					2.78		2.33	3.16			3.22	
350					2.79		2.33	3.16			3.23	
351					2.79		2.33	3.16			3.23	
352					2.79		2.34	3.17			3.23	
353					2.80		2.34	3.17			3.25	
354					2.80		2.34	3.17			3.26	
355					2.80		2.34	3.18			3.28	
356					2.81		2.34	3.18			3.30	
357					2.81		2.35	3.18			3.30	
358					2.81		2.35	3.18			3.32	
359					2.81		2.35	3.18			3.32	
360					2.81		2.35	3.18			3.32	
361					2.81		2.35	3.19			3.36	
362					2.81		2.35	3.19			3.40	
363					2.81		2.35	3.19			3.41	
364					2.81		2.35	3.20			3.41	
365					2.82		2.35	3.22			3.44	
366					2.82		2.35	3.22			3.44	
367					2.82		2.35	3.22			3.47	
368					2.82		2.35	3.23			3.49	
369					2.82		2.35	3.23			3.51	
370					2.83		2.35	3.24			3.53	
371					2.83		2.35	3.25			3.53	
372					2.83		2.36	3.25			3.53	
373					2.83		2.36	3.25			3.54	
374					2.83		2.36	3.26			3.54	
375					2.83		2.37	3.26			3.56	
376					2.84		2.37	3.27			3.57	
377					2.84		2.37	3.27			3.58	
378					2.84		2.38	3.27			3.60	
379					2.84		2.38	3.28			3.62	
380					2.84		2.38	3.28			3.63	
381					2.85		2.38	3.28			3.64	
382					2.85		2.38	3.28			3.65	
383					2.85		2.38	3.31			3.65	
384					2.85		2.38	3.32			3.68	
385					2.85		2.38	3.33			3.68	
386					2.86		2.39	3.33			3.71	
387					2.86		2.39	3.33			3.78	
388					2.87		2.39	3.33			3.78	
389					2.87		2.39	3.33			3.83	
390					2.87		2.39	3.34			3.87	
391					2.87		2.39	3.34			3.90	
392					2.88		2.39	3.34			3.91	
393					2.88		2.39	3.35			3.91	
394					2.88		2.39	3.35			3.92	
395					2.88		2.40	3.36			4.03	
396					2.89		2.40	3.37			4.10	
397					2.89		2.40	3.37			4.21	
398					2.89		2.40	3.37			4.31	
399					2.89		2.40	3.38			4.41	
400					2.89		2.40	3.38			4.43	
401					2.89		2.40	3.38				
402					2.89		2.41	3.39				

Table A4: cont.

403					2.90		2.41	3.40				
404					2.90		2.41	3.40				
405					2.90		2.41	3.41				
406					2.90		2.41	3.41				
407					2.90		2.42	3.41				
408					2.90		2.42	3.41				
409					2.90		2.42	3.42				
410					2.90		2.42	3.42				
411					2.91		2.42	3.42				
412					2.91		2.43	3.43				
413					2.91		2.43	3.43				
414					2.91		2.43	3.43				
415					2.91		2.43	3.44				
416					2.91		2.43	3.44				
417					2.92		2.43	3.45				
418					2.92		2.43	3.46				
419					2.92		2.44	3.46				
420					2.92		2.44	3.47				
421					2.93		2.44	3.47				
422					2.94		2.44	3.47				
423					2.94		2.44	3.48				
424					2.94		2.44	3.49				
425					2.95		2.45	3.50				
426					2.95		2.45	3.50				
427					2.95		2.45	3.51				
428					2.95		2.45	3.51				
429					2.95		2.45	3.51				
430					2.96		2.45	3.53				
431					2.96		2.46	3.53				
432					2.96		2.46	3.53				
433					2.96		2.46	3.53				
434					2.96		2.46	3.53				
435					2.96		2.46	3.54				
436					2.96		2.46	3.55				
437					2.97		2.46	3.55				
438					2.97		2.46	3.55				
439					2.97		2.46	3.55				
440					2.98		2.47	3.56				
441					2.98		2.47	3.56				
442					2.99		2.47	3.57				
443					2.99		2.47	3.57				
444					2.99		2.47	3.57				
445					3.00		2.47	3.58				
446					3.01		2.48	3.59				
447					3.01		2.48	3.59				
448					3.01		2.48	3.60				
449					3.01		2.48	3.60				
450					3.02		2.48	3.60				
451					3.02		2.48	3.61				
452					3.02		2.49	3.61				
453					3.02		2.49	3.61				
454					3.02		2.49	3.61				
455					3.03		2.49	3.61				
456					3.03		2.49	3.62				
457					3.03		2.49	3.62				
458					3.03		2.49	3.62				
459					3.03		2.49	3.62				
460					3.03		2.49	3.63				
461					3.04		2.50	3.63				
462					3.04		2.50	3.64				
463					3.04		2.50	3.64				
464					3.04		2.50	3.64				
465					3.04		2.50	3.64				
466					3.04		2.50	3.64				
467					3.04		2.50	3.65				
468					3.05		2.50	3.65				
469					3.05		2.50	3.65				
470					3.05		2.50	3.67				

Table A4: cont.

471					3.05		2.50	3.67					
472					3.05		2.51	3.68					
473					3.05		2.51	3.69					
474					3.05		2.51	3.69					
475					3.06		2.51	3.69					
476					3.06		2.51	3.70					
477					3.06		2.51	3.70					
478					3.06		2.51	3.70					
479					3.06		2.51	3.70					
480					3.06		2.52	3.71					
481					3.07		2.52	3.72					
482					3.07		2.52	3.72					
483					3.08		2.52	3.72					
484					3.08		2.52	3.73					
485					3.08		2.52	3.73					
486					3.08		2.52	3.74					
487					3.08		2.52	3.75					
488					3.08		2.52	3.75					
489					3.08		2.52	3.75					
490					3.09		2.52	3.76					
491					3.09		2.53	3.77					
492					3.09		2.53	3.77					
493					3.09		2.53	3.78					
494					3.09		2.53	3.78					
495					3.09		2.53	3.78					
496					3.10		2.53	3.78					
497					3.10		2.53	3.79					
498					3.10		2.54	3.79					
499					3.10		2.54	3.80					
500					3.11		2.54	3.80					
501					3.11		2.54	3.80					
502					3.11		2.54	3.80					
503					3.11		2.54	3.81					
504					3.11		2.54	3.81					
505					3.12		2.55	3.81					
506					3.12		2.55	3.81					
507					3.12		2.55	3.81					
508					3.12		2.55	3.82					
509					3.13		2.55	3.82					
510					3.13		2.56	3.83					
511					3.13		2.56	3.84					
512					3.14		2.56	3.84					
513					3.14		2.56	3.84					
514					3.14		2.56	3.85					
515					3.14		2.56	3.86					
516					3.14		2.56	3.86					
517					3.14		2.56	3.86					
518					3.14		2.56	3.87					
519					3.14		2.56	3.87					
520					3.14		2.57	3.88					
521					3.15		2.57	3.88					
522					3.15		2.57	3.88					
523					3.15		2.57	3.89					
524					3.15		2.57	3.89					
525					3.16		2.57	3.89					
526					3.16		2.57	3.90					
527					3.16		2.57	3.90					
528					3.17		2.57	3.91					
529					3.17		2.58	3.91					
530					3.17		2.58	3.93					
531					3.17		2.58	3.93					
532					3.17		2.59	3.93					
533					3.17		2.59	3.93					
534					3.18		2.59	3.94					
535					3.18		2.59	3.95					
536					3.18		2.59	3.95					
537					3.18		2.59	3.97					
538					3.18		2.60	3.97					

Table A4: cont.

539					3.18		2.60	3.98				
540					3.18		2.61	3.99				
541					3.18		2.61	3.99				
542					3.18		2.61	4.00				
543					3.19		2.61	4.01				
544					3.20		2.62	4.02				
545					3.20		2.62	4.02				
546					3.21		2.62	4.03				
547					3.21		2.62	4.04				
548					3.21		2.62	4.04				
549					3.21		2.62	4.05				
550					3.21		2.62	4.06				
551					3.21		2.62	4.07				
552					3.22		2.62	4.07				
553					3.22		2.62	4.07				
554					3.22		2.63	4.07				
555					3.23		2.63	4.08				
556					3.23		2.63	4.08				
557					3.23		2.63	4.09				
558					3.23		2.63	4.09				
559					3.23		2.63	4.10				
560					3.24		2.63	4.10				
561					3.24		2.63	4.11				
562					3.25		2.63	4.11				
563					3.25		2.64	4.11				
564					3.25		2.64	4.12				
565					3.25		2.64	4.12				
566					3.25		2.64	4.13				
567					3.26		2.64	4.13				
568					3.26		2.64	4.13				
569					3.27		2.65	4.16				
570					3.27		2.65	4.16				
571					3.27		2.65	4.17				
572					3.27		2.66	4.17				
573					3.28		2.66	4.19				
574					3.28		2.66	4.19				
575					3.28		2.66	4.20				
576					3.29		2.66	4.20				
577					3.29		2.66	4.21				
578					3.30		2.66	4.21				
579					3.30		2.66	4.21				
580					3.30		2.67	4.22				
581					3.31		2.67	4.22				
582					3.32		2.67	4.22				
583					3.32		2.67	4.24				
584					3.32		2.67	4.26				
585					3.32		2.67	4.26				
586					3.32		2.67	4.26				
587					3.32		2.68	4.27				
588					3.32		2.68	4.27				
589					3.33		2.68	4.27				
590					3.33		2.68	4.27				
591					3.33		2.69	4.27				
592					3.33		2.69	4.27				
593					3.33		2.69	4.27				
594					3.33		2.69	4.29				
595					3.33		2.69	4.30				
596					3.33		2.69	4.30				
597					3.33		2.70	4.32				
598					3.34		2.70	4.32				
599					3.34		2.70	4.32				
600					3.34		2.70	4.33				
601					3.34		2.70	4.36				
602					3.34		2.70	4.36				
603					3.35		2.70	4.37				
604					3.35		2.70	4.37				
605					3.35		2.70	4.37				
606					3.36		2.71	4.37				

Table A4: cont.

607					3.36		2.71	4.37				
608					3.36		2.71	4.37				
609					3.36		2.71	4.38				
610					3.36		2.71	4.39				
611					3.36		2.71	4.39				
612					3.36		2.72	4.40				
613					3.37		2.72	4.40				
614					3.37		2.72	4.40				
615					3.37		2.72	4.40				
616					3.37		2.72	4.41				
617					3.37		2.72	4.41				
618					3.37		2.73	4.42				
619					3.38		2.73	4.42				
620					3.38		2.73	4.43				
621					3.38		2.73	4.43				
622					3.39		2.73	4.44				
623					3.39		2.73	4.44				
624					3.39		2.73	4.45				
625					3.39		2.73	4.46				
626					3.39		2.73	4.46				
627					3.40		2.74	4.48				
628					3.40		2.74	4.48				
629					3.40		2.74	4.48				
630					3.41		2.74	4.49				
631					3.41		2.75	4.50				
632					3.41		2.75	4.52				
633					3.41		2.76	4.52				
634					3.41		2.76	4.54				
635					3.41		2.76	4.58				
636					3.42		2.76	4.58				
637					3.42		2.76	4.59				
638					3.42		2.77	4.59				
639					3.42		2.77	4.60				
640					3.42		2.77	4.62				
641					3.42		2.78	4.64				
642					3.42		2.78	4.64				
643					3.43		2.78	4.66				
644					3.43		2.78	4.66				
645					3.44		2.78	4.67				
646					3.44		2.78	4.67				
647					3.44		2.79	4.68				
648					3.44		2.79	4.69				
649					3.44		2.79	4.69				
650					3.44		2.79	4.70				
651					3.44		2.80	4.70				
652					3.45		2.80	4.70				
653					3.45		2.80	4.72				
654					3.45		2.80	4.73				
655					3.45		2.81	4.77				
656					3.45		2.81	4.77				
657					3.45		2.81	4.78				
658					3.45		2.81	4.78				
659					3.46		2.82	4.81				
660					3.46		2.82	4.82				
661					3.46		2.83	4.83				
662					3.46		2.83	4.83				
663					3.46		2.83	4.84				
664					3.46		2.83	4.91				
665					3.47		2.83	4.93				
666					3.47		2.84	4.95				
667					3.47		2.84	4.95				
668					3.47		2.84	4.98				
669					3.48		2.84	5.00				
670					3.48		2.85	5.00				
671					3.49		2.85	5.00				
672					3.49		2.85	5.02				
673					3.49		2.85	5.03				
674					3.50		2.86	5.06				

Table A4: cont.

675					3.51		2.86	5.07				
676					3.51		2.86	5.07				
677					3.51		2.87	5.07				
678					3.51		2.87	5.09				
679					3.51		2.87	5.12				
680					3.52		2.88	5.14				
681					3.52		2.88	5.14				
682					3.52		2.88	5.16				
683					3.52		2.88	5.17				
684					3.52		2.88	5.17				
685					3.53		2.88	5.18				
686					3.53		2.88	5.20				
687					3.54		2.88	5.22				
688					3.54		2.89	5.23				
689					3.54		2.89	5.24				
690					3.54		2.89	5.29				
691					3.54		2.89	5.30				
692					3.55		2.89	5.30				
693					3.55		2.89	5.32				
694					3.55		2.89	5.32				
695					3.56		2.90	5.33				
696					3.56		2.90	5.34				
697					3.56		2.90	5.37				
698					3.56		2.90	5.37				
699					3.56		2.90	5.39				
700					3.57		2.91	5.41				
701					3.57		2.91	5.44				
702					3.57		2.91	5.45				
703					3.57		2.91	5.46				
704					3.58		2.92	5.48				
705					3.58		2.92	5.51				
706					3.58		2.92	5.54				
707					3.58		2.93	5.54				
708					3.59		2.94	5.59				
709					3.59		2.94	5.60				
710					3.60		2.94	5.61				
711					3.60		2.94	5.62				
712					3.61		2.94	5.63				
713					3.61		2.96	5.64				
714					3.61		2.96	5.64				
715					3.61		2.97	5.72				
716					3.62		2.97	5.73				
717					3.62		2.97	5.76				
718					3.62		2.98	5.76				
719					3.62		2.98	5.79				
720					3.62		2.98	5.79				
721					3.63		2.99	5.93				
722					3.63		2.99	6.03				
723					3.63		2.99	6.05				
724					3.63		3.00	6.13				
725					3.63		3.00	6.13				
726					3.64		3.00	6.17				
727					3.64		3.00	6.19				
728					3.65		3.01	6.19				
729					3.65		3.01	6.25				
730					3.65		3.02	6.26				
731					3.66		3.02	6.35				
732					3.66		3.02	6.35				
733					3.66		3.03	6.43				
734					3.67		3.03	6.52				
735					3.67		3.03	6.53				
736					3.68		3.03	6.64				
737					3.68		3.04	7.02				
738					3.68		3.04	7.09				
739					3.68		3.05	7.18				
740					3.68		3.06	7.31				
741					3.69		3.06	7.53				
742					3.69		3.07					

Table A4: cont.

743					3.69		3.07					
744					3.70		3.07					
745					3.70		3.07					
746					3.71		3.07					
747					3.72		3.07					
748					3.73		3.08					
749					3.73		3.08					
750					3.74		3.08					
751					3.74		3.08					
752					3.75		3.08					
753					3.75		3.09					
754					3.75		3.10					
755					3.76		3.11					
756					3.77		3.11					
757					3.77		3.11					
758					3.77		3.12					
759					3.77		3.12					
760					3.78		3.12					
761					3.78		3.13					
762					3.78		3.13					
763					3.78		3.13					
764					3.79		3.14					
765					3.79		3.14					
766					3.80		3.14					
767					3.80		3.14					
768					3.80		3.14					
769					3.80		3.14					
770					3.80		3.15					
771					3.80		3.16					
772					3.81		3.16					
773					3.82		3.16					
774					3.82		3.16					
775					3.82		3.16					
776					3.83		3.17					
777					3.83		3.18					
778					3.83		3.19					
779					3.84		3.20					
780					3.86		3.20					
781					3.86		3.21					
782					3.86		3.21					
783					3.86		3.22					
784					3.87		3.23					
785					3.87		3.24					
786					3.88		3.24					
787					3.88		3.25					
788					3.88		3.25					
789					3.88		3.25					
790					3.88		3.26					
791					3.88		3.26					
792					3.89		3.26					
793					3.89		3.27					
794					3.89		3.27					
795					3.89		3.28					
796					3.91		3.28					
797					3.92		3.28					
798					3.92		3.28					
799					3.92		3.29					
800					3.93		3.29					
801					3.93		3.29					
802					3.93		3.30					
803					3.93		3.30					
804					3.93		3.31					
805					3.94		3.31					
806					3.94		3.32					
807					3.95		3.33					
808					3.95		3.34					
809					3.96		3.34					
810					3.96		3.34					

Table A4: cont.

811					3.96		3.34					
812					3.98		3.35					
813					3.99		3.35					
814					3.99		3.35					
815					4.00		3.36					
816					4.00		3.36					
817					4.00		3.37					
818					4.00		3.38					
819					4.01		3.38					
820					4.01		3.40					
821					4.01		3.40					
822					4.02		3.40					
823					4.03		3.41					
824					4.03		3.41					
825					4.04		3.42					
826					4.04		3.43					
827					4.05		3.43					
828					4.06		3.43					
829					4.06		3.43					
830					4.06		3.43					
831					4.06		3.43					
832					4.08		3.43					
833					4.08		3.44					
834					4.08		3.45					
835					4.09		3.45					
836					4.10		3.45					
837					4.11		3.46					
838					4.12		3.46					
839					4.13		3.47					
840					4.13		3.47					
841					4.13		3.49					
842					4.13		3.49					
843					4.15		3.50					
844					4.16		3.51					
845					4.16		3.52					
846					4.18		3.52					
847					4.19		3.52					
848					4.19		3.54					
849					4.19		3.54					
850					4.21		3.55					
851					4.21		3.56					
852					4.22		3.56					
853					4.22		3.58					
854					4.22		3.59					
855					4.23		3.60					
856					4.24		3.62					
857					4.26		3.62					
858					4.29		3.64					
859					4.29		3.64					
860					4.31		3.66					
861					4.32		3.67					
862					4.34		3.68					
863					4.35		3.70					
864					4.35		3.71					
865					4.36		3.73					
866					4.36		3.75					
867					4.36		3.76					
868					4.36		3.79					
869					4.38		3.80					
870					4.38		3.81					
871					4.39		3.83					
872					4.39		3.84					
873					4.39		3.90					
874					4.40		3.98					
875					4.42		3.99					
876					4.44		4.02					
877					4.44		4.03					
878					4.44		4.04					

Table A4: cont.

879					4.47		4.07					
880					4.47		4.09					
881					4.49		4.12					
882					4.52		4.13					
883					4.55		4.16					
884					4.55		4.16					
885					4.56		4.41					
886					4.57		4.43					
887					4.57		4.47					
888					4.57		4.73					
889					4.59		5.00					
890					4.59		5.08					
891					4.61							
892					4.61							
893					4.62							
894					4.64							
895					4.65							
896					4.65							
897					4.67							
898					4.69							
899					4.70							
900					4.72							
901					4.73							
902					4.74							
903					4.74							
904					4.75							
905					4.77							
906					4.79							
907					4.80							
908					4.84							
909					4.86							
910					4.87							
911					4.96							
912					4.98							
913					4.98							
914					5.04							
915					5.13							
916					5.15							
917					5.16							
918					5.25							
919					5.25							
920					5.29							
921					5.30							
922					5.31							
923					5.35							
924					5.37							
925					5.43							
926					5.81							
927					5.82							
928					5.83							

Table A5: Summary of the equivalent bubble size distribution data for ONP with 1.7 ml/kg of BRD 2342 added to the system and an air flow rate of 0.25 slpm.

	BRD 2342 1.7 ml/kg (3 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	2.03	3.62	2.27	3.86
Median Equivalent Bubble Diameter (mm)	1.97	3.40	2.24	3.74
Minimum Equivalent Bubble Diameter (mm)	1.30	1.54	1.00	1.07
Maximum Equivalent Bubble Diameter (mm)	4.04	8.10	4.26	7.91
Standard Deviation (mm)	0.42	1.19	0.57	1.06
Variance (mm^2)	0.17	1.41	0.32	1.11
Bubble Population Size	305	326	403	544
Equivalent Sauter Mean Diameter (mm)	2.21	4.42	2.55	4.44
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	20	0	31	2
$1.5 < R_B \leq 2$	140	13	103	8
$2 < R_B \leq 2.5$	112	39	143	33
$2.5 < R_B \leq 3$	25	62	90	73
$3 < R_B \leq 3.5$	6	60	21	104
$3.5 < R_B \leq 4$	1	48	14	104
$4 < R_B \leq 4.5$	1	31	1	80
$4.5 < R_B \leq 5$	0	28	0	62
$5 < R_B \leq 5.5$	0	22	0	40
$5.5 < R_B \leq 6$	0	9	0	25
$6 < R_B \leq 6.5$	0	7	0	4
$6.5 < R_B \leq 7$	0	2	0	2
$7 < R_B \leq 7.5$	0	3	0	5
$7.5 < R_B \leq 8$	0	1	0	2
$8 < R_B \leq 8.5$	0	1	0	0
$8.5 < R_B \leq 9$	0	0	0	0
$9 < R_B \leq 9.5$	0	0	0	0
$9.5 < R_B \leq 10$	0	0	0	0
$R_B > 10$	0	0	0	0

Table A6: Summary of the equivalent bubble size distribution data for ONP with 3.3 ml/kg of BRD 2342 added to the system and an air flow rate of 0.25 slpm.

	BRD 2342 3.3 ml/kg (6 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	2.33	3.90	2.33	4.17
Median Equivalent Bubble Diameter (mm)	2.28	3.93	2.33	3.87
Minimum Equivalent Bubble Diameter (mm)	1.15	1.36	1.01	1.56
Maximum Equivalent Bubble Diameter (mm)	3.81	6.82	3.72	11.26
Standard Deviation (mm)	0.51	0.96	0.48	1.60
Variance (mm^2)	0.26	0.92	0.23	2.56
Bubble Population Size	268	254	387	361
Equivalent Sauter Mean Diameter (mm)	2.54	4.34	2.52	5.42
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	14	2	21	0
$1.5 < R_B \leq 2$	52	5	77	17
$2 < R_B \leq 2.5$	107	14	145	33
$2.5 < R_B \leq 3$	67	26	116	41
$3 < R_B \leq 3.5$	27	34	24	46
$3.5 < R_B \leq 4$	1	56	4	53
$4 < R_B \leq 4.5$	0	47	0	52
$4.5 < R_B \leq 5$	0	40	0	30
$5 < R_B \leq 5.5$	0	19	0	22
$5.5 < R_B \leq 6$	0	8	0	16
$6 < R_B \leq 6.5$	0	2	0	14
$6.5 < R_B \leq 7$	0	1	0	10
$7 < R_B \leq 7.5$	0	0	0	13
$7.5 < R_B \leq 8$	0	0	0	8
$8 < R_B \leq 8.5$	0	0	0	2
$8.5 < R_B \leq 9$	0	0	0	2
$9 < R_B \leq 9.5$	0	0	0	1
$9.5 < R_B \leq 10$	0	0	0	0
$R_B > 10$	0	0	0	1

Table A7: Equivalent bubble diameter data sorted by size for ONP with BRD 2342 added to the system and an air flow rate of 0.25 slpm.

	BRD 2342 1.7 ml/kg (3 lbs/ton)				BRD 2342 3.3 ml/kg (6 lbs/ton)			
	Gasket		Sparger		Gasket		Sparger	
Consistency	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP
Bubble Count	Equivalent Bubble Diameter (mm)							
1	1.30	1.54	1.00	1.07	1.15	1.36	1.01	1.56
2	1.33	1.56	1.01	1.43	1.15	1.49	1.15	1.63
3	1.35	1.63	1.05	1.59	1.19	1.54	1.21	1.66
4	1.36	1.63	1.08	1.61	1.25	1.59	1.21	1.68
5	1.36	1.64	1.08	1.62	1.26	1.75	1.23	1.72
6	1.37	1.73	1.13	1.72	1.33	1.85	1.25	1.72
7	1.40	1.79	1.13	1.80	1.34	1.88	1.35	1.75
8	1.40	1.87	1.14	1.91	1.35	2.06	1.36	1.78
9	1.41	1.88	1.16	1.93	1.37	2.07	1.38	1.79
10	1.41	1.89	1.18	1.96	1.38	2.22	1.40	1.87
11	1.43	1.92	1.20	2.06	1.45	2.26	1.40	1.88
12	1.43	1.94	1.21	2.08	1.46	2.30	1.41	1.91
13	1.45	1.99	1.22	2.09	1.47	2.33	1.42	1.91
14	1.47	2.00	1.22	2.17	1.49	2.35	1.42	1.95
15	1.48	2.04	1.24	2.17	1.55	2.36	1.43	1.97
16	1.48	2.04	1.33	2.19	1.56	2.36	1.43	1.97
17	1.48	2.05	1.33	2.24	1.58	2.41	1.44	1.97
18	1.48	2.06	1.33	2.25	1.60	2.43	1.46	2.03
19	1.49	2.11	1.34	2.25	1.60	2.46	1.49	2.04
20	1.50	2.13	1.35	2.29	1.62	2.48	1.50	2.05
21	1.52	2.13	1.40	2.34	1.62	2.48	1.50	2.05
22	1.52	2.14	1.41	2.34	1.63	2.51	1.50	2.05
23	1.52	2.15	1.41	2.37	1.64	2.53	1.51	2.07
24	1.54	2.18	1.41	2.37	1.65	2.54	1.52	2.08
25	1.54	2.20	1.42	2.37	1.65	2.60	1.56	2.09
26	1.54	2.21	1.43	2.39	1.66	2.61	1.57	2.10
27	1.55	2.22	1.45	2.39	1.66	2.68	1.58	2.12
28	1.56	2.23	1.47	2.39	1.67	2.71	1.59	2.13
29	1.57	2.24	1.48	2.39	1.69	2.72	1.60	2.16
30	1.57	2.25	1.49	2.40	1.71	2.72	1.60	2.17
31	1.57	2.25	1.49	2.42	1.71	2.74	1.61	2.18
32	1.57	2.28	1.50	2.42	1.73	2.77	1.63	2.18
33	1.58	2.31	1.52	2.43	1.73	2.81	1.64	2.25
34	1.58	2.31	1.53	2.43	1.74	2.84	1.65	2.26
35	1.58	2.32	1.53	2.46	1.74	2.84	1.68	2.27
36	1.59	2.33	1.55	2.46	1.74	2.86	1.70	2.33
37	1.59	2.33	1.56	2.46	1.74	2.87	1.70	2.34
38	1.59	2.34	1.56	2.47	1.75	2.88	1.71	2.35
39	1.60	2.34	1.56	2.47	1.75	2.89	1.71	2.37
40	1.60	2.35	1.57	2.47	1.76	2.92	1.73	2.37
41	1.60	2.37	1.57	2.48	1.76	2.93	1.74	2.38
42	1.61	2.40	1.59	2.48	1.77	2.94	1.74	2.39
43	1.61	2.42	1.59	2.49	1.78	2.95	1.74	2.40
44	1.61	2.44	1.60	2.50	1.78	2.95	1.75	2.41
45	1.61	2.46	1.60	2.51	1.78	2.96	1.77	2.42
46	1.61	2.46	1.61	2.53	1.80	2.99	1.78	2.43
47	1.62	2.48	1.63	2.55	1.80	3.00	1.78	2.46
48	1.62	2.49	1.63	2.55	1.82	3.06	1.79	2.46
49	1.62	2.49	1.65	2.56	1.83	3.06	1.79	2.46
50	1.63	2.49	1.65	2.57	1.84	3.06	1.80	2.49
51	1.64	2.50	1.65	2.58	1.85	3.09	1.81	2.52
52	1.64	2.50	1.66	2.58	1.86	3.10	1.81	2.52
53	1.65	2.51	1.67	2.60	1.87	3.10	1.82	2.56
54	1.65	2.52	1.67	2.60	1.87	3.11	1.82	2.59
55	1.65	2.52	1.67	2.60	1.88	3.11	1.82	2.61
56	1.66	2.52	1.69	2.61	1.90	3.13	1.83	2.62
57	1.66	2.53	1.69	2.62	1.91	3.15	1.83	2.62
58	1.66	2.53	1.69	2.63	1.92	3.19	1.83	2.64
59	1.66	2.53	1.69	2.63	1.92	3.20	1.83	2.64
60	1.67	2.53	1.70	2.63	1.93	3.20	1.83	2.66
61	1.67	2.54	1.71	2.64	1.96	3.21	1.84	2.67
62	1.68	2.54	1.72	2.64	1.97	3.23	1.84	2.72

Table A7: cont.

63	1.69	2.55	1.72	2.65	1.97	3.24	1.84	2.73
64	1.69	2.56	1.72	2.66	1.97	3.28	1.85	2.74
65	1.69	2.56	1.74	2.68	1.97	3.28	1.85	2.74
66	1.69	2.57	1.74	2.68	2.00	3.29	1.85	2.75
67	1.70	2.58	1.74	2.71	2.01	3.32	1.87	2.75
68	1.71	2.58	1.74	2.73	2.01	3.32	1.87	2.76
69	1.71	2.59	1.75	2.73	2.01	3.33	1.88	2.77
70	1.71	2.60	1.76	2.74	2.02	3.37	1.88	2.77
71	1.71	2.64	1.76	2.74	2.02	3.40	1.88	2.77
72	1.71	2.64	1.77	2.74	2.02	3.41	1.90	2.78
73	1.72	2.67	1.77	2.77	2.03	3.42	1.90	2.82
74	1.72	2.69	1.78	2.77	2.04	3.42	1.90	2.84
75	1.72	2.69	1.78	2.77	2.04	3.44	1.90	2.85
76	1.72	2.70	1.79	2.78	2.04	3.44	1.91	2.86
77	1.72	2.70	1.79	2.78	2.04	3.44	1.91	2.86
78	1.74	2.71	1.80	2.79	2.04	3.45	1.91	2.88
79	1.74	2.74	1.81	2.80	2.06	3.46	1.92	2.88
80	1.74	2.74	1.81	2.80	2.06	3.49	1.92	2.88
81	1.74	2.75	1.81	2.81	2.06	3.50	1.93	2.89
82	1.74	2.77	1.81	2.82	2.06	3.51	1.93	2.90
83	1.75	2.77	1.82	2.83	2.06	3.52	1.93	2.91
84	1.75	2.79	1.83	2.83	2.07	3.54	1.94	2.93
85	1.76	2.79	1.83	2.83	2.08	3.54	1.94	2.95
86	1.76	2.82	1.83	2.84	2.08	3.55	1.94	2.95
87	1.76	2.82	1.84	2.85	2.09	3.55	1.95	2.97
88	1.77	2.82	1.84	2.85	2.10	3.55	1.95	2.97
89	1.77	2.83	1.85	2.86	2.10	3.55	1.95	2.97
90	1.77	2.84	1.85	2.86	2.10	3.56	1.95	2.97
91	1.77	2.87	1.85	2.86	2.10	3.57	1.96	3.00
92	1.77	2.87	1.85	2.86	2.11	3.57	1.96	3.03
93	1.77	2.87	1.86	2.88	2.11	3.58	1.98	3.03
94	1.78	2.87	1.86	2.88	2.11	3.59	1.99	3.04
95	1.79	2.87	1.86	2.90	2.11	3.61	1.99	3.04
96	1.79	2.89	1.86	2.90	2.12	3.61	1.99	3.04
97	1.79	2.89	1.86	2.91	2.12	3.62	1.99	3.08
98	1.80	2.90	1.86	2.91	2.13	3.63	2.00	3.08
99	1.80	2.90	1.86	2.92	2.13	3.64	2.00	3.08
100	1.80	2.90	1.87	2.94	2.13	3.65	2.00	3.12
101	1.80	2.93	1.87	2.94	2.14	3.67	2.00	3.13
102	1.80	2.94	1.88	2.94	2.14	3.68	2.01	3.14
103	1.80	2.94	1.88	2.95	2.14	3.68	2.01	3.15
104	1.80	2.94	1.88	2.95	2.14	3.69	2.01	3.16
105	1.81	2.95	1.88	2.96	2.15	3.69	2.01	3.19
106	1.81	2.96	1.89	2.96	2.15	3.70	2.02	3.20
107	1.82	2.96	1.90	2.96	2.15	3.70	2.02	3.20
108	1.82	2.96	1.90	2.96	2.17	3.72	2.02	3.21
109	1.82	2.98	1.91	2.96	2.18	3.73	2.03	3.22
110	1.82	2.98	1.91	2.98	2.18	3.74	2.04	3.23
111	1.82	2.99	1.92	2.98	2.20	3.74	2.05	3.23
112	1.83	2.99	1.92	2.99	2.20	3.79	2.05	3.29
113	1.83	3.00	1.92	2.99	2.21	3.82	2.05	3.29
114	1.84	3.00	1.92	2.99	2.21	3.82	2.06	3.31
115	1.84	3.02	1.93	3.00	2.21	3.83	2.06	3.31
116	1.85	3.03	1.93	3.00	2.21	3.87	2.06	3.31
117	1.85	3.03	1.93	3.00	2.21	3.88	2.06	3.32
118	1.85	3.04	1.93	3.01	2.22	3.88	2.06	3.32
119	1.85	3.05	1.93	3.01	2.24	3.88	2.06	3.33
120	1.86	3.06	1.94	3.03	2.24	3.88	2.07	3.33
121	1.86	3.07	1.95	3.03	2.24	3.88	2.08	3.34
122	1.87	3.07	1.95	3.03	2.25	3.88	2.09	3.34
123	1.87	3.08	1.95	3.03	2.25	3.89	2.10	3.35
124	1.88	3.09	1.95	3.04	2.26	3.90	2.11	3.36
125	1.88	3.09	1.95	3.04	2.26	3.91	2.12	3.38
126	1.89	3.10	1.96	3.04	2.26	3.91	2.12	3.39
127	1.89	3.11	1.96	3.04	2.26	3.92	2.12	3.41
128	1.90	3.12	1.97	3.05	2.26	3.94	2.13	3.41
129	1.90	3.12	1.97	3.05	2.27	3.94	2.13	3.42
130	1.91	3.12	1.98	3.06	2.27	3.94	2.13	3.42

Table A7: cont.

131	1.91	3.14	1.99	3.06	2.27	3.94	2.14	3.43
132	1.91	3.15	1.99	3.07	2.28	3.95	2.14	3.45
133	1.91	3.15	1.99	3.08	2.28	3.96	2.15	3.46
134	1.92	3.16	1.99	3.08	2.28	3.96	2.15	3.46
135	1.92	3.16	2.00	3.08	2.28	3.97	2.15	3.48
136	1.92	3.18	2.01	3.10	2.29	3.98	2.16	3.49
137	1.92	3.20	2.01	3.10	2.29	3.99	2.16	3.49
138	1.92	3.21	2.01	3.11	2.29	4.01	2.16	3.50
139	1.92	3.21	2.01	3.12	2.30	4.01	2.17	3.51
140	1.93	3.22	2.02	3.12	2.31	4.02	2.17	3.51
141	1.93	3.23	2.03	3.14	2.31	4.02	2.17	3.52
142	1.94	3.24	2.04	3.14	2.32	4.03	2.17	3.54
143	1.94	3.24	2.04	3.15	2.32	4.04	2.17	3.54
144	1.94	3.24	2.04	3.15	2.33	4.06	2.18	3.54
145	1.95	3.25	2.05	3.15	2.34	4.08	2.18	3.55
146	1.95	3.25	2.05	3.16	2.35	4.08	2.20	3.55
147	1.95	3.25	2.06	3.16	2.35	4.08	2.20	3.58
148	1.95	3.27	2.06	3.16	2.35	4.08	2.20	3.58
149	1.95	3.28	2.06	3.16	2.36	4.10	2.20	3.59
150	1.96	3.28	2.07	3.16	2.36	4.10	2.20	3.61
151	1.96	3.31	2.07	3.16	2.37	4.12	2.21	3.61
152	1.96	3.32	2.07	3.17	2.38	4.12	2.21	3.63
153	1.97	3.32	2.07	3.17	2.39	4.14	2.22	3.64
154	1.97	3.33	2.08	3.17	2.39	4.17	2.22	3.65
155	1.98	3.34	2.08	3.17	2.39	4.19	2.22	3.65
156	1.98	3.35	2.09	3.18	2.39	4.19	2.23	3.65
157	1.98	3.36	2.09	3.18	2.40	4.20	2.23	3.67
158	1.99	3.36	2.09	3.19	2.40	4.20	2.23	3.70
159	2.00	3.38	2.09	3.20	2.40	4.20	2.23	3.70
160	2.00	3.39	2.10	3.21	2.41	4.22	2.24	3.70
161	2.01	3.40	2.10	3.21	2.42	4.23	2.24	3.71
162	2.02	3.40	2.10	3.21	2.42	4.24	2.24	3.71
163	2.02	3.40	2.11	3.22	2.42	4.25	2.24	3.71
164	2.02	3.41	2.11	3.22	2.43	4.26	2.24	3.72
165	2.02	3.41	2.12	3.22	2.43	4.28	2.24	3.72
166	2.02	3.41	2.12	3.22	2.44	4.29	2.25	3.74
167	2.02	3.42	2.12	3.24	2.44	4.32	2.25	3.76
168	2.03	3.43	2.14	3.25	2.45	4.32	2.25	3.76
169	2.03	3.44	2.14	3.25	2.47	4.33	2.25	3.77
170	2.04	3.47	2.14	3.25	2.47	4.33	2.26	3.77
171	2.04	3.48	2.14	3.25	2.47	4.33	2.26	3.78
172	2.04	3.49	2.15	3.25	2.48	4.36	2.26	3.80
173	2.04	3.49	2.15	3.26	2.50	4.37	2.26	3.81
174	2.05	3.49	2.15	3.26	2.50	4.38	2.27	3.81
175	2.05	3.50	2.15	3.27	2.50	4.38	2.27	3.81
176	2.05	3.52	2.16	3.27	2.52	4.40	2.27	3.81
177	2.05	3.52	2.16	3.27	2.52	4.42	2.27	3.82
178	2.05	3.53	2.16	3.27	2.52	4.42	2.27	3.83
179	2.05	3.55	2.17	3.28	2.53	4.45	2.27	3.86
180	2.06	3.55	2.17	3.29	2.54	4.46	2.27	3.87
181	2.06	3.56	2.17	3.30	2.54	4.46	2.28	3.87
182	2.06	3.56	2.18	3.30	2.56	4.47	2.28	3.93
183	2.06	3.58	2.18	3.30	2.57	4.48	2.28	3.93
184	2.07	3.58	2.18	3.31	2.57	4.49	2.28	3.95
185	2.07	3.59	2.19	3.32	2.58	4.50	2.28	3.95
186	2.08	3.60	2.19	3.33	2.58	4.51	2.29	3.96
187	2.08	3.61	2.20	3.33	2.59	4.52	2.29	3.96
188	2.08	3.62	2.20	3.33	2.59	4.54	2.29	3.99
189	2.10	3.62	2.21	3.34	2.60	4.54	2.29	3.99
190	2.10	3.62	2.22	3.35	2.60	4.55	2.30	4.00
191	2.10	3.64	2.22	3.36	2.60	4.55	2.31	4.01
192	2.10	3.65	2.22	3.36	2.60	4.55	2.31	4.01
193	2.11	3.66	2.22	3.36	2.62	4.57	2.32	4.02
194	2.11	3.67	2.22	3.36	2.64	4.59	2.33	4.02
195	2.11	3.68	2.23	3.36	2.65	4.63	2.33	4.02
196	2.11	3.71	2.23	3.36	2.65	4.65	2.33	4.04
197	2.11	3.72	2.23	3.39	2.66	4.67	2.33	4.04
198	2.12	3.74	2.24	3.39	2.67	4.68	2.33	4.05

Table A7: cont.

199	2.12	3.74	2.24	3.39	2.68	4.69	2.34	4.06
200	2.13	3.74	2.24	3.40	2.68	4.71	2.35	4.07
201	2.14	3.74	2.24	3.40	2.69	4.71	2.35	4.08
202	2.14	3.75	2.24	3.41	2.71	4.72	2.35	4.09
203	2.15	3.76	2.25	3.41	2.72	4.72	2.35	4.10
204	2.15	3.77	2.26	3.42	2.72	4.73	2.35	4.11
205	2.15	3.77	2.27	3.42	2.72	4.74	2.36	4.13
206	2.16	3.77	2.28	3.43	2.72	4.75	2.36	4.14
207	2.16	3.77	2.28	3.44	2.73	4.75	2.36	4.14
208	2.17	3.80	2.28	3.44	2.74	4.76	2.37	4.16
209	2.18	3.81	2.30	3.44	2.74	4.77	2.37	4.16
210	2.18	3.83	2.30	3.45	2.76	4.78	2.37	4.17
211	2.18	3.85	2.30	3.45	2.77	4.79	2.39	4.17
212	2.18	3.85	2.30	3.46	2.79	4.82	2.39	4.19
213	2.19	3.87	2.30	3.47	2.79	4.82	2.39	4.20
214	2.19	3.90	2.30	3.47	2.80	4.83	2.40	4.24
215	2.20	3.90	2.30	3.47	2.80	4.86	2.40	4.25
216	2.20	3.93	2.31	3.48	2.80	4.88	2.40	4.26
217	2.21	3.93	2.31	3.48	2.81	4.88	2.41	4.27
218	2.21	3.93	2.32	3.49	2.81	4.89	2.42	4.28
219	2.21	3.93	2.33	3.49	2.85	4.89	2.42	4.28
220	2.22	3.94	2.33	3.50	2.85	4.91	2.42	4.29
221	2.22	3.95	2.33	3.50	2.85	4.91	2.42	4.32
222	2.22	3.99	2.33	3.51	2.85	4.92	2.43	4.33
223	2.22	4.02	2.33	3.51	2.86	4.96	2.43	4.34
224	2.23	4.03	2.34	3.51	2.87	4.97	2.45	4.34
225	2.24	4.05	2.34	3.52	2.88	5.02	2.45	4.35
226	2.25	4.05	2.35	3.53	2.88	5.02	2.45	4.36
227	2.25	4.06	2.35	3.53	2.90	5.04	2.45	4.36
228	2.25	4.07	2.35	3.53	2.91	5.06	2.45	4.36
229	2.25	4.08	2.36	3.53	2.91	5.08	2.46	4.37
230	2.27	4.11	2.37	3.53	2.91	5.10	2.46	4.38
231	2.28	4.11	2.37	3.54	2.91	5.12	2.46	4.38
232	2.28	4.12	2.38	3.55	2.92	5.15	2.47	4.39
233	2.29	4.13	2.38	3.55	2.94	5.16	2.47	4.42
234	2.29	4.14	2.38	3.55	2.94	5.18	2.47	4.44
235	2.29	4.14	2.38	3.55	2.96	5.22	2.47	4.44
236	2.31	4.19	2.39	3.56	2.97	5.23	2.47	4.45
237	2.32	4.22	2.39	3.57	2.97	5.26	2.47	4.46
238	2.32	4.23	2.39	3.57	2.98	5.32	2.48	4.46
239	2.33	4.26	2.39	3.57	2.98	5.34	2.48	4.46
240	2.33	4.27	2.39	3.58	2.99	5.35	2.49	4.47
241	2.33	4.27	2.39	3.58	3.01	5.44	2.49	4.48
242	2.34	4.27	2.40	3.58	3.01	5.46	2.49	4.50
243	2.34	4.31	2.40	3.59	3.04	5.47	2.50	4.51
244	2.34	4.34	2.40	3.59	3.04	5.60	2.51	4.51
245	2.35	4.35	2.40	3.59	3.05	5.61	2.51	4.59
246	2.35	4.37	2.41	3.59	3.06	5.62	2.51	4.59
247	2.36	4.39	2.41	3.59	3.07	5.79	2.52	4.59
248	2.36	4.39	2.42	3.60	3.09	5.84	2.52	4.60
249	2.36	4.40	2.42	3.60	3.10	5.84	2.53	4.63
250	2.36	4.40	2.42	3.61	3.13	5.85	2.53	4.64
251	2.36	4.46	2.43	3.61	3.14	5.90	2.53	4.65
252	2.37	4.46	2.43	3.62	3.16	6.04	2.53	4.65
253	2.37	4.49	2.44	3.62	3.17	6.05	2.53	4.67
254	2.38	4.51	2.44	3.63	3.17	6.82	2.53	4.74
255	2.38	4.51	2.44	3.63	3.23		2.53	4.79
256	2.39	4.54	2.44	3.63	3.23		2.53	4.79
257	2.39	4.56	2.44	3.64	3.23		2.54	4.85
258	2.40	4.57	2.45	3.65	3.25		2.54	4.86
259	2.40	4.57	2.45	3.65	3.27		2.54	4.87
260	2.40	4.57	2.45	3.65	3.28		2.55	4.88
261	2.40	4.60	2.45	3.65	3.35		2.56	4.90
262	2.40	4.62	2.45	3.65	3.36		2.56	4.92
263	2.41	4.65	2.46	3.66	3.39		2.56	4.94
264	2.42	4.67	2.46	3.68	3.41		2.56	4.95
265	2.43	4.71	2.46	3.69	3.41		2.56	4.97
266	2.45	4.73	2.47	3.69	3.42		2.57	4.99

Table A7: cont.

267	2.46	4.74	2.47	3.70	3.42		2.57	4.99
268	2.47	4.77	2.47	3.70	3.81		2.58	4.99
269	2.47	4.77	2.48	3.71			2.59	5.00
270	2.48	4.78	2.48	3.72			2.59	5.00
271	2.49	4.78	2.48	3.73			2.59	5.00
272	2.50	4.79	2.48	3.73			2.59	5.00
273	2.50	4.80	2.49	3.75			2.59	5.02
274	2.51	4.81	2.49	3.75			2.60	5.03
275	2.51	4.82	2.49	3.76			2.60	5.07
276	2.54	4.83	2.50	3.78			2.60	5.14
277	2.54	4.86	2.50	3.78			2.61	5.19
278	2.55	4.89	2.50	3.79			2.61	5.20
279	2.55	4.91	2.51	3.79			2.61	5.24
280	2.56	4.95	2.51	3.79			2.61	5.24
281	2.56	4.96	2.51	3.79			2.62	5.25
282	2.58	5.00	2.51	3.81			2.62	5.26
283	2.61	5.01	2.52	3.81			2.62	5.27
284	2.67	5.05	2.52	3.82			2.63	5.29
285	2.68	5.09	2.52	3.82			2.64	5.29
286	2.70	5.10	2.53	3.83			2.65	5.29
287	2.78	5.11	2.53	3.83			2.65	5.31
288	2.79	5.15	2.53	3.83			2.65	5.32
289	2.80	5.16	2.54	3.83			2.65	5.33
290	2.81	5.18	2.54	3.84			2.66	5.33
291	2.82	5.19	2.55	3.84			2.67	5.39
292	2.85	5.20	2.55	3.84			2.68	5.41
293	2.87	5.22	2.55	3.85			2.68	5.48
294	2.88	5.22	2.57	3.86			2.69	5.50
295	2.88	5.24	2.57	3.86			2.69	5.53
296	2.90	5.32	2.57	3.86			2.69	5.55
297	2.99	5.34	2.57	3.86			2.69	5.55
298	3.09	5.35	2.57	3.87			2.69	5.56
299	3.14	5.35	2.58	3.88			2.69	5.69
300	3.20	5.37	2.58	3.88			2.70	5.69
301	3.24	5.41	2.58	3.89			2.70	5.75
302	3.36	5.43	2.58	3.89			2.70	5.82
303	3.41	5.46	2.59	3.89			2.71	5.83
304	3.68	5.53	2.59	3.89			2.73	5.85
305	4.04	5.55	2.59	3.90			2.73	5.89
306		5.61	2.59	3.91			2.73	5.90
307		5.62	2.59	3.91			2.74	5.91
308		5.62	2.59	3.92			2.74	5.94
309		5.65	2.59	3.92			2.74	5.97
310		5.69	2.60	3.92			2.75	5.98
311		5.79	2.61	3.93			2.75	6.00
312		5.84	2.61	3.93			2.75	6.02
313		6.07	2.61	3.93			2.76	6.04
314		6.10	2.61	3.93			2.76	6.07
315		6.20	2.61	3.93			2.76	6.08
316		6.24	2.62	3.93			2.76	6.08
317		6.24	2.63	3.95			2.76	6.09
318		6.32	2.63	3.95			2.77	6.13
319		6.41	2.63	3.97			2.77	6.19
320		6.58	2.63	3.99			2.78	6.24
321		6.62	2.64	3.99			2.78	6.37
322		7.03	2.65	3.99			2.78	6.38
323		7.09	2.65	4.00			2.78	6.40
324		7.50	2.66	4.00			2.78	6.49
325		7.82	2.67	4.00			2.79	6.53
326		8.10	2.67	4.02			2.80	6.64
327			2.68	4.04			2.80	6.67
328			2.68	4.04			2.80	6.71
329			2.70	4.05			2.80	6.79
330			2.70	4.05			2.81	6.81
331			2.70	4.05			2.82	6.81
332			2.71	4.06			2.82	6.86
333			2.71	4.06			2.82	6.89
334			2.71	4.06			2.83	6.89

Table A7: cont.

335			2.73	4.06			2.84	7.02
336			2.73	4.07			2.84	7.04
337			2.74	4.08			2.85	7.08
338			2.74	4.08			2.85	7.11
339			2.75	4.08			2.86	7.12
340			2.75	4.08			2.86	7.13
341			2.75	4.09			2.86	7.16
342			2.76	4.09			2.87	7.23
343			2.76	4.09			2.88	7.30
344			2.77	4.09			2.89	7.32
345			2.78	4.09			2.90	7.33
346			2.79	4.11			2.90	7.37
347			2.80	4.12			2.91	7.37
348			2.80	4.12			2.92	7.52
349			2.80	4.12			2.93	7.54
350			2.82	4.13			2.94	7.59
351			2.84	4.14			2.94	7.77
352			2.84	4.14			2.94	7.79
353			2.85	4.16			2.95	7.81
354			2.86	4.17			2.96	7.86
355			2.87	4.17			2.97	7.92
356			2.88	4.19			2.98	8.01
357			2.88	4.20			2.99	8.33
358			2.88	4.21			2.99	8.57
359			2.88	4.21			2.99	8.70
360			2.90	4.21			3.00	9.34
361			2.90	4.23			3.01	11.26
362			2.90	4.23			3.02	
363			2.91	4.24			3.03	
364			2.92	4.25			3.04	
365			2.92	4.26			3.05	
366			2.93	4.26			3.07	
367			2.97	4.26			3.08	
368			3.03	4.26			3.08	
369			3.05	4.26			3.12	
370			3.07	4.27			3.13	
371			3.07	4.27			3.16	
372			3.11	4.27			3.17	
373			3.13	4.29			3.18	
374			3.14	4.29			3.19	
375			3.17	4.30			3.26	
376			3.19	4.30			3.30	
377			3.19	4.31			3.31	
378			3.21	4.32			3.31	
379			3.23	4.34			3.33	
380			3.25	4.34			3.34	
381			3.29	4.34			3.36	
382			3.31	4.35			3.43	
383			3.32	4.37			3.44	
384			3.32	4.37			3.62	
385			3.36	4.37			3.70	
386			3.42	4.37			3.70	
387			3.45	4.37			3.72	
388			3.49	4.38				
389			3.50	4.39				
390			3.54	4.40				
391			3.56	4.40				
392			3.56	4.40				
393			3.61	4.41				
394			3.66	4.42				
395			3.68	4.42				
396			3.72	4.42				
397			3.75	4.42				
398			3.76	4.43				
399			3.76	4.44				
400			3.81	4.44				
401			3.95	4.46				
402			3.97	4.46				

Table A7: cont.

403			4.26	4.47				
404				4.49				
405				4.51				
406				4.51				
407				4.52				
408				4.53				
409				4.54				
410				4.55				
411				4.55				
412				4.56				
413				4.56				
414				4.57				
415				4.57				
416				4.57				
417				4.57				
418				4.58				
419				4.59				
420				4.59				
421				4.59				
422				4.60				
423				4.60				
424				4.65				
425				4.65				
426				4.66				
427				4.68				
428				4.68				
429				4.68				
430				4.69				
431				4.70				
432				4.71				
433				4.71				
434				4.71				
435				4.72				
436				4.73				
437				4.73				
438				4.74				
439				4.74				
440				4.77				
441				4.77				
442				4.77				
443				4.78				
444				4.82				
445				4.84				
446				4.85				
447				4.85				
448				4.85				
449				4.87				
450				4.88				
451				4.89				
452				4.89				
453				4.90				
454				4.91				
455				4.91				
456				4.92				
457				4.92				
458				4.92				
459				4.94				
460				4.94				
461				4.95				
462				4.97				
463				4.97				
464				4.98				
465				4.98				
466				4.98				
467				5.01				
468				5.02				
469				5.03				
470				5.06				

Table A7: cont.

471				5.06				
472				5.06				
473				5.07				
474				5.08				
475				5.08				
476				5.09				
477				5.11				
478				5.11				
479				5.12				
480				5.16				
481				5.17				
482				5.18				
483				5.18				
484				5.20				
485				5.22				
486				5.23				
487				5.24				
488				5.24				
489				5.26				
490				5.28				
491				5.28				
492				5.29				
493				5.30				
494				5.32				
495				5.32				
496				5.33				
497				5.33				
498				5.34				
499				5.34				
500				5.41				
501				5.42				
502				5.42				
503				5.48				
504				5.48				
505				5.49				
506				5.49				
507				5.51				
508				5.52				
509				5.52				
510				5.53				
511				5.53				
512				5.54				
513				5.56				
514				5.57				
515				5.58				
516				5.59				
517				5.60				
518				5.60				
519				5.61				
520				5.63				
521				5.63				
522				5.66				
523				5.70				
524				5.77				
525				5.80				
526				5.80				
527				5.80				
528				5.86				
529				5.90				
530				5.91				
531				5.96				
532				6.07				
533				6.17				
534				6.28				
535				6.48				
536				6.78				
537				6.82				
538				7.02				

Table A7: cont.

539				7.17				
540				7.19				
541				7.29				
542				7.29				
543				7.82				
544				7.91				

Table A8: Summary of the equivalent bubble size distribution data for ONP with 1.7 ml/kg of BRD 2363 added to the system and an air flow rate of 0.25 slpm.

	BRD 2363 1.7 ml/kg (3 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	2.83	4.11	2.38	3.78
Median Equivalent Bubble Diameter (mm)	2.75	4.26	2.28	3.44
Minimum Equivalent Bubble Diameter (mm)	1.13	1.22	1.01	1.00
Maximum Equivalent Bubble Diameter (mm)	4.56	7.52	4.99	13.77
Standard Deviation (mm)	0.61	1.49	0.75	1.82
Variance (mm^2)	0.37	2.23	0.56	3.31
Bubble Population Size	216	227	485	396
Equivalent Sauter Mean Diameter (mm)	3.08	5.09	2.84	5.64
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	3	4	62	25
$1.5 < R_B \leq 2$	14	20	84	24
$2 < R_B \leq 2.5$	49	16	147	39
$2.5 < R_B \leq 3$	69	19	104	53
$3 < R_B \leq 3.5$	51	19	53	62
$3.5 < R_B \leq 4$	24	23	20	66
$4 < R_B \leq 4.5$	5	25	10	31
$4.5 < R_B \leq 5$	1	35	5	15
$5 < R_B \leq 5.5$	0	29	0	18
$5.5 < R_B \leq 6$	0	12	0	13
$6 < R_B \leq 6.5$	0	10	0	16
$6.5 < R_B \leq 7$	0	6	0	7
$7 < R_B \leq 7.5$	0	8	0	7
$7.5 < R_B \leq 8$	0	1	0	5
$8 < R_B \leq 8.5$	0	0	0	10
$8.5 < R_B \leq 9$	0	0	0	0
$9 < R_B \leq 9.5$	0	0	0	1
$9.5 < R_B \leq 10$	0	0	0	2
$R_B > 10$	0	0	0	2

Table A9: Summary of the equivalent bubble size distribution data for ONP with 3.3 ml/kg of BRD 2363 added to the system and an air flow rate of 0.25 slpm.

	BRD 2363 3.3 ml/kg (6 lbs/ton)			
	Gasket		Sparger	
Consistency	0%	1%	0%	1%
Average Equivalent Bubble Diameter (mm)	3.23	4.27	2.61	3.30
Median Equivalent Bubble Diameter (mm)	3.22	4.27	2.59	2.91
Minimum Equivalent Bubble Diameter (mm)	1.25	1.07	1.04	1.10
Maximum Equivalent Bubble Diameter (mm)	4.99	8.24	5.81	9.11
Standard Deviation (mm)	0.59	1.50	0.72	1.52
Variance (mm^2)	0.34	2.24	0.52	2.31
Bubble Population Size	192	244	579	288
Equivalent Sauter Mean Diameter (mm)	3.43	5.22	3.01	4.73
Bubble Size Range (mm)	Frequency			
$0 < R_B \leq 1$	0	0	0	0
$1 < R_B \leq 1.5$	1	3	39	20
$1.5 < R_B \leq 2$	4	13	68	31
$2 < R_B \leq 2.5$	15	21	149	60
$2.5 < R_B \leq 3$	49	16	166	40
$3 < R_B \leq 3.5$	59	24	93	39
$3.5 < R_B \leq 4$	49	27	45	26
$4 < R_B \leq 4.5$	13	35	14	15
$4.5 < R_B \leq 5$	2	25	3	13
$5 < R_B \leq 5.5$	0	28	0	12
$5.5 < R_B \leq 6$	0	19	2	10
$6 < R_B \leq 6.5$	0	15	0	8
$6.5 < R_B \leq 7$	0	10	0	6
$7 < R_B \leq 7.5$	0	5	0	6
$7.5 < R_B \leq 8$	0	1	0	0
$8 < R_B \leq 8.5$	0	2	0	1
$8.5 < R_B \leq 9$	0	0	0	0
$9 < R_B \leq 9.5$	0	0	0	1
$9.5 < R_B \leq 10$	0	0	0	0
$R_B > 10$	0	0	0	0

Table A10: Equivalent bubble diameter data sorted by size for ONP with BRD 2363 added to the system and an air flow rate of 0.25 slpm.

	BRD 2363 1.7 ml/kg (3 lbs/ton)				BRD 2363 3.3 ml/kg (6 lbs/ton)			
	Gasket		Sparger		Gasket		Sparger	
Consistency	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP	0% ONP	1.0% ONP
Bubble Count	Equivalent Bubble Diameter (mm)							
1	1.13	1.22	1.01	1.00	1.25	1.07	1.04	1.10
2	1.27	1.34	1.01	1.02	1.59	1.10	1.05	1.21
3	1.48	1.41	1.02	1.02	1.79	1.46	1.07	1.23
4	1.59	1.43	1.02	1.02	1.86	1.56	1.11	1.28
5	1.63	1.51	1.03	1.02	1.97	1.59	1.14	1.31
6	1.66	1.55	1.04	1.02	2.15	1.63	1.15	1.31
7	1.69	1.55	1.05	1.04	2.17	1.70	1.17	1.33
8	1.72	1.66	1.05	1.06	2.17	1.75	1.17	1.35
9	1.79	1.66	1.09	1.07	2.21	1.77	1.18	1.38
10	1.84	1.66	1.09	1.08	2.23	1.80	1.19	1.38
11	1.92	1.69	1.10	1.11	2.25	1.87	1.20	1.40
12	1.94	1.76	1.12	1.14	2.29	1.87	1.25	1.40
13	1.95	1.79	1.12	1.16	2.30	1.92	1.27	1.41
14	1.98	1.80	1.12	1.19	2.33	1.97	1.28	1.43
15	1.99	1.89	1.13	1.20	2.36	1.97	1.28	1.45
16	1.99	1.89	1.13	1.22	2.39	2.00	1.29	1.46
17	1.99	1.94	1.13	1.22	2.43	2.01	1.31	1.47
18	2.00	1.94	1.14	1.26	2.47	2.04	1.31	1.47
19	2.03	1.95	1.15	1.29	2.47	2.05	1.31	1.48
20	2.03	1.96	1.16	1.30	2.48	2.10	1.31	1.48
21	2.06	1.98	1.16	1.35	2.51	2.12	1.31	1.52
22	2.08	1.98	1.17	1.36	2.55	2.14	1.32	1.56
23	2.11	1.99	1.17	1.38	2.57	2.16	1.33	1.59
24	2.11	1.99	1.22	1.40	2.63	2.21	1.33	1.64
25	2.15	2.01	1.23	1.43	2.65	2.22	1.33	1.68
26	2.17	2.02	1.23	1.52	2.66	2.23	1.34	1.70
27	2.20	2.07	1.25	1.54	2.69	2.25	1.34	1.70
28	2.20	2.10	1.25	1.61	2.69	2.26	1.36	1.71
29	2.22	2.11	1.25	1.62	2.71	2.27	1.36	1.72
30	2.22	2.13	1.25	1.64	2.71	2.27	1.38	1.74
31	2.24	2.14	1.26	1.65	2.71	2.30	1.38	1.74
32	2.24	2.17	1.26	1.65	2.73	2.30	1.39	1.76
33	2.25	2.17	1.26	1.65	2.74	2.33	1.41	1.76
34	2.26	2.21	1.27	1.67	2.76	2.39	1.41	1.76
35	2.29	2.26	1.27	1.68	2.76	2.40	1.42	1.77
36	2.29	2.29	1.28	1.69	2.77	2.40	1.42	1.80
37	2.30	2.30	1.29	1.70	2.79	2.46	1.42	1.81
38	2.30	2.30	1.29	1.72	2.79	2.53	1.45	1.83
39	2.32	2.30	1.31	1.79	2.79	2.53	1.49	1.87
40	2.33	2.48	1.32	1.80	2.80	2.56	1.54	1.88
41	2.33	2.50	1.32	1.82	2.81	2.59	1.54	1.90
42	2.34	2.52	1.32	1.82	2.82	2.64	1.54	1.90
43	2.34	2.55	1.32	1.84	2.83	2.65	1.54	1.90
44	2.35	2.59	1.33	1.86	2.84	2.75	1.57	1.91
45	2.35	2.65	1.35	1.88	2.84	2.76	1.58	1.91
46	2.36	2.66	1.35	1.90	2.84	2.79	1.61	1.92
47	2.37	2.68	1.35	1.90	2.85	2.84	1.63	1.92
48	2.37	2.72	1.37	1.95	2.85	2.86	1.63	1.92
49	2.39	2.72	1.37	1.95	2.86	2.89	1.63	1.93
50	2.40	2.74	1.40	2.04	2.86	2.90	1.63	1.98
51	2.41	2.82	1.40	2.05	2.86	2.91	1.64	1.99
52	2.42	2.87	1.40	2.06	2.86	2.92	1.65	2.01
53	2.42	2.90	1.43	2.06	2.87	3.00	1.65	2.01
54	2.43	2.91	1.43	2.08	2.88	3.03	1.65	2.01
55	2.44	2.92	1.45	2.09	2.88	3.05	1.65	2.02
56	2.45	2.96	1.46	2.12	2.89	3.05	1.65	2.02
57	2.45	2.96	1.47	2.13	2.89	3.12	1.66	2.04
58	2.45	2.98	1.48	2.13	2.91	3.18	1.66	2.05
59	2.45	2.98	1.48	2.16	2.91	3.18	1.66	2.08
60	2.45	3.00	1.49	2.23	2.94	3.20	1.68	2.08
61	2.46	3.00	1.50	2.23	2.94	3.21	1.70	2.08
62	2.46	3.03	1.50	2.27	2.94	3.22	1.70	2.09
63	2.47	3.06	1.54	2.27	2.95	3.24	1.71	2.10

Table A10: cont.

64	2.48	3.09	1.57	2.27	2.95	3.25	1.71	2.10
65	2.48	3.10	1.57	2.28	2.98	3.27	1.73	2.11
66	2.49	3.12	1.58	2.29	2.99	3.27	1.73	2.11
67	2.51	3.13	1.58	2.33	2.99	3.28	1.74	2.12
68	2.52	3.13	1.58	2.35	3.00	3.29	1.76	2.14
69	2.52	3.16	1.58	2.36	3.00	3.33	1.79	2.16
70	2.53	3.22	1.60	2.37	3.00	3.39	1.79	2.16
71	2.53	3.30	1.61	2.38	3.01	3.43	1.80	2.17
72	2.53	3.37	1.61	2.38	3.01	3.43	1.80	2.17
73	2.55	3.41	1.61	2.38	3.01	3.44	1.80	2.18
74	2.56	3.43	1.61	2.38	3.03	3.44	1.82	2.18
75	2.56	3.46	1.64	2.38	3.03	3.45	1.84	2.19
76	2.57	3.48	1.64	2.40	3.04	3.47	1.84	2.20
77	2.57	3.48	1.64	2.42	3.04	3.49	1.84	2.20
78	2.58	3.49	1.65	2.42	3.04	3.51	1.86	2.20
79	2.59	3.51	1.66	2.42	3.04	3.51	1.86	2.22
80	2.59	3.54	1.66	2.42	3.05	3.54	1.86	2.23
81	2.59	3.54	1.67	2.42	3.06	3.56	1.88	2.23
82	2.60	3.54	1.67	2.43	3.08	3.56	1.89	2.23
83	2.60	3.56	1.67	2.43	3.10	3.60	1.89	2.25
84	2.61	3.61	1.67	2.45	3.12	3.64	1.90	2.25
85	2.61	3.63	1.68	2.46	3.13	3.66	1.90	2.26
86	2.61	3.67	1.72	2.47	3.14	3.66	1.90	2.26
87	2.63	3.68	1.72	2.47	3.15	3.67	1.90	2.26
88	2.63	3.68	1.73	2.49	3.15	3.72	1.90	2.27
89	2.64	3.71	1.74	2.50	3.16	3.74	1.91	2.28
90	2.66	3.72	1.74	2.51	3.18	3.75	1.91	2.29
91	2.66	3.77	1.74	2.51	3.18	3.80	1.92	2.30
92	2.67	3.77	1.75	2.51	3.19	3.81	1.93	2.30
93	2.68	3.78	1.76	2.51	3.19	3.81	1.94	2.30
94	2.69	3.85	1.76	2.52	3.19	3.84	1.94	2.35
95	2.69	3.89	1.77	2.58	3.21	3.85	1.94	2.36
96	2.69	3.90	1.77	2.58	3.21	3.86	1.95	2.37
97	2.69	3.90	1.78	2.61	3.23	3.86	1.95	2.38
98	2.69	3.91	1.78	2.61	3.23	3.87	1.96	2.38
99	2.70	3.93	1.78	2.61	3.24	3.88	1.96	2.39
100	2.70	3.94	1.78	2.62	3.27	3.93	1.96	2.41
101	2.71	4.00	1.79	2.62	3.27	3.94	1.97	2.41
102	2.71	4.00	1.79	2.62	3.31	3.95	1.98	2.41
103	2.72	4.01	1.81	2.63	3.31	3.96	1.98	2.41
104	2.72	4.02	1.81	2.63	3.31	3.96	1.98	2.43
105	2.72	4.02	1.83	2.63	3.34	4.01	1.98	2.43
106	2.73	4.03	1.84	2.63	3.36	4.02	1.99	2.43
107	2.73	4.04	1.84	2.63	3.36	4.04	1.99	2.44
108	2.74	4.04	1.85	2.63	3.37	4.10	2.00	2.45
109	2.75	4.07	1.86	2.64	3.38	4.10	2.00	2.46
110	2.76	4.09	1.86	2.65	3.39	4.11	2.00	2.48
111	2.76	4.09	1.88	2.67	3.39	4.13	2.01	2.50
112	2.77	4.16	1.88	2.69	3.41	4.13	2.02	2.52
113	2.83	4.17	1.88	2.71	3.41	4.15	2.03	2.55
114	2.83	4.26	1.90	2.72	3.42	4.15	2.04	2.59
115	2.85	4.27	1.90	2.72	3.42	4.16	2.04	2.60
116	2.85	4.27	1.91	2.73	3.42	4.16	2.05	2.62
117	2.87	4.27	1.91	2.74	3.42	4.20	2.05	2.62
118	2.87	4.32	1.91	2.74	3.43	4.22	2.06	2.63
119	2.88	4.35	1.91	2.74	3.43	4.23	2.06	2.64
120	2.90	4.36	1.91	2.75	3.43	4.24	2.06	2.64
121	2.90	4.41	1.91	2.76	3.45	4.26	2.06	2.65
122	2.92	4.41	1.92	2.76	3.46	4.27	2.08	2.65
123	2.92	4.45	1.92	2.76	3.47	4.27	2.08	2.66
124	2.92	4.49	1.92	2.76	3.49	4.28	2.08	2.68
125	2.92	4.49	1.92	2.77	3.49	4.29	2.08	2.72
126	2.93	4.50	1.92	2.77	3.50	4.35	2.08	2.72
127	2.93	4.50	1.93	2.77	3.50	4.35	2.09	2.72
128	2.94	4.50	1.93	2.78	3.50	4.37	2.10	2.72
129	2.95	4.51	1.93	2.79	3.51	4.37	2.10	2.72
130	2.96	4.53	1.93	2.80	3.52	4.38	2.10	2.75
131	2.97	4.53	1.94	2.82	3.53	4.38	2.10	2.76

Table A10: cont.

132	2.98	4.54	1.94	2.84	3.55	4.38	2.10	2.77
133	2.98	4.55	1.95	2.85	3.57	4.41	2.11	2.80
134	2.99	4.56	1.96	2.88	3.58	4.41	2.11	2.81
135	2.99	4.57	1.96	2.89	3.59	4.43	2.11	2.81
136	3.01	4.57	1.96	2.90	3.60	4.45	2.11	2.83
137	3.02	4.59	1.97	2.91	3.60	4.46	2.11	2.84
138	3.02	4.59	1.97	2.92	3.61	4.48	2.12	2.84
139	3.03	4.61	1.97	2.94	3.63	4.50	2.13	2.86
140	3.04	4.62	1.97	2.96	3.64	4.51	2.13	2.88
141	3.06	4.62	1.97	2.97	3.64	4.52	2.13	2.88
142	3.08	4.64	1.97	3.00	3.64	4.53	2.14	2.88
143	3.09	4.64	1.98	3.01	3.65	4.54	2.14	2.89
144	3.12	4.65	1.99	3.01	3.66	4.55	2.14	2.90
145	3.12	4.67	1.99	3.01	3.66	4.55	2.15	2.93
146	3.15	4.68	1.99	3.01	3.67	4.61	2.15	2.95
147	3.15	4.69	2.01	3.01	3.67	4.63	2.15	2.97
148	3.15	4.71	2.01	3.02	3.67	4.70	2.15	2.97
149	3.17	4.71	2.01	3.06	3.67	4.71	2.16	2.99
150	3.17	4.75	2.02	3.07	3.68	4.73	2.16	3.00
151	3.17	4.76	2.02	3.07	3.70	4.75	2.18	3.00
152	3.17	4.77	2.03	3.08	3.72	4.77	2.18	3.01
153	3.17	4.78	2.03	3.08	3.73	4.78	2.18	3.02
154	3.18	4.78	2.03	3.08	3.73	4.80	2.18	3.08
155	3.19	4.81	2.03	3.08	3.74	4.82	2.18	3.10
156	3.20	4.88	2.03	3.09	3.75	4.88	2.18	3.10
157	3.20	4.91	2.04	3.09	3.77	4.89	2.19	3.11
158	3.20	4.92	2.04	3.10	3.78	4.92	2.20	3.13
159	3.20	4.94	2.04	3.11	3.80	4.95	2.21	3.13
160	3.20	4.95	2.04	3.12	3.80	4.95	2.21	3.14
161	3.20	4.97	2.04	3.13	3.82	4.96	2.21	3.15
162	3.20	5.00	2.04	3.13	3.82	4.96	2.21	3.16
163	3.21	5.02	2.04	3.13	3.83	4.97	2.21	3.17
164	3.23	5.03	2.04	3.13	3.85	4.98	2.22	3.17
165	3.24	5.04	2.05	3.16	3.85	5.01	2.22	3.17
166	3.24	5.04	2.05	3.16	3.86	5.03	2.22	3.18
167	3.24	5.06	2.05	3.17	3.87	5.04	2.22	3.19
168	3.25	5.06	2.05	3.23	3.89	5.06	2.22	3.20
169	3.27	5.06	2.05	3.23	3.92	5.07	2.22	3.23
170	3.28	5.09	2.05	3.24	3.94	5.10	2.22	3.25
171	3.29	5.10	2.05	3.25	3.94	5.10	2.23	3.27
172	3.29	5.11	2.05	3.25	3.94	5.11	2.23	3.30
173	3.31	5.13	2.06	3.26	3.95	5.11	2.23	3.31
174	3.32	5.15	2.06	3.26	3.95	5.15	2.23	3.33
175	3.33	5.21	2.06	3.28	3.96	5.17	2.23	3.35
176	3.34	5.22	2.06	3.31	3.96	5.18	2.24	3.38
177	3.34	5.23	2.07	3.31	3.99	5.18	2.24	3.40
178	3.37	5.24	2.08	3.31	4.02	5.20	2.25	3.40
179	3.42	5.24	2.08	3.32	4.06	5.20	2.26	3.41
180	3.42	5.26	2.09	3.32	4.06	5.22	2.26	3.42
181	3.44	5.27	2.09	3.32	4.06	5.27	2.26	3.42
182	3.46	5.31	2.09	3.32	4.10	5.28	2.26	3.43
183	3.46	5.31	2.09	3.34	4.11	5.28	2.27	3.44
184	3.47	5.34	2.10	3.35	4.11	5.28	2.27	3.44
185	3.48	5.37	2.10	3.35	4.11	5.29	2.27	3.45
186	3.48	5.38	2.10	3.35	4.15	5.31	2.27	3.46
187	3.51	5.39	2.11	3.37	4.15	5.34	2.27	3.46
188	3.53	5.41	2.12	3.37	4.26	5.35	2.27	3.48
189	3.53	5.43	2.12	3.37	4.29	5.36	2.28	3.49
190	3.54	5.47	2.13	3.37	4.43	5.38	2.28	3.50
191	3.56	5.56	2.13	3.38	4.64	5.40	2.28	3.57
192	3.58	5.58	2.13	3.38	4.99	5.49	2.28	3.57
193	3.62	5.60	2.13	3.41		5.50	2.29	3.60
194	3.63	5.61	2.13	3.43		5.55	2.30	3.61
195	3.63	5.63	2.14	3.43		5.55	2.31	3.63
196	3.67	5.66	2.14	3.43		5.56	2.31	3.65
197	3.69	5.66	2.14	3.43		5.58	2.31	3.65
198	3.71	5.72	2.15	3.44		5.61	2.31	3.66
199	3.73	5.76	2.15	3.45		5.62	2.31	3.70

Table A10: cont.

200	3.77	5.81	2.15	3.47		5.63	2.31	3.70
201	3.79	5.81	2.15	3.48		5.66	2.32	3.71
202	3.80	5.83	2.15	3.48		5.84	2.32	3.71
203	3.81	6.08	2.16	3.50		5.84	2.33	3.71
204	3.82	6.09	2.16	3.50		5.87	2.33	3.72
205	3.84	6.12	2.16	3.52		5.92	2.33	3.72
206	3.87	6.12	2.17	3.54		5.92	2.33	3.74
207	3.89	6.14	2.17	3.55		5.94	2.33	3.78
208	3.90	6.15	2.17	3.56		5.97	2.33	3.81
209	3.97	6.18	2.17	3.57		5.97	2.34	3.83
210	3.97	6.34	2.17	3.57		5.97	2.34	3.84
211	4.04	6.41	2.17	3.57		5.97	2.35	3.86
212	4.07	6.43	2.17	3.57		6.02	2.35	3.91
213	4.21	6.58	2.18	3.58		6.04	2.35	3.92
214	4.30	6.61	2.18	3.58		6.09	2.36	3.92
215	4.50	6.75	2.18	3.59		6.13	2.36	3.92
216	4.56	6.81	2.19	3.60		6.14	2.36	3.99
217		6.86	2.19	3.61		6.15	2.36	4.03
218		6.96	2.20	3.61		6.15	2.37	4.04
219		7.04	2.21	3.62		6.19	2.39	4.06
220		7.04	2.22	3.63		6.29	2.39	4.10
221		7.13	2.22	3.64		6.30	2.39	4.10
222		7.22	2.22	3.66		6.34	2.40	4.18
223		7.36	2.23	3.67		6.34	2.40	4.20
224		7.36	2.24	3.68		6.39	2.41	4.25
225		7.37	2.24	3.70		6.42	2.41	4.27
226		7.44	2.24	3.72		6.44	2.42	4.31
227		7.52	2.24	3.72		6.55	2.42	4.38
228			2.24	3.74		6.68	2.42	4.43
229			2.24	3.74		6.71	2.43	4.44
230			2.25	3.74		6.71	2.43	4.47
231			2.25	3.74		6.84	2.43	4.47
232			2.25	3.78		6.84	2.43	4.50
233			2.25	3.78		6.87	2.43	4.60
234			2.25	3.78		6.91	2.43	4.67
235			2.26	3.80		6.93	2.43	4.68
236			2.26	3.80		6.97	2.44	4.70
237			2.27	3.81		7.00	2.44	4.79
238			2.27	3.81		7.03	2.45	4.81
239			2.27	3.82		7.05	2.46	4.84
240			2.28	3.82		7.15	2.46	4.84
241			2.28	3.85		7.39	2.46	4.87
242			2.28	3.85		7.64	2.46	4.90
243			2.28	3.85		8.21	2.47	4.98
244			2.29	3.86		8.24	2.47	4.99
245			2.31	3.89			2.48	5.00
246			2.31	3.89			2.48	5.01
247			2.31	3.90			2.48	5.02
248			2.31	3.90			2.48	5.11
249			2.31	3.91			2.49	5.15
250			2.31	3.92			2.49	5.21
251			2.32	3.92			2.49	5.28
252			2.32	3.92			2.49	5.29
253			2.33	3.93			2.50	5.36
254			2.33	3.93			2.50	5.42
255			2.33	3.93			2.50	5.46
256			2.34	3.94			2.50	5.48
257			2.34	3.94			2.50	5.50
258			2.34	3.94			2.50	5.56
259			2.34	3.96			2.50	5.64
260			2.35	3.96			2.50	5.70
261			2.35	3.96			2.50	5.71
262			2.36	3.96			2.51	5.71
263			2.36	3.96			2.51	5.79
264			2.36	3.96			2.52	5.84
265			2.37	3.96			2.52	5.91
266			2.37	3.96			2.52	5.95
267			2.38	3.97			2.53	6.02

Table A10: cont.

268			2.38	3.97			2.53	6.08
269			2.38	3.99			2.53	6.10
270			2.39	4.01			2.53	6.10
271			2.39	4.02			2.53	6.19
272			2.39	4.02			2.55	6.29
273			2.39	4.02			2.55	6.47
274			2.40	4.02			2.55	6.50
275			2.40	4.05			2.55	6.51
276			2.42	4.05			2.55	6.56
277			2.42	4.06			2.55	6.59
278			2.42	4.06			2.56	6.60
279			2.42	4.08			2.56	6.67
280			2.44	4.09			2.56	6.77
281			2.44	4.10			2.57	7.03
282			2.44	4.10			2.57	7.08
283			2.47	4.12			2.57	7.09
284			2.47	4.15			2.57	7.25
285			2.47	4.17			2.57	7.25
286			2.47	4.18			2.59	7.40
287			2.47	4.19			2.59	8.25
288			2.48	4.21			2.59	9.11
289			2.48	4.22			2.59	
290			2.48	4.22			2.59	
291			2.49	4.25			2.59	
292			2.49	4.28			2.60	
293			2.49	4.30			2.60	
294			2.50	4.30			2.60	
295			2.51	4.36			2.61	
296			2.51	4.36			2.61	
297			2.51	4.39			2.61	
298			2.52	4.43			2.61	
299			2.52	4.44			2.61	
300			2.52	4.45			2.62	
301			2.53	4.53			2.62	
302			2.55	4.55			2.63	
303			2.55	4.57			2.63	
304			2.55	4.58			2.63	
305			2.57	4.61			2.64	
306			2.57	4.71			2.65	
307			2.57	4.78			2.65	
308			2.58	4.81			2.65	
309			2.58	4.85			2.66	
310			2.59	4.88			2.66	
311			2.59	4.90			2.66	
312			2.59	4.91			2.66	
313			2.60	4.94			2.67	
314			2.60	4.97			2.67	
315			2.60	4.99			2.67	
316			2.60	5.06			2.68	
317			2.61	5.06			2.68	
318			2.61	5.06			2.69	
319			2.61	5.06			2.69	
320			2.62	5.12			2.69	
321			2.63	5.14			2.69	
322			2.63	5.17			2.69	
323			2.64	5.19			2.69	
324			2.64	5.20			2.69	
325			2.64	5.23			2.69	
326			2.65	5.29			2.70	
327			2.65	5.31			2.70	
328			2.66	5.37			2.70	
329			2.66	5.40			2.70	
330			2.67	5.49			2.71	
331			2.68	5.49			2.71	
332			2.68	5.49			2.71	
333			2.68	5.49			2.71	
334			2.68	5.51			2.71	
335			2.69	5.51			2.71	

Table A10: cont.

336			2.69	5.63			2.71	
337			2.69	5.64			2.71	
338			2.70	5.67			2.71	
339			2.70	5.67			2.73	
340			2.70	5.73			2.73	
341			2.70	5.73			2.74	
342			2.71	5.74			2.74	
343			2.71	5.87			2.75	
344			2.71	5.89			2.75	
345			2.71	5.94			2.75	
346			2.71	5.94			2.75	
347			2.72	6.02			2.75	
348			2.73	6.12			2.75	
349			2.73	6.13			2.76	
350			2.73	6.14			2.76	
351			2.73	6.15			2.76	
352			2.73	6.17			2.77	
353			2.75	6.17			2.77	
354			2.75	6.25			2.78	
355			2.75	6.27			2.79	
356			2.76	6.31			2.79	
357			2.77	6.31			2.79	
358			2.78	6.31			2.79	
359			2.78	6.31			2.79	
360			2.78	6.33			2.80	
361			2.78	6.35			2.80	
362			2.79	6.36			2.80	
363			2.79	6.63			2.80	
364			2.79	6.70			2.80	
365			2.79	6.71			2.81	
366			2.79	6.75			2.81	
367			2.80	6.78			2.81	
368			2.81	6.88			2.81	
369			2.81	6.89			2.81	
370			2.81	7.08			2.82	
371			2.81	7.09			2.82	
372			2.81	7.16			2.82	
373			2.81	7.17			2.83	
374			2.82	7.25			2.83	
375			2.82	7.31			2.83	
376			2.83	7.42			2.83	
377			2.84	7.55			2.84	
378			2.84	7.77			2.85	
379			2.85	7.79			2.85	
380			2.87	7.81			2.85	
381			2.87	7.94			2.85	
382			2.88	8.02			2.87	
383			2.88	8.05			2.88	
384			2.89	8.14			2.88	
385			2.90	8.25			2.88	
386			2.92	8.25			2.88	
387			2.93	8.25			2.88	
388			2.97	8.25			2.88	
389			2.97	8.27			2.88	
390			2.97	8.33			2.88	
391			2.97	8.36			2.88	
392			2.97	9.40			2.89	
393			2.97	9.56			2.89	
394			2.98	9.69			2.90	
395			2.98	10.28			2.90	
396			2.99	13.77			2.90	
397			3.00				2.90	
398			3.03				2.90	
399			3.03				2.91	
400			3.04				2.91	
401			3.05				2.92	
402			3.06				2.92	
403			3.07				2.92	

Table A10: cont.

404			3.08				2.92	
405			3.09				2.92	
406			3.10				2.93	
407			3.10				2.93	
408			3.11				2.93	
409			3.11				2.93	
410			3.11				2.94	
411			3.12				2.95	
412			3.13				2.96	
413			3.13				2.96	
414			3.14				2.96	
415			3.16				2.96	
416			3.18				2.97	
417			3.18				2.97	
418			3.20				2.97	
419			3.23				2.97	
420			3.24				2.98	
421			3.24				2.99	
422			3.25				3.00	
423			3.26				3.00	
424			3.27				3.01	
425			3.27				3.01	
426			3.29				3.01	
427			3.30				3.01	
428			3.31				3.02	
429			3.31				3.02	
430			3.31				3.03	
431			3.33				3.04	
432			3.34				3.04	
433			3.34				3.04	
434			3.34				3.05	
435			3.35				3.06	
436			3.36				3.06	
437			3.37				3.06	
438			3.42				3.07	
439			3.44				3.08	
440			3.45				3.08	
441			3.45				3.08	
442			3.45				3.08	
443			3.45				3.08	
444			3.47				3.08	
445			3.48				3.09	
446			3.49				3.09	
447			3.49				3.09	
448			3.50				3.10	
449			3.50				3.11	
450			3.50				3.12	
451			3.50				3.12	
452			3.50				3.12	
453			3.51				3.12	
454			3.55				3.12	
455			3.57				3.13	
456			3.58				3.13	
457			3.59				3.14	
458			3.60				3.15	
459			3.63				3.15	
460			3.63				3.16	
461			3.65				3.16	
462			3.67				3.16	
463			3.74				3.16	
464			3.81				3.17	
465			3.91				3.17	
466			3.93				3.17	
467			3.93				3.17	
468			3.94				3.18	
469			3.95				3.18	
470			3.97				3.19	
471			4.04				3.19	

Table A10: cont.

472			4.06				3.20	
473			4.10				3.21	
474			4.10				3.22	
475			4.11				3.23	
476			4.12				3.25	
477			4.15				3.25	
478			4.24				3.25	
479			4.35				3.26	
480			4.36				3.26	
481			4.56				3.26	
482			4.65				3.26	
483			4.78				3.26	
484			4.87				3.27	
485			4.99				3.28	
486							3.28	
487							3.28	
488							3.28	
489							3.28	
490							3.29	
491							3.29	
492							3.29	
493							3.32	
494							3.34	
495							3.34	
496							3.34	
497							3.34	
498							3.35	
499							3.35	
500							3.37	
501							3.38	
502							3.40	
503							3.40	
504							3.43	
505							3.44	
506							3.44	
507							3.44	
508							3.45	
509							3.46	
510							3.47	
511							3.47	
512							3.48	
513							3.48	
514							3.49	
515							3.50	
516							3.50	
517							3.51	
518							3.53	
519							3.53	
520							3.54	
521							3.55	
522							3.55	
523							3.56	
524							3.57	
525							3.57	
526							3.58	
527							3.58	
528							3.58	
529							3.58	
530							3.58	
531							3.58	
532							3.62	
533							3.62	
534							3.63	
535							3.66	
536							3.68	
537							3.68	
538							3.68	
539							3.68	

Table A10: cont.

540							3.68	
541							3.70	
542							3.70	
543							3.70	
544							3.71	
545							3.73	
546							3.75	
547							3.78	
548							3.80	
549							3.81	
550							3.83	
551							3.83	
552							3.87	
553							3.87	
554							3.90	
555							3.93	
556							3.95	
557							3.95	
558							3.95	
559							3.95	
560							3.97	
561							4.03	
562							4.06	
563							4.09	
564							4.14	
565							4.14	
566							4.14	
567							4.16	
568							4.20	
569							4.25	
570							4.29	
571							4.32	
572							4.35	
573							4.35	
574							4.41	
575							4.51	
576							4.63	
577							4.85	
578							5.81	
579							5.81	

APPENDIX B: EQUIVALENT BUBBLE DIAMETER MEASUREMENTS FOR NBSK AND DATA OBTAINED AT AN AIR FLOW RATE OF 2 slpm

This Appendix tabulates the equivalent bubble diameter measurements recorded from Position 2 x-rays for the following conditions: Tables B1 and B2 include NBSK data taken at an air flow rate of 0.25 slpm; Tables B3 and B4 contain NBSK data taken at an air flow rate of 2 slpm; and Tables B5 and B6 entail the air/water, ONP, and copy paper data taken at an air flow rate of 2 slpm. All data tabulated in this Appendix did not have any additional chemistry added to the system.

Table B1: Summary of the equivalent bubble size distribution data for NBSK at an air flow rate of 0.25 slpm.

	NBSK @ 0.25 slpm	
	Gasket	**Sparger**
Consistency	0.10%	0.10%
Average Equivalent Bubble Diameter (mm)	2.82	3.87
Median Equivalent Bubble Diameter (mm)	2.74	3.93
Minimum Equivalent Bubble Diameter (mm)	1.01	1.01
Maximum Equivalent Bubble Diameter (mm)	5.37	6.88
Standard Deviation (mm)	0.73	0.99
Variance (mm^2)	0.54	0.97
Bubble Population Size	759	752
Equivalent Sauter Mean Diameter (mm)	3.20	4.32
Bubble Size Rang (mm)	Frequency	
$0 < R_B \leq 1$	0	0
$1 < R_B \leq 1.5$	16	19
$1.5 < R_B \leq 2$	68	15
$2 < R_B \leq 2.5$	177	35
$2.5 < R_B \leq 3$	239	55
$3 < R_B \leq 3.5$	131	129
$3.5 < R_B \leq 4$	73	151
$4 < R_B \leq 4.5$	34	160
$4.5 < R_B \leq 5$	19	109
$5 < R_B \leq 5.5$	2	50
$5.5 < R_B \leq 6$	0	18
$6 < R_B \leq 6.5$	0	9
$6.5 < R_B \leq 7$	0	2
$7 < R_B \leq 7.5$	0	0
$7.5 < R_B \leq 8$	0	0
$8 < R_B \leq 8.5$	0	0
$8.5 < R_B \leq 9$	0	0
$9 < R_B \leq 9.5$	0	0
$9.5 < R_B \leq 10$	0	0
$R_B > 10$	0	0

Table B2: Equivalent bubble diameter data sorted by size for NBSK at an air flow rate of 0.25 slpm.

	NBSK @ 0.25 slpm	
	Gasket	Sparger
Consistency	0.10%	0.10%
Bubble Count	Equivalent Diameter (mm)	
1	1.01	1.01
2	1.01	1.01
3	1.02	1.01
4	1.05	1.05
5	1.13	1.07
6	1.22	1.09
7	1.23	1.10
8	1.29	1.11
9	1.36	1.17
10	1.38	1.26
11	1.39	1.26
12	1.40	1.30
13	1.40	1.30
14	1.43	1.31
15	1.46	1.31
16	1.48	1.35
17	1.52	1.38
18	1.53	1.44
19	1.54	1.50
20	1.58	1.51
21	1.61	1.57
22	1.62	1.61
23	1.62	1.68
24	1.65	1.69
25	1.66	1.69
26	1.66	1.78
27	1.67	1.78
28	1.68	1.85
29	1.68	1.89
30	1.68	1.91
31	1.72	1.96
32	1.72	1.96
33	1.72	1.96
34	1.73	1.99
35	1.73	2.03
36	1.73	2.05
37	1.74	2.07
38	1.74	2.09
39	1.74	2.12
40	1.76	2.17
41	1.78	2.22
42	1.78	2.23
43	1.80	2.24
44	1.81	2.24
45	1.81	2.28
46	1.82	2.29
47	1.83	2.30
48	1.83	2.31
49	1.84	2.32
50	1.84	2.32
51	1.84	2.33
52	1.85	2.34
53	1.86	2.34
54	1.87	2.35
55	1.88	2.37
56	1.89	2.37
57	1.90	2.38
58	1.91	2.41
59	1.91	2.42
60	1.91	2.42
61	1.92	2.42
62	1.93	2.44
63	1.93	2.45
64	1.94	2.45
65	1.94	2.46
66	1.94	2.48
67	1.95	2.49
68	1.95	2.50
69	1.95	2.50
70	1.96	2.53
71	1.96	2.57
72	1.96	2.58
73	1.96	2.60
74	1.96	2.61
75	1.96	2.62
76	1.96	2.64
77	1.96	2.66
78	1.97	2.67
79	1.97	2.68
80	1.98	2.70
81	1.98	2.70
82	1.98	2.70
83	1.99	2.71
84	2.00	2.72
85	2.01	2.72
86	2.01	2.74
87	2.01	2.74
88	2.01	2.74
89	2.02	2.74
90	2.02	2.75
91	2.03	2.76
92	2.03	2.78
93	2.03	2.78
94	2.03	2.78
95	2.04	2.80
96	2.04	2.80
97	2.06	2.80
98	2.07	2.80
99	2.07	2.81
100	2.07	2.82
101	2.07	2.82
102	2.08	2.82
103	2.08	2.82
104	2.09	2.83
105	2.09	2.83
106	2.10	2.85
107	2.10	2.86
108	2.10	2.88
109	2.10	2.89
110	2.11	2.89
111	2.11	2.90
112	2.12	2.90
113	2.13	2.92
114	2.14	2.93
115	2.14	2.94
116	2.14	2.94
117	2.14	2.94
118	2.14	2.96
119	2.14	2.96
120	2.15	2.97
121	2.15	2.98
122	2.15	2.99
123	2.16	2.99
124	2.16	3.00
125	2.17	3.00
126	2.17	3.02
127	2.17	3.02
128	2.17	3.03

Table B2: cont.

129	2.17	3.04
130	2.18	3.06
131	2.18	3.06
132	2.18	3.06
133	2.18	3.06
134	2.19	3.06
135	2.19	3.06
136	2.20	3.08
137	2.20	3.08
138	2.20	3.08
139	2.20	3.08
140	2.20	3.09
141	2.21	3.09
142	2.21	3.09
143	2.21	3.10
144	2.22	3.10
145	2.22	3.11
146	2.22	3.13
147	2.22	3.13
148	2.22	3.14
149	2.22	3.14
150	2.22	3.14
151	2.23	3.14
152	2.23	3.15
153	2.23	3.15
154	2.23	3.15
155	2.24	3.15
156	2.24	3.16
157	2.24	3.17
158	2.25	3.17
159	2.25	3.18
160	2.25	3.19
161	2.25	3.19
162	2.25	3.19
163	2.26	3.19
164	2.26	3.20
165	2.26	3.20
166	2.27	3.20
167	2.27	3.21
168	2.27	3.21
169	2.27	3.21
170	2.28	3.22
171	2.28	3.23
172	2.28	3.23
173	2.28	3.24
174	2.28	3.25
175	2.29	3.25
176	2.29	3.25
177	2.29	3.26
178	2.29	3.26
179	2.29	3.26
180	2.29	3.26
181	2.29	3.26
182	2.29	3.27
183	2.30	3.29
184	2.30	3.29
185	2.30	3.29
186	2.30	3.30
187	2.31	3.30
188	2.31	3.30
189	2.32	3.30
190	2.32	3.30
191	2.32	3.31
192	2.32	3.31
193	2.32	3.31
194	2.33	3.31
195	2.33	3.32
196	2.33	3.32
197	2.33	3.32
198	2.33	3.32
199	2.33	3.32
200	2.33	3.32
201	2.34	3.32
202	2.34	3.33
203	2.34	3.33
204	2.35	3.34
205	2.35	3.34
206	2.35	3.34
207	2.36	3.35
208	2.36	3.35
209	2.36	3.35
210	2.36	3.36
211	2.36	3.36
212	2.37	3.36
213	2.37	3.37
214	2.37	3.38
215	2.37	3.38
216	2.37	3.38
217	2.37	3.38
218	2.38	3.39
219	2.38	3.39
220	2.38	3.39
221	2.38	3.40
222	2.38	3.40
223	2.38	3.41
224	2.38	3.41
225	2.39	3.41
226	2.40	3.42
227	2.40	3.43
228	2.40	3.43
229	2.42	3.43
230	2.42	3.44
231	2.42	3.44
232	2.42	3.44
233	2.42	3.45
234	2.42	3.46
235	2.43	3.46
236	2.43	3.46
237	2.44	3.46
238	2.45	3.46
239	2.46	3.46
240	2.46	3.47
241	2.46	3.48
242	2.46	3.48
243	2.46	3.48
244	2.47	3.48
245	2.47	3.48
246	2.47	3.48
247	2.48	3.48
248	2.48	3.48
249	2.48	3.48
250	2.48	3.50
251	2.48	3.50
252	2.48	3.50
253	2.48	3.50
254	2.49	3.50
255	2.49	3.51
256	2.49	3.51
257	2.49	3.51
258	2.49	3.52
259	2.49	3.52
260	2.49	3.53
261	2.50	3.53
262	2.50	3.53
263	2.50	3.53
264	2.50	3.54
265	2.50	3.54

Table B2: cont.

266	2.50	3.55
267	2.50	3.55
268	2.51	3.55
269	2.51	3.55
270	2.51	3.56
271	2.52	3.56
272	2.53	3.56
273	2.53	3.57
274	2.53	3.59
275	2.53	3.59
276	2.53	3.59
277	2.55	3.60
278	2.55	3.60
279	2.55	3.60
280	2.55	3.61
281	2.55	3.61
282	2.55	3.62
283	2.55	3.62
284	2.55	3.62
285	2.56	3.62
286	2.56	3.63
287	2.56	3.63
288	2.56	3.63
289	2.56	3.63
290	2.56	3.63
291	2.56	3.63
292	2.57	3.63
293	2.57	3.65
294	2.57	3.67
295	2.57	3.67
296	2.57	3.67
297	2.57	3.67
298	2.57	3.68
299	2.57	3.69
300	2.57	3.70
301	2.57	3.70
302	2.58	3.70
303	2.58	3.71
304	2.58	3.71
305	2.58	3.71
306	2.58	3.71
307	2.58	3.72
308	2.59	3.72
309	2.59	3.72
310	2.59	3.72
311	2.59	3.72
312	2.59	3.72
313	2.59	3.73
314	2.59	3.73
315	2.59	3.73
316	2.60	3.73
317	2.60	3.74
318	2.60	3.74
319	2.60	3.74
320	2.60	3.74
321	2.61	3.75
322	2.61	3.75
323	2.61	3.75
324	2.61	3.75
325	2.61	3.75
326	2.62	3.75
327	2.62	3.75
328	2.62	3.76
329	2.62	3.76
330	2.62	3.77
331	2.62	3.77
332	2.62	3.78
333	2.62	3.78
334	2.63	3.78
335	2.63	3.79
336	2.64	3.79
337	2.64	3.79
338	2.64	3.79
339	2.64	3.79
340	2.64	3.80
341	2.64	3.80
342	2.64	3.80
343	2.65	3.80
344	2.65	3.80
345	2.66	3.80
346	2.67	3.81
347	2.67	3.81
348	2.67	3.81
349	2.67	3.82
350	2.67	3.82
351	2.68	3.82
352	2.68	3.82
353	2.68	3.83
354	2.68	3.83
355	2.68	3.83
356	2.69	3.84
357	2.69	3.84
358	2.69	3.86
359	2.69	3.87
360	2.69	3.87
361	2.69	3.88
362	2.69	3.89
363	2.69	3.89
364	2.69	3.89
365	2.70	3.89
366	2.70	3.89
367	2.71	3.90
368	2.71	3.90
369	2.71	3.90
370	2.71	3.90
371	2.72	3.90
372	2.72	3.90
373	2.72	3.90
374	2.73	3.91
375	2.73	3.91
376	2.73	3.92
377	2.73	3.93
378	2.73	3.93
379	2.74	3.93
380	2.74	3.93
381	2.75	3.93
382	2.75	3.94
383	2.76	3.94
384	2.76	3.95
385	2.76	3.95
386	2.77	3.96
387	2.77	3.96
388	2.77	3.97
389	2.77	3.97
390	2.77	3.97
391	2.77	3.98
392	2.78	3.98
393	2.78	3.98
394	2.78	3.98
395	2.78	3.99
396	2.78	3.99
397	2.78	3.99
398	2.78	3.99
399	2.78	3.99
400	2.78	3.99
401	2.79	4.00
402	2.79	4.00
403	2.79	4.00
404	2.80	4.00

Table B2: cont.

405	2.80	4.00
406	2.80	4.01
407	2.80	4.01
408	2.80	4.01
409	2.80	4.02
410	2.80	4.02
411	2.80	4.03
412	2.81	4.03
413	2.81	4.03
414	2.81	4.03
415	2.81	4.04
416	2.82	4.04
417	2.82	4.05
418	2.82	4.05
419	2.83	4.06
420	2.83	4.06
421	2.83	4.06
422	2.83	4.07
423	2.84	4.07
424	2.84	4.07
425	2.85	4.07
426	2.85	4.08
427	2.85	4.08
428	2.85	4.09
429	2.86	4.10
430	2.86	4.10
431	2.87	4.11
432	2.87	4.12
433	2.87	4.12
434	2.87	4.13
435	2.88	4.13
436	2.88	4.13
437	2.88	4.14
438	2.88	4.15
439	2.88	4.15
440	2.88	4.15
441	2.88	4.15
442	2.89	4.16
443	2.89	4.16
444	2.89	4.17
445	2.89	4.17
446	2.89	4.17
447	2.89	4.17
448	2.89	4.18
449	2.90	4.18
450	2.90	4.19
451	2.90	4.19
452	2.90	4.19
453	2.90	4.19
454	2.90	4.19
455	2.91	4.19
456	2.91	4.21
457	2.91	4.21
458	2.92	4.21
459	2.92	4.21
460	2.92	4.21
461	2.92	4.21
462	2.92	4.21
463	2.92	4.22
464	2.93	4.22
465	2.93	4.22
466	2.93	4.22
467	2.94	4.22
468	2.94	4.22
469	2.95	4.23
470	2.95	4.23
471	2.95	4.23
472	2.95	4.23
473	2.95	4.23
474	2.95	4.23
475	2.95	4.24
476	2.95	4.24
477	2.95	4.24
478	2.95	4.24
479	2.96	4.24
480	2.96	4.25
481	2.96	4.25
482	2.96	4.26
483	2.96	4.26
484	2.97	4.26
485	2.97	4.27
486	2.97	4.27
487	2.97	4.27
488	2.97	4.27
489	2.98	4.28
490	2.98	4.28
491	2.98	4.28
492	2.98	4.28
493	2.98	4.28
494	2.99	4.29
495	2.99	4.29
496	2.99	4.29
497	2.99	4.29
498	2.99	4.29
499	3.00	4.30
500	3.00	4.30
501	3.01	4.30
502	3.01	4.30
503	3.01	4.31
504	3.02	4.31
505	3.02	4.32
506	3.02	4.32
507	3.02	4.32
508	3.02	4.32
509	3.03	4.33
510	3.03	4.33
511	3.04	4.35
512	3.04	4.35
513	3.05	4.35
514	3.05	4.35
515	3.06	4.36
516	3.06	4.36
517	3.06	4.37
518	3.07	4.37
519	3.07	4.37
520	3.07	4.37
521	3.07	4.37
522	3.08	4.38
523	3.08	4.38
524	3.09	4.38
525	3.10	4.38
526	3.10	4.38
527	3.10	4.39
528	3.11	4.39
529	3.11	4.39
530	3.12	4.39
531	3.12	4.40
532	3.13	4.40
533	3.13	4.40
534	3.13	4.40
535	3.13	4.41
536	3.14	4.41
537	3.15	4.41
538	3.16	4.42
539	3.16	4.42
540	3.16	4.44
541	3.17	4.44
542	3.17	4.45
543	3.17	4.45

Table B2: cont.

544	3.18	4.45
545	3.18	4.45
546	3.18	4.45
547	3.19	4.46
548	3.19	4.46
549	3.20	4.46
550	3.21	4.46
551	3.21	4.46
552	3.21	4.46
553	3.21	4.46
554	3.22	4.47
555	3.22	4.47
556	3.22	4.47
557	3.22	4.48
558	3.22	4.49
559	3.23	4.49
560	3.23	4.50
561	3.23	4.50
562	3.23	4.50
563	3.23	4.50
564	3.24	4.50
565	3.25	4.51
566	3.26	4.51
567	3.26	4.52
568	3.26	4.53
569	3.26	4.53
570	3.27	4.53
571	3.27	4.54
572	3.27	4.54
573	3.28	4.55
574	3.28	4.55
575	3.29	4.55
576	3.29	4.55
577	3.30	4.55
578	3.30	4.55
579	3.30	4.56
580	3.31	4.57
581	3.31	4.58
582	3.31	4.59
583	3.33	4.59
584	3.33	4.59
585	3.34	4.59
586	3.34	4.60
587	3.35	4.60
588	3.35	4.60
589	3.36	4.60
590	3.36	4.62
591	3.37	4.62
592	3.37	4.62
593	3.38	4.62
594	3.39	4.62
595	3.39	4.63
596	3.40	4.64
597	3.40	4.65
598	3.40	4.66
599	3.41	4.66
600	3.42	4.67
601	3.42	4.69
602	3.42	4.70
603	3.43	4.70
604	3.43	4.70
605	3.44	4.71
606	3.44	4.71
607	3.44	4.71
608	3.44	4.71
609	3.44	4.72
610	3.44	4.72
611	3.44	4.73
612	3.44	4.73
613	3.46	4.74
614	3.46	4.75
615	3.46	4.75
616	3.46	4.75
617	3.47	4.76
618	3.47	4.77
619	3.47	4.77
620	3.48	4.77
621	3.48	4.77
622	3.48	4.77
623	3.48	4.78
624	3.49	4.78
625	3.49	4.78
626	3.49	4.78
627	3.49	4.79
628	3.49	4.80
629	3.49	4.80
630	3.50	4.80
631	3.50	4.80
632	3.50	4.81
633	3.50	4.81
634	3.51	4.81
635	3.52	4.81
636	3.52	4.81
637	3.52	4.81
638	3.52	4.81
639	3.54	4.82
640	3.54	4.82
641	3.55	4.82
642	3.55	4.82
643	3.55	4.83
644	3.55	4.84
645	3.55	4.84
646	3.56	4.85
647	3.57	4.85
648	3.57	4.85
649	3.58	4.85
650	3.58	4.85
651	3.60	4.86
652	3.61	4.86
653	3.61	4.86
654	3.61	4.88
655	3.62	4.89
656	3.62	4.89
657	3.64	4.90
658	3.64	4.90
659	3.64	4.92
660	3.64	4.92
661	3.65	4.92
662	3.66	4.93
663	3.66	4.93
664	3.66	4.94
665	3.67	4.95
666	3.67	4.96
667	3.67	4.96
668	3.68	4.96
669	3.68	4.97
670	3.69	4.97
671	3.70	4.98
672	3.71	4.98
673	3.71	5.00
674	3.72	5.01
675	3.72	5.01
676	3.74	5.01
677	3.74	5.02
678	3.75	5.04
679	3.78	5.05
680	3.78	5.05
681	3.78	5.06
682	3.78	5.07
683	3.78	5.07

Table B2: cont.

684	3.79	5.07
685	3.79	5.07
686	3.84	5.08
687	3.84	5.09
688	3.85	5.09
689	3.86	5.09
690	3.87	5.10
691	3.88	5.11
692	3.89	5.11
693	3.89	5.13
694	3.91	5.13
695	3.91	5.14
696	3.92	5.14
697	3.94	5.14
698	3.94	5.15
699	3.95	5.15
700	3.96	5.17
701	3.97	5.18
702	3.99	5.20
703	3.99	5.22
704	3.99	5.24
705	4.01	5.26
706	4.01	5.27
707	4.02	5.28
708	4.02	5.30
709	4.04	5.30
710	4.07	5.31
711	4.07	5.32
712	4.08	5.33
713	4.08	5.33
714	4.09	5.34
715	4.09	5.34
716	4.10	5.35
717	4.16	5.40
718	4.16	5.40
719	4.16	5.40
720	4.17	5.43
721	4.17	5.44
722	4.18	5.44
723	4.18	5.44
724	4.21	5.51
725	4.23	5.52
726	4.23	5.52
727	4.23	5.57
728	4.24	5.61
729	4.28	5.61
730	4.31	5.62
731	4.32	5.63
732	4.33	5.64
733	4.35	5.66
734	4.35	5.68
735	4.40	5.71
736	4.40	5.72
737	4.43	5.74
738	4.48	5.86
739	4.51	5.86
740	4.52	5.88
741	4.55	5.89
742	4.58	6.14
743	4.58	6.15
744	4.58	6.16
745	4.59	6.19
746	4.66	6.25
747	4.67	6.25
748	4.69	6.38
749	4.82	6.40
750	4.84	6.46
751	4.89	6.53
752	4.89	6.88
753	4.91	
754	4.93	
755	4.94	
756	4.97	
757	4.97	
758	5.13	
759	5.37	

Table B3: Summary of the equivalent bubble size distribution data for NBSK at an air flow rate of 2.0 slpm.

	Northern Bleached Softwood Kraft X-rays					
	Gasket			Sparger		
Consistency	0.50%	1.00%	1.50%	0.50%	1.00%	1.50%
Average Equivalent Bubble Diameter (mm)	6.48	10.10	7.48	3.53	4.16	6.26
Median Equivalent Bubble Diameter (mm)	4.02	11.40	4.94	2.75	2.83	2.95
Minimum Equivalent Bubble Diameter (mm)	1.22	1.46	1.54	1.05	1.00	1.03
Maximum Equivalent Bubble Diameter (mm)	22.31	15.68	18.62	32.70	43.71	42.48
Standard Deviation (mm)	5.18	3.93	4.66	3.65	5.82	9.29
Variance (mm^2)	26.82	15.44	21.71	13.30	33.86	86.39
Bubble Population Size	211	52	118	320	203	168
Equivalent Sauter Mean Diameter (mm)	13.86	12.26	12.23	17.73	27.60	32.45
Bubble Size Range (mm)	Frequency					
$0 < R_B \leq 1$	0	0	0	0	0	0
$1 < R_B \leq 2$	16	2	4	62	50	39
$2 < R_B \leq 3$	44	2	17	127	63	50
$3 < R_B \leq 4$	45	4	20	63	46	22
$4 < R_B \leq 5$	26	3	20	43	15	18
$5 < R_B \leq 6$	12	0	1	10	13	5
$6 < R_B \leq 7$	5	0	0	6	4	6
$7 < R_B \leq 8$	3	1	5	0	1	4
$8 < R_B \leq 9$	5	3	2	1	0	3
$9 < R_B \leq 10$	2	1	4	0	0	3
$10 < R_B \leq 11$	7	6	10	0	2	0
$11 < R_B \leq 12$	5	7	9	0	1	0
$12 < R_B \leq 13$	4	13	9	0	0	1
$13 < R_B \leq 14$	6	6	3	0	0	0
$14 < R_B \leq 15$	5	1	7	0	0	0
$15 < R_B \leq 16$	7	3	4	0	0	0
$16 < R_B \leq 17$	5	0	2	0	0	1
$17 < R_B \leq 18$	8	0	0	0	0	0
$18 < R_B \leq 19$	2	0	1	1	0	0
$19 < R_B \leq 20$	3	0	0	1	0	1
$20 < R_B \leq 21$	0	0	0	1	1	0
$21 < R_B \leq 22$	0	0	0	1	0	0
$22 < R_B \leq 23$	1	0	0	0	1	2
$23 < R_B \leq 24$	0	0	0	0	0	0
$24 < R_B \leq 25$	0	0	0	0	0	1
$R_B > 25$	0	0	0	4	6	12

Table B4: Equivalent bubble diameter data sorted by size for NBSK at an air flow rate of 2.0 slpm.

	Northern Bleached Softwood Kraft X-rays					
	Gasket			Sparger		
Consistency	0.50%	1.00%	1.50%	0.50%	1.00%	1.50%
Bubble Count	Equivalent Diameter (mm)					
1	1.22	1.46	1.54	1.05	1.00	1.03
2	1.26	1.93	1.65	1.08	1.04	1.09
3	1.36	2.27	1.69	1.10	1.08	1.14
4	1.45	2.97	1.69	1.21	1.11	1.15
5	1.55	3.56	2.13	1.33	1.15	1.18
6	1.56	3.57	2.13	1.34	1.16	1.18
7	1.62	3.58	2.29	1.34	1.21	1.20
8	1.65	3.90	2.46	1.34	1.25	1.25
9	1.67	4.17	2.48	1.37	1.26	1.26
10	1.68	4.39	2.53	1.47	1.29	1.26
11	1.78	4.69	2.56	1.47	1.30	1.27
12	1.82	7.85	2.65	1.51	1.30	1.36
13	1.84	8.18	2.66	1.52	1.32	1.50
14	1.90	8.41	2.69	1.53	1.33	1.52
15	1.93	8.85	2.74	1.54	1.34	1.56
16	1.97	9.74	2.74	1.55	1.37	1.59
17	2.03	10.11	2.81	1.55	1.41	1.60
18	2.03	10.15	2.82	1.56	1.44	1.63
19	2.04	10.24	2.82	1.56	1.46	1.64
20	2.05	10.41	2.94	1.56	1.46	1.67
21	2.08	10.72	3.00	1.56	1.52	1.67
22	2.10	10.76	3.10	1.59	1.54	1.70
23	2.12	11.03	3.16	1.60	1.56	1.70
24	2.13	11.12	3.17	1.60	1.60	1.74
25	2.15	11.29	3.23	1.62	1.62	1.79
26	2.17	11.39	3.28	1.66	1.64	1.80
27	2.18	11.41	3.31	1.67	1.67	1.81
28	2.19	11.80	3.31	1.71	1.68	1.81
29	2.22	11.91	3.34	1.71	1.69	1.82
30	2.23	12.02	3.38	1.73	1.69	1.83
31	2.25	12.16	3.39	1.78	1.71	1.84
32	2.35	12.18	3.45	1.79	1.72	1.86
33	2.37	12.18	3.45	1.79	1.74	1.86
34	2.39	12.39	3.51	1.79	1.74	1.87
35	2.41	12.50	3.53	1.79	1.76	1.90
36	2.42	12.55	3.53	1.82	1.76	1.92
37	2.44	12.55	3.61	1.82	1.77	1.93
38	2.46	12.60	3.66	1.85	1.79	1.93
39	2.48	12.70	3.67	1.85	1.79	1.95
40	2.55	12.79	3.68	1.87	1.80	2.01
41	2.55	12.82	3.95	1.87	1.80	2.04
42	2.56	12.85	4.03	1.89	1.83	2.06
43	2.58	13.01	4.04	1.90	1.83	2.07
44	2.59	13.08	4.07	1.90	1.91	2.09
45	2.60	13.30	4.12	1.90	1.92	2.10
46	2.61	13.41	4.13	1.90	1.94	2.11
47	2.61	13.57	4.19	1.91	1.95	2.14
48	2.62	13.67	4.36	1.92	1.95	2.17
49	2.69	14.87	4.36	1.92	1.96	2.18
50	2.71	15.12	4.40	1.92	1.98	2.19
51	2.74	15.21	4.48	1.92	2.01	2.20
52	2.76	15.68	4.59	1.92	2.01	2.21
53	2.81		4.62	1.92	2.08	2.26
54	2.82		4.63	1.97	2.09	2.28
55	2.87		4.69	1.97	2.10	2.31
56	2.89		4.71	1.97	2.14	2.39
57	2.89		4.79	1.97	2.15	2.40
58	2.91		4.84	1.97	2.15	2.40
59	2.95		4.93	1.97	2.16	2.41
60	2.98		4.95	1.99	2.17	2.45
61	3.03		4.97	1.99	2.17	2.46
62	3.04		5.25	2.00	2.18	2.48

Table B4: cont.

63	3.07		7.04	2.00	2.21	2.53
64	3.09		7.10	2.00	2.22	2.54
65	3.09		7.21	2.02	2.25	2.55
66	3.11		7.24	2.03	2.29	2.59
67	3.13		7.77	2.03	2.30	2.59
68	3.16		8.22	2.03	2.30	2.60
69	3.17		8.45	2.03	2.30	2.60
70	3.17		9.19	2.04	2.38	2.60
71	3.24		9.46	2.05	2.39	2.62
72	3.27		9.80	2.05	2.39	2.69
73	3.27		9.97	2.06	2.39	2.70
74	3.28		10.10	2.06	2.41	2.71
75	3.29		10.11	2.06	2.42	2.73
76	3.30		10.23	2.07	2.43	2.74
77	3.32		10.24	2.07	2.43	2.79
78	3.35		10.31	2.09	2.45	2.81
79	3.36		10.46	2.09	2.46	2.82
80	3.39		10.56	2.10	2.47	2.82
81	3.42		10.58	2.12	2.47	2.85
82	3.43		10.82	2.13	2.48	2.88
83	3.44		10.96	2.13	2.48	2.89
84	3.49		11.12	2.14	2.51	2.94
85	3.51		11.15	2.15	2.55	2.95
86	3.54		11.17	2.18	2.56	2.95
87	3.55		11.33	2.18	2.57	2.95
88	3.57		11.36	2.18	2.58	2.97
89	3.64		11.48	2.19	2.58	2.98
90	3.65		11.62	2.20	2.58	3.04
91	3.69		11.86	2.21	2.60	3.08
92	3.71		11.89	2.22	2.63	3.09
93	3.74		12.11	2.24	2.63	3.10
94	3.75		12.15	2.24	2.64	3.13
95	3.75		12.18	2.25	2.65	3.14
96	3.78		12.55	2.26	2.66	3.23
97	3.80		12.56	2.27	2.75	3.28
98	3.85		12.71	2.27	2.77	3.29
99	3.86		12.82	2.28	2.82	3.29
100	3.88		12.83	2.29	2.82	3.32
101	3.92		12.99	2.31	2.82	3.34
102	3.92		13.33	2.31	2.83	3.41
103	3.94		13.63	2.33	2.84	3.42
104	3.98		13.93	2.35	2.86	3.43
105	3.99		14.15	2.35	2.88	3.54
106	4.02		14.30	2.36	2.89	3.58
107	4.04		14.35	2.37	2.90	3.59
108	4.10		14.52	2.37	2.91	3.59
109	4.11		14.63	2.38	2.91	3.75
110	4.11		14.66	2.38	2.96	3.76
111	4.20		14.66	2.38	2.98	3.86
112	4.29		15.22	2.38	2.98	4.07
113	4.34		15.36	2.39	2.98	4.18
114	4.34		15.92	2.41	3.01	4.19
115	4.38		15.97	2.41	3.05	4.31
116	4.40		16.05	2.42	3.05	4.35
117	4.44		16.77	2.44	3.06	4.37
118	4.51		18.62	2.44	3.06	4.38
119	4.52			2.45	3.07	4.40
120	4.54			2.45	3.12	4.45
121	4.57			2.48	3.12	4.47
122	4.59			2.48	3.13	4.56
123	4.61			2.50	3.13	4.65
124	4.62			2.51	3.15	4.70
125	4.62			2.51	3.16	4.72
126	4.67			2.52	3.19	4.81
127	4.71			2.52	3.22	4.94
128	4.77			2.53	3.25	4.96
129	4.81			2.53	3.26	4.99
130	4.96			2.53	3.28	5.26
131	4.99			2.54	3.28	5.32

Table B4: cont.

132	5.16			2.54	3.28	5.37
133	5.30			2.54	3.33	5.44
134	5.32			2.55	3.35	5.98
135	5.36			2.56	3.37	6.12
136	5.38			2.58	3.40	6.33
137	5.40			2.58	3.47	6.38
138	5.65			2.59	3.48	6.42
139	5.80			2.59	3.49	6.50
140	5.83			2.59	3.51	6.74
141	5.95			2.60	3.61	7.08
142	5.97			2.62	3.62	7.28
143	5.98			2.62	3.63	7.29
144	6.05			2.62	3.64	7.40
145	6.29			2.62	3.65	8.03
146	6.70			2.63	3.67	8.72
147	6.78			2.64	3.67	8.83
148	6.94			2.64	3.67	9.04
149	7.68			2.65	3.68	9.28
150	7.79			2.65	3.69	9.91
151	7.87			2.67	3.72	12.05
152	8.03			2.67	3.78	16.20
153	8.19			2.67	3.80	19.15
154	8.22			2.68	3.83	22.23
155	8.39			2.68	3.87	22.99
156	8.97			2.70	3.87	24.69
157	9.04			2.73	3.87	28.15
158	9.37			2.74	3.90	33.43
159	10.10			2.74	3.98	33.94
160	10.34			2.75	4.19	35.54
161	10.38			2.75	4.19	36.28
162	10.51			2.76	4.22	36.78
163	10.53			2.77	4.27	37.33
164	10.65			2.78	4.29	38.19
165	10.98			2.79	4.31	38.58
166	11.03			2.80	4.37	40.46
167	11.06			2.81	4.48	41.11
168	11.07			2.82	4.53	42.48
169	11.18			2.84	4.56	
170	11.24			2.85	4.61	
171	12.38			2.85	4.75	
172	12.52			2.86	4.76	
173	12.83			2.87	4.86	
174	12.86			2.87	4.91	
175	13.01			2.88	5.01	
176	13.11			2.89	5.08	
177	13.16			2.89	5.15	
178	13.39			2.89	5.19	
179	13.46			2.91	5.31	
180	13.47			2.94	5.55	
181	14.09			2.97	5.56	
182	14.20			2.97	5.56	
183	14.33			2.97	5.64	
184	14.52			2.98	5.66	
185	14.81			2.98	5.68	
186	15.03			2.99	5.82	
187	15.05			2.99	5.99	
188	15.05			2.99	6.20	
189	15.17			3.00	6.32	
190	15.38			3.00	6.57	
191	15.67			3.02	6.80	
192	15.86			3.06	7.76	
193	16.24			3.07	10.21	
194	16.33			3.08	10.27	
195	16.51			3.09	11.52	
196	16.69			3.11	20.59	
197	16.86			3.12	22.03	
198	17.22			3.13	27.14	
199	17.23			3.16	30.29	
200	17.27			3.16	30.36	

Table B4: cont.

201	17.31			3.18	34.49	
202	17.32			3.18	37.86	
203	17.33			3.24	43.71	
204	17.33			3.24		
205	17.49			3.25		
206	18.20			3.25		
207	18.25			3.26		
208	19.20			3.30		
209	19.41			3.30		
210	19.64			3.31		
211	22.31			3.31		
212				3.32		
213				3.33		
214				3.36		
215				3.37		
216				3.37		
217				3.42		
218				3.42		
219				3.43		
220				3.45		
221				3.47		
222				3.48		
223				3.49		
224				3.51		
225				3.51		
226				3.52		
227				3.55		
228				3.60		
229				3.61		
230				3.61		
231				3.65		
232				3.66		
233				3.66		
234				3.71		
235				3.72		
236				3.72		
237				3.82		
238				3.83		
239				3.84		
240				3.85		
241				3.86		
242				3.86		
243				3.87		
244				3.87		
245				3.87		
246				3.89		
247				3.91		
248				3.93		
249				3.94		
250				3.95		
251				3.97		
252				3.99		
253				4.01		
254				4.01		
255				4.01		
256				4.04		
257				4.05		
258				4.06		
259				4.11		
260				4.15		
261				4.20		
262				4.25		
263				4.26		
264				4.31		
265				4.32		
266				4.34		
267				4.36		
268				4.38		
269				4.39		

Table B4: cont.

270				4.39		
271				4.40		
272				4.41		
273				4.42		
274				4.42		
275				4.44		
276				4.50		
277				4.52		
278				4.54		
279				4.55		
280				4.55		
281				4.58		
282				4.59		
283				4.60		
284				4.61		
285				4.61		
286				4.64		
287				4.67		
288				4.72		
289				4.75		
290				4.84		
291				4.86		
292				4.94		
293				4.94		
294				4.99		
295				4.99		
296				5.02		
297				5.03		
298				5.05		
299				5.27		
300				5.34		
301				5.41		
302				5.49		
303				5.61		
304				5.83		
305				5.94		
306				6.23		
307				6.23		
308				6.29		
309				6.45		
310				6.58		
311				6.62		
312				8.54		
313				18.61		
314				19.80		
315				20.11		
316				21.37		
317				25.82		
318				26.42		
319				31.26		
320				32.70		

Table B5: Summary of the equivalent bubble size distribution data for an air/water, ONP, and copy paper system at an air flow rate of 2.0 slpm.

	Flow Rate @ 2.0 slpm Summary Data					
	Gasket			Sparger		
Consistency	0%	1.0% ONP	1.0% Copy Paper	0%	1.0% ONP	1.0% Copy Paper
Average Equivalent Bubble Diameter (mm)	3.98	6.24	11.43	3.03	2.85	4.11
Median Equivalent Bubble Diameter (mm)	4.02	6.46	11.79	2.83	2.30	3.21
Minimum Equivalent Bubble Diameter (mm)	1.44	1.12	4.22	1.00	1.02	1.21
Maximum Equivalent Bubble Diameter (mm)	8.84	10.14	14.62	10.71	27.23	44.65
Standard Deviation (mm)	1.40	1.61	2.17	1.24	2.68	5.47
Variance (mm^2)	1.95	2.60	4.69	1.55	7.18	29.92
Bubble Population Size	342	196	52	1265	424	219
Equivalent Sauter Mean Diameter (mm)	4.90	6.96	12.11	4.13	13.40	30.06
Bubble Size Range (mm)	Frequency					
$0 < R_B \leq 1$	0	0	0	0	0	0
$1 < R_B \leq 1.5$	3	2	0	94	86	4
$1.5 < R_B \leq 2$	18	0	0	147	83	15
$2 < R_B \leq 2.5$	38	2	0	226	64	37
$2.5 < R_B \leq 3$	39	3	0	247	65	36
$3 < R_B \leq 3.5$	37	7	0	190	38	50
$3.5 < R_B \leq 4$	35	4	0	137	28	27
$4 < R_B \leq 4.5$	53	12	2	83	19	22
$4.5 < R_B \leq 5$	35	9	0	51	15	9
$5 < R_B \leq 5.5$	37	9	0	31	7	4
$5.5 < R_B \leq 6$	18	20	0	22	6	7
$6 < R_B \leq 6.5$	14	32	0	18	2	1
$6.5 < R_B \leq 7$	11	31	0	9	1	0
$7 < R_B \leq 7.5$	2	30	0	4	2	0
$7.5 < R_B \leq 8$	0	16	0	3	1	0
$8 < R_B \leq 8.5$	1	7	2	0	0	0
$8.5 < R_B \leq 9$	1	5	1	0	1	0
$9 < R_B \leq 9.5$	0	2	4	1	1	0
$9.5 < R_B \leq 10$	0	2	2	0	0	0
$R_B > 10$	0	2	41	2	5	7

Table B6: Equivalent bubble diameter data sorted by size for an air/water, ONP, and copy paper system at an air flow rate of 2.0 slpm.

	Flow Rate @ 2.0 slpm Summary Data					
	Gasket			Sparger		
Consistency	0%	1.0% ONP	1.0% Copy Paper	0%	1.0% ONP	1.0% Copy Paper
Bubble Count	Equivalent Bubble Diameter (mm)					
1	1.44	1.12	4.22	1.00	1.02	1.21
2	1.46	1.35	4.26	1.01	1.02	1.30
3	1.48	1.73	8.28	1.01	1.02	1.43
4	1.53	2.37	8.41	1.01	1.03	1.45
5	1.58	2.48	8.96	1.02	1.03	1.56
6	1.58	2.68	9.05	1.03	1.04	1.57
7	1.59	2.79	9.13	1.05	1.06	1.57
8	1.60	2.87	9.30	1.07	1.06	1.58
9	1.69	3.02	9.39	1.07	1.06	1.68
10	1.74	3.08	9.78	1.09	1.07	1.74
11	1.77	3.13	9.87	1.09	1.08	1.81
12	1.79	3.24	10.35	1.10	1.09	1.84
13	1.81	3.39	10.56	1.11	1.09	1.84
14	1.81	3.45	10.61	1.12	1.10	1.88
15	1.83	3.45	10.82	1.12	1.11	1.89
16	1.87	3.52	10.91	1.12	1.12	1.89
17	1.93	3.57	10.98	1.12	1.12	1.95
18	1.95	3.70	10.98	1.13	1.12	1.95
19	1.96	3.71	11.11	1.14	1.14	1.95
20	1.98	4.05	11.19	1.14	1.14	2.04
21	2.00	4.05	11.22	1.14	1.14	2.05
22	2.01	4.12	11.45	1.14	1.15	2.05
23	2.01	4.22	11.63	1.16	1.15	2.07
24	2.03	4.27	11.64	1.18	1.15	2.10
25	2.04	4.29	11.67	1.19	1.16	2.11
26	2.04	4.31	11.71	1.19	1.16	2.12
27	2.06	4.36	11.87	1.20	1.16	2.12
28	2.06	4.40	11.92	1.21	1.17	2.15
29	2.07	4.44	11.92	1.21	1.17	2.19
30	2.11	4.45	11.97	1.21	1.17	2.20
31	2.12	4.47	11.97	1.21	1.17	2.21
32	2.14	4.62	12.00	1.21	1.18	2.22
33	2.14	4.69	12.12	1.22	1.18	2.23
34	2.14	4.71	12.13	1.22	1.19	2.24
35	2.15	4.75	12.13	1.22	1.19	2.25
36	2.15	4.76	12.40	1.22	1.19	2.27
37	2.17	4.80	12.41	1.23	1.19	2.27
38	2.20	4.81	12.63	1.23	1.20	2.29
39	2.22	4.88	12.81	1.23	1.20	2.33
40	2.23	4.96	12.91	1.23	1.21	2.35
41	2.25	5.07	13.11	1.24	1.21	2.35
42	2.26	5.09	13.25	1.24	1.23	2.38
43	2.29	5.16	13.32	1.25	1.24	2.38
44	2.30	5.17	13.73	1.25	1.25	2.39
45	2.31	5.30	13.75	1.26	1.26	2.39
46	2.32	5.33	13.82	1.26	1.26	2.40
47	2.33	5.33	13.84	1.26	1.27	2.41
48	2.37	5.36	13.87	1.27	1.27	2.43
49	2.37	5.38	13.97	1.28	1.28	2.43
50	2.40	5.52	14.28	1.29	1.28	2.44
51	2.40	5.54	14.38	1.29	1.29	2.44
52	2.40	5.60	14.62	1.29	1.29	2.44
53	2.41	5.65		1.29	1.30	2.47
54	2.42	5.70		1.30	1.31	2.48
55	2.46	5.71		1.30	1.32	2.48
56	2.46	5.76		1.31	1.33	2.49
57	2.47	5.79		1.32	1.33	2.50
58	2.48	5.85		1.33	1.33	2.51
59	2.49	5.85		1.33	1.33	2.52
60	2.50	5.87		1.34	1.33	2.53
61	2.52	5.89		1.34	1.34	2.53
62	2.52	5.93		1.35	1.35	2.53
63	2.53	5.98		1.36	1.35	2.54
64	2.53	5.98		1.37	1.35	2.54

Table B6: cont.

65	2.53	5.98		1.38	1.36	2.56
66	2.53	5.98		1.38	1.38	2.60
67	2.53	5.98		1.39	1.38	2.60
68	2.55	5.99		1.40	1.38	2.60
69	2.57	5.99		1.40	1.38	2.60
70	2.60	6.04		1.40	1.38	2.61
71	2.62	6.06		1.41	1.38	2.61
72	2.65	6.09		1.41	1.40	2.63
73	2.65	6.10		1.42	1.41	2.65
74	2.67	6.10		1.42	1.42	2.67
75	2.68	6.13		1.42	1.42	2.67
76	2.68	6.18		1.42	1.42	2.68
77	2.70	6.20		1.44	1.44	2.71
78	2.76	6.22		1.45	1.45	2.71
79	2.76	6.24		1.46	1.47	2.72
80	2.76	6.24		1.46	1.47	2.72
81	2.77	6.26		1.46	1.47	2.73
82	2.78	6.27		1.47	1.47	2.73
83	2.79	6.27		1.47	1.47	2.80
84	2.79	6.27		1.48	1.48	2.81
85	2.80	6.28		1.48	1.49	2.83
86	2.83	6.30		1.48	1.50	2.87
87	2.83	6.33		1.48	1.51	2.90
88	2.84	6.33		1.48	1.51	2.92
89	2.86	6.33		1.49	1.52	2.92
90	2.86	6.33		1.49	1.53	2.98
91	2.87	6.35		1.49	1.53	2.98
92	2.89	6.36		1.49	1.54	2.98
93	2.89	6.37		1.49	1.54	3.01
94	2.95	6.38		1.50	1.55	3.02
95	2.96	6.38		1.50	1.56	3.03
96	2.99	6.39		1.51	1.56	3.03
97	2.99	6.42		1.52	1.57	3.04
98	3.00	6.46		1.52	1.58	3.06
99	3.02	6.46		1.53	1.58	3.09
100	3.02	6.49		1.53	1.58	3.09
101	3.05	6.50		1.54	1.59	3.11
102	3.09	6.53		1.55	1.59	3.12
103	3.10	6.57		1.55	1.60	3.12
104	3.10	6.59		1.56	1.61	3.14
105	3.11	6.62		1.56	1.63	3.15
106	3.13	6.65		1.57	1.64	3.17
107	3.15	6.68		1.57	1.65	3.18
108	3.17	6.68		1.57	1.65	3.18
109	3.19	6.69		1.57	1.66	3.18
110	3.19	6.70		1.59	1.66	3.21
111	3.21	6.71		1.59	1.66	3.22
112	3.21	6.71		1.60	1.68	3.24
113	3.22	6.71		1.60	1.68	3.25
114	3.23	6.73		1.61	1.68	3.26
115	3.23	6.74		1.62	1.69	3.27
116	3.25	6.78		1.62	1.69	3.29
117	3.25	6.78		1.62	1.69	3.29
118	3.25	6.79		1.63	1.69	3.30
119	3.26	6.80		1.64	1.69	3.31
120	3.27	6.82		1.64	1.70	3.32
121	3.27	6.83		1.65	1.71	3.32
122	3.29	6.85		1.65	1.73	3.34
123	3.29	6.87		1.65	1.73	3.34
124	3.30	6.88		1.65	1.73	3.36
125	3.35	6.88		1.65	1.75	3.36
126	3.35	6.89		1.66	1.75	3.38
127	3.36	6.89		1.66	1.76	3.38
128	3.36	6.90		1.66	1.77	3.39
129	3.38	6.90		1.67	1.77	3.40
130	3.40	6.91		1.67	1.77	3.41
131	3.41	6.95		1.67	1.77	3.42
132	3.47	6.99		1.67	1.78	3.42
133	3.48	7.01		1.68	1.79	3.43

Table B6: cont.

134	3.49	7.03		1.68	1.80	3.44
135	3.50	7.03		1.68	1.80	3.45
136	3.52	7.04		1.68	1.80	3.45
137	3.53	7.08		1.69	1.81	3.46
138	3.56	7.09		1.69	1.82	3.47
139	3.56	7.14		1.70	1.82	3.48
140	3.56	7.17		1.71	1.82	3.49
141	3.56	7.17		1.72	1.82	3.50
142	3.59	7.18		1.72	1.83	3.50
143	3.61	7.19		1.72	1.84	3.51
144	3.63	7.23		1.73	1.85	3.54
145	3.66	7.24		1.73	1.86	3.54
146	3.67	7.24		1.73	1.86	3.59
147	3.70	7.25		1.74	1.87	3.60
148	3.70	7.28		1.74	1.87	3.61
149	3.70	7.30		1.75	1.88	3.67
150	3.70	7.32		1.75	1.89	3.68
151	3.74	7.32		1.76	1.91	3.70
152	3.76	7.32		1.76	1.92	3.71
153	3.76	7.33		1.76	1.92	3.71
154	3.76	7.37		1.76	1.92	3.72
155	3.76	7.39		1.76	1.93	3.73
156	3.77	7.40		1.77	1.93	3.76
157	3.77	7.40		1.77	1.93	3.82
158	3.79	7.43		1.78	1.93	3.82
159	3.81	7.44		1.78	1.93	3.84
160	3.84	7.48		1.78	1.94	3.86
161	3.84	7.49		1.79	1.95	3.87
162	3.89	7.50		1.79	1.96	3.89
163	3.90	7.50		1.79	1.96	3.92
164	3.90	7.54		1.79	1.96	3.93
165	3.90	7.58		1.79	1.97	3.94
166	3.92	7.63		1.80	1.97	3.95
167	3.95	7.64		1.80	1.97	3.95
168	3.97	7.65		1.80	1.99	3.96
169	3.98	7.66		1.80	1.99	3.98
170	3.99	7.69		1.80	2.00	4.02
171	4.02	7.75		1.81	2.00	4.03
172	4.02	7.79		1.81	2.00	4.04
173	4.02	7.79		1.82	2.02	4.09
174	4.02	7.82		1.82	2.02	4.10
175	4.02	7.90		1.83	2.02	4.12
176	4.03	7.90		1.83	2.02	4.12
177	4.04	7.92		1.83	2.03	4.13
178	4.04	7.94		1.84	2.04	4.16
179	4.05	8.01		1.84	2.05	4.21
180	4.07	8.06		1.84	2.06	4.22
181	4.09	8.09		1.85	2.06	4.23
182	4.10	8.14		1.85	2.06	4.26
183	4.10	8.28		1.85	2.07	4.26
184	4.11	8.30		1.85	2.07	4.28
185	4.12	8.46		1.85	2.08	4.30
186	4.17	8.52		1.86	2.09	4.30
187	4.17	8.53		1.86	2.09	4.36
188	4.18	8.61		1.86	2.09	4.45
189	4.19	8.76		1.86	2.10	4.46
190	4.20	8.79		1.87	2.11	4.49
191	4.21	9.13		1.87	2.12	4.50
192	4.21	9.13		1.87	2.15	4.63
193	4.22	9.62		1.87	2.17	4.68
194	4.22	9.63		1.87	2.17	4.69
195	4.23	10.09		1.88	2.19	4.71
196	4.25	10.14		1.88	2.19	4.71
197	4.25			1.89	2.19	4.73
198	4.25			1.89	2.20	4.74
199	4.26			1.89	2.21	4.79
200	4.29			1.89	2.21	4.86
201	4.33			1.90	2.22	5.07
202	4.33			1.90	2.22	5.09

Table B6: cont.

203	4.34			1.91	2.23	5.17
204	4.34			1.91	2.23	5.24
205	4.34			1.91	2.26	5.51
206	4.39			1.91	2.27	5.53
207	4.39			1.91	2.27	5.57
208	4.39			1.92	2.28	5.59
209	4.40			1.93	2.28	5.68
210	4.40			1.93	2.28	5.73
211	4.42			1.93	2.29	5.88
212	4.43			1.93	2.30	6.31
213	4.43			1.93	2.31	10.13
214	4.44			1.94	2.33	18.06
215	4.44			1.94	2.33	30.38
216	4.45			1.95	2.34	35.19
217	4.46			1.95	2.34	39.90
218	4.46			1.95	2.35	40.65
219	4.47			1.95	2.38	44.65
220	4.48			1.95	2.38	
221	4.49			1.95	2.39	
222	4.49			1.96	2.40	
223	4.49			1.97	2.42	
224	4.51			1.97	2.42	
225	4.51			1.97	2.43	
226	4.51			1.97	2.44	
227	4.54			1.97	2.45	
228	4.57			1.97	2.46	
229	4.58			1.98	2.47	
230	4.62			1.98	2.47	
231	4.62			1.98	2.47	
232	4.65			1.98	2.49	
233	4.66			1.98	2.50	
234	4.67			1.98	2.51	
235	4.67			1.98	2.52	
236	4.68			1.98	2.53	
237	4.69			1.99	2.54	
238	4.71			1.99	2.54	
239	4.74			1.99	2.54	
240	4.74			1.99	2.54	
241	4.74			1.99	2.55	
242	4.76			2.01	2.56	
243	4.79			2.01	2.57	
244	4.80			2.01	2.57	
245	4.83			2.01	2.57	
246	4.83			2.02	2.59	
247	4.84			2.03	2.59	
248	4.86			2.03	2.59	
249	4.86			2.04	2.60	
250	4.87			2.04	2.60	
251	4.88			2.04	2.61	
252	4.90			2.04	2.62	
253	4.92			2.04	2.62	
254	4.92			2.04	2.62	
255	4.92			2.04	2.63	
256	4.95			2.04	2.64	
257	4.96			2.04	2.64	
258	4.96			2.05	2.64	
259	5.02			2.05	2.65	
260	5.03			2.05	2.65	
261	5.04			2.05	2.67	
262	5.05			2.06	2.69	
263	5.08			2.06	2.70	
264	5.10			2.06	2.70	
265	5.10			2.06	2.71	
266	5.12			2.06	2.71	
267	5.12			2.06	2.72	
268	5.12			2.06	2.75	
269	5.14			2.06	2.77	
270	5.14			2.07	2.77	
271	5.14			2.07	2.79	

Table B6: cont.

272	5.16			2.07	2.80	
273	5.19			2.07	2.82	
274	5.22			2.07	2.83	
275	5.23			2.08	2.83	
276	5.23			2.08	2.83	
277	5.29			2.08	2.84	
278	5.30			2.09	2.84	
279	5.30			2.09	2.87	
280	5.30			2.09	2.88	
281	5.31			2.10	2.88	
282	5.33			2.10	2.88	
283	5.34			2.10	2.90	
284	5.35			2.10	2.90	
285	5.35			2.10	2.90	
286	5.38			2.10	2.91	
287	5.39			2.10	2.91	
288	5.40			2.10	2.91	
289	5.42			2.11	2.93	
290	5.45			2.11	2.95	
291	5.45			2.11	2.96	
292	5.47			2.11	2.96	
293	5.48			2.12	2.96	
294	5.50			2.12	2.96	
295	5.50			2.13	2.97	
296	5.50			2.13	2.97	
297	5.57			2.14	2.98	
298	5.58			2.14	2.98	
299	5.59			2.14	3.00	
300	5.60			2.14	3.01	
301	5.62			2.14	3.07	
302	5.62			2.14	3.07	
303	5.64			2.14	3.08	
304	5.68			2.14	3.08	
305	5.69			2.14	3.09	
306	5.73			2.15	3.10	
307	5.74			2.15	3.13	
308	5.75			2.16	3.14	
309	5.75			2.16	3.15	
310	5.75			2.16	3.19	
311	5.83			2.17	3.21	
312	5.88			2.17	3.21	
313	5.93			2.17	3.21	
314	6.00			2.17	3.21	
315	6.01			2.17	3.22	
316	6.02			2.17	3.24	
317	6.06			2.18	3.26	
318	6.10			2.19	3.26	
319	6.15			2.19	3.26	
320	6.15			2.19	3.28	
321	6.19			2.19	3.29	
322	6.20			2.19	3.29	
323	6.20			2.19	3.30	
324	6.32			2.20	3.30	
325	6.39			2.20	3.32	
326	6.42			2.20	3.33	
327	6.48			2.20	3.34	
328	6.55			2.20	3.35	
329	6.55			2.21	3.40	
330	6.59			2.21	3.41	
331	6.61			2.21	3.41	
332	6.65			2.22	3.43	
333	6.74			2.22	3.44	
334	6.91			2.22	3.45	
335	6.95			2.23	3.47	
336	6.96			2.23	3.48	
337	6.96			2.23	3.51	
338	6.99			2.23	3.51	
339	7.11			2.23	3.52	
340	7.15			2.23	3.53	

Table B6: cont.

341	8.41			2.24	3.55	
342	8.84			2.24	3.55	
343				2.24	3.57	
344				2.24	3.58	
345				2.24	3.60	
346				2.24	3.61	
347				2.24	3.62	
348				2.24	3.68	
349				2.25	3.70	
350				2.25	3.74	
351				2.26	3.76	
352				2.26	3.78	
353				2.26	3.80	
354				2.26	3.85	
355				2.26	3.86	
356				2.27	3.87	
357				2.27	3.88	
358				2.27	3.88	
359				2.27	3.88	
360				2.27	3.92	
361				2.27	3.92	
362				2.27	3.94	
363				2.27	3.97	
364				2.27	3.99	
365				2.28	4.01	
366				2.28	4.15	
367				2.28	4.20	
368				2.28	4.23	
369				2.29	4.23	
370				2.29	4.28	
371				2.30	4.30	
372				2.30	4.34	
373				2.30	4.36	
374				2.31	4.38	
375				2.31	4.39	
376				2.32	4.40	
377				2.32	4.43	
378				2.32	4.45	
379				2.33	4.45	
380				2.33	4.45	
381				2.33	4.48	
382				2.33	4.48	
383				2.33	4.50	
384				2.33	4.52	
385				2.34	4.53	
386				2.34	4.53	
387				2.34	4.60	
388				2.34	4.64	
389				2.35	4.69	
390				2.35	4.70	
391				2.35	4.83	
392				2.35	4.84	
393				2.35	4.93	
394				2.35	4.93	
395				2.35	4.94	
396				2.35	4.96	
397				2.35	4.97	
398				2.35	4.99	
399				2.35	5.01	
400				2.35	5.21	
401				2.36	5.25	
402				2.36	5.38	
403				2.36	5.40	
404				2.36	5.43	
405				2.37	5.47	
406				2.37	5.51	
407				2.37	5.54	
408				2.37	5.57	
409				2.37	5.59	

Table B6: cont.

410				2.37	5.74	
411				2.38	5.77	
412				2.38	6.08	
413				2.38	6.37	
414				2.38	6.79	
415				2.38	7.04	
416				2.39	7.11	
417				2.39	7.89	
418				2.39	8.56	
419				2.39	9.00	
420				2.39	20.08	
421				2.39	23.71	
422				2.40	24.11	
423				2.40	25.67	
424				2.40	27.23	
425				2.40		
426				2.40		
427				2.40		
428				2.40		
429				2.41		
430				2.41		
431				2.41		
432				2.41		
433				2.42		
434				2.42		
435				2.42		
436				2.43		
437				2.43		
438				2.43		
439				2.43		
440				2.43		
441				2.43		
442				2.44		
443				2.44		
444				2.44		
445				2.45		
446				2.45		
447				2.45		
448				2.45		
449				2.46		
450				2.46		
451				2.46		
452				2.46		
453				2.47		
454				2.47		
455				2.47		
456				2.48		
457				2.48		
458				2.48		
459				2.48		
460				2.48		
461				2.48		
462				2.49		
463				2.49		
464				2.49		
465				2.49		
466				2.49		
467				2.50		
468				2.50		
469				2.50		
470				2.50		
471				2.51		
472				2.51		
473				2.51		
474				2.51		
475				2.51		
476				2.51		
477				2.52		
478				2.52		

Table B6: cont.

479				2.52		
480				2.52		
481				2.52		
482				2.53		
483				2.53		
484				2.53		
485				2.53		
486				2.53		
487				2.53		
488				2.53		
489				2.54		
490				2.55		
491				2.55		
492				2.55		
493				2.55		
494				2.55		
495				2.55		
496				2.55		
497				2.56		
498				2.56		
499				2.56		
500				2.57		
501				2.57		
502				2.57		
503				2.57		
504				2.57		
505				2.58		
506				2.58		
507				2.58		
508				2.58		
509				2.59		
510				2.59		
511				2.60		
512				2.60		
513				2.60		
514				2.60		
515				2.61		
516				2.61		
517				2.61		
518				2.61		
519				2.62		
520				2.62		
521				2.62		
522				2.62		
523				2.62		
524				2.62		
525				2.62		
526				2.62		
527				2.62		
528				2.63		
529				2.63		
530				2.63		
531				2.63		
532				2.63		
533				2.64		
534				2.64		
535				2.64		
536				2.65		
537				2.65		
538				2.65		
539				2.65		
540				2.65		
541				2.66		
542				2.66		
543				2.66		
544				2.66		
545				2.66		
546				2.67		
547				2.67		

Table B6: cont.

548				2.67		
549				2.67		
550				2.67		
551				2.67		
552				2.67		
553				2.67		
554				2.67		
555				2.67		
556				2.68		
557				2.68		
558				2.68		
559				2.68		
560				2.69		
561				2.69		
562				2.69		
563				2.69		
564				2.69		
565				2.70		
566				2.70		
567				2.70		
568				2.70		
569				2.70		
570				2.70		
571				2.71		
572				2.71		
573				2.71		
574				2.71		
575				2.71		
576				2.72		
577				2.72		
578				2.72		
579				2.72		
580				2.72		
581				2.72		
582				2.72		
583				2.72		
584				2.73		
585				2.73		
586				2.73		
587				2.74		
588				2.74		
589				2.74		
590				2.75		
591				2.75		
592				2.75		
593				2.76		
594				2.76		
595				2.76		
596				2.76		
597				2.76		
598				2.76		
599				2.77		
600				2.77		
601				2.77		
602				2.77		
603				2.77		
604				2.77		
605				2.77		
606				2.77		
607				2.78		
608				2.78		
609				2.78		
610				2.78		
611				2.78		
612				2.78		
613				2.79		
614				2.79		
615				2.79		
616				2.79		

Table B6: cont.

617				2.80		
618				2.80		
619				2.80		
620				2.80		
621				2.81		
622				2.81		
623				2.81		
624				2.81		
625				2.81		
626				2.81		
627				2.82		
628				2.82		
629				2.82		
630				2.82		
631				2.82		
632				2.82		
633				2.83		
634				2.83		
635				2.83		
636				2.83		
637				2.83		
638				2.83		
639				2.83		
640				2.83		
641				2.84		
642				2.85		
643				2.85		
644				2.85		
645				2.85		
646				2.85		
647				2.85		
648				2.85		
649				2.85		
650				2.85		
651				2.86		
652				2.86		
653				2.86		
654				2.86		
655				2.87		
656				2.87		
657				2.88		
658				2.88		
659				2.88		
660				2.88		
661				2.89		
662				2.89		
663				2.89		
664				2.89		
665				2.90		
666				2.90		
667				2.90		
668				2.90		
669				2.90		
670				2.91		
671				2.91		
672				2.91		
673				2.91		
674				2.91		
675				2.91		
676				2.91		
677				2.91		
678				2.92		
679				2.92		
680				2.92		
681				2.92		
682				2.92		
683				2.93		
684				2.93		
685				2.93		

Table B6: cont.

686				2.94		
687				2.94		
688				2.94		
689				2.94		
690				2.94		
691				2.94		
692				2.94		
693				2.95		
694				2.95		
695				2.96		
696				2.96		
697				2.96		
698				2.97		
699				2.97		
700				2.97		
701				2.97		
702				2.97		
703				2.98		
704				2.98		
705				2.98		
706				2.98		
707				2.98		
708				2.98		
709				2.98		
710				2.99		
711				2.99		
712				2.99		
713				3.00		
714				3.00		
715				3.00		
716				3.00		
717				3.00		
718				3.00		
719				3.01		
720				3.01		
721				3.02		
722				3.02		
723				3.03		
724				3.03		
725				3.03		
726				3.03		
727				3.03		
728				3.03		
729				3.04		
730				3.04		
731				3.04		
732				3.04		
733				3.05		
734				3.05		
735				3.06		
736				3.06		
737				3.06		
738				3.06		
739				3.06		
740				3.06		
741				3.06		
742				3.07		
743				3.07		
744				3.07		
745				3.07		
746				3.07		
747				3.07		
748				3.07		
749				3.08		
750				3.08		
751				3.08		
752				3.08		
753				3.09		
754				3.09		

Table B6: cont.

755				3.09		
756				3.10		
757				3.10		
758				3.10		
759				3.10		
760				3.11		
761				3.11		
762				3.11		
763				3.11		
764				3.12		
765				3.12		
766				3.12		
767				3.12		
768				3.12		
769				3.13		
770				3.13		
771				3.13		
772				3.14		
773				3.14		
774				3.15		
775				3.15		
776				3.16		
777				3.16		
778				3.16		
779				3.16		
780				3.16		
781				3.17		
782				3.17		
783				3.17		
784				3.17		
785				3.17		
786				3.17		
787				3.18		
788				3.18		
789				3.18		
790				3.18		
791				3.19		
792				3.19		
793				3.19		
794				3.20		
795				3.20		
796				3.21		
797				3.21		
798				3.21		
799				3.21		
800				3.21		
801				3.22		
802				3.22		
803				3.22		
804				3.22		
805				3.23		
806				3.23		
807				3.23		
808				3.24		
809				3.24		
810				3.24		
811				3.25		
812				3.25		
813				3.25		
814				3.25		
815				3.25		
816				3.26		
817				3.26		
818				3.26		
819				3.26		
820				3.26		
821				3.26		
822				3.27		
823				3.27		

Table B6: cont.

824				3.27		
825				3.28		
826				3.28		
827				3.28		
828				3.28		
829				3.28		
830				3.29		
831				3.29		
832				3.30		
833				3.30		
834				3.30		
835				3.30		
836				3.31		
837				3.31		
838				3.31		
839				3.31		
840				3.31		
841				3.32		
842				3.32		
843				3.32		
844				3.32		
845				3.32		
846				3.32		
847				3.32		
848				3.32		
849				3.33		
850				3.33		
851				3.34		
852				3.34		
853				3.34		
854				3.34		
855				3.34		
856				3.34		
857				3.35		
858				3.35		
859				3.35		
860				3.37		
861				3.38		
862				3.39		
863				3.39		
864				3.39		
865				3.39		
866				3.39		
867				3.39		
868				3.39		
869				3.39		
870				3.40		
871				3.40		
872				3.41		
873				3.41		
874				3.42		
875				3.42		
876				3.42		
877				3.42		
878				3.43		
879				3.43		
880				3.43		
881				3.43		
882				3.43		
883				3.44		
884				3.44		
885				3.44		
886				3.45		
887				3.45		
888				3.45		
889				3.45		
890				3.46		
891				3.47		
892				3.47		

Table B6: cont.

893				3.48		
894				3.48		
895				3.48		
896				3.48		
897				3.48		
898				3.48		
899				3.48		
900				3.49		
901				3.49		
902				3.49		
903				3.50		
904				3.50		
905				3.50		
906				3.50		
907				3.51		
908				3.52		
909				3.52		
910				3.53		
911				3.53		
912				3.53		
913				3.53		
914				3.53		
915				3.54		
916				3.54		
917				3.54		
918				3.55		
919				3.55		
920				3.56		
921				3.56		
922				3.56		
923				3.56		
924				3.57		
925				3.57		
926				3.57		
927				3.57		
928				3.57		
929				3.57		
930				3.58		
931				3.58		
932				3.58		
933				3.58		
934				3.58		
935				3.59		
936				3.59		
937				3.59		
938				3.60		
939				3.60		
940				3.60		
941				3.61		
942				3.61		
943				3.61		
944				3.62		
945				3.62		
946				3.62		
947				3.62		
948				3.63		
949				3.64		
950				3.64		
951				3.64		
952				3.66		
953				3.67		
954				3.67		
955				3.67		
956				3.67		
957				3.67		
958				3.68		
959				3.68		
960				3.69		
961				3.69		

Table B6: cont.

962				3.69			
963				3.70			
964				3.70			
965				3.70			
966				3.70			
967				3.71			
968				3.71			
969				3.71			
970				3.71			
971				3.71			
972				3.72			
973				3.73			
974				3.73			
975				3.73			
976				3.73			
977				3.73			
978				3.73			
979				3.74			
980				3.75			
981				3.75			
982				3.75			
983				3.75			
984				3.75			
985				3.75			
986				3.76			
987				3.76			
988				3.76			
989				3.76			
990				3.77			
991				3.77			
992				3.77			
993				3.77			
994				3.77			
995				3.77			
996				3.78			
997				3.79			
998				3.79			
999				3.80			
1000				3.80			
1001				3.81			
1002				3.81			
1003				3.82			
1004				3.82			
1005				3.83			
1006				3.83			
1007				3.84			
1008				3.84			
1009				3.84			
1010				3.84			
1011				3.85			
1012				3.85			
1013				3.85			
1014				3.85			
1015				3.85			
1016				3.85			
1017				3.86			
1018				3.86			
1019				3.86			
1020				3.87			
1021				3.88			
1022				3.88			
1023				3.90			
1024				3.91			
1025				3.91			
1026				3.91			
1027				3.91			
1028				3.92			
1029				3.92			
1030				3.92			

Table B6: cont.

1031				3.93		
1032				3.93		
1033				3.94		
1034				3.95		
1035				3.95		
1036				3.96		
1037				3.96		
1038				3.97		
1039				3.97		
1040				3.98		
1041				4.00		
1042				4.01		
1043				4.01		
1044				4.03		
1045				4.03		
1046				4.03		
1047				4.03		
1048				4.04		
1049				4.04		
1050				4.05		
1051				4.05		
1052				4.05		
1053				4.06		
1054				4.06		
1055				4.07		
1056				4.07		
1057				4.07		
1058				4.07		
1059				4.09		
1060				4.13		
1061				4.13		
1062				4.13		
1063				4.14		
1064				4.14		
1065				4.15		
1066				4.17		
1067				4.18		
1068				4.18		
1069				4.18		
1070				4.19		
1071				4.20		
1072				4.20		
1073				4.21		
1074				4.21		
1075				4.21		
1076				4.22		
1077				4.23		
1078				4.23		
1079				4.23		
1080				4.23		
1081				4.24		
1082				4.24		
1083				4.24		
1084				4.25		
1085				4.25		
1086				4.25		
1087				4.26		
1088				4.26		
1089				4.26		
1090				4.27		
1091				4.27		
1092				4.28		
1093				4.29		
1094				4.29		
1095				4.30		
1096				4.31		
1097				4.32		
1098				4.32		
1099				4.33		

Table B6: cont.

1100				4.34		
1101				4.34		
1102				4.35		
1103				4.36		
1104				4.36		
1105				4.36		
1106				4.36		
1107				4.37		
1108				4.37		
1109				4.37		
1110				4.38		
1111				4.39		
1112				4.40		
1113				4.40		
1114				4.42		
1115				4.42		
1116				4.42		
1117				4.42		
1118				4.44		
1119				4.45		
1120				4.46		
1121				4.48		
1122				4.49		
1123				4.50		
1124				4.50		
1125				4.52		
1126				4.53		
1127				4.53		
1128				4.56		
1129				4.60		
1130				4.60		
1131				4.61		
1132				4.61		
1133				4.63		
1134				4.65		
1135				4.65		
1136				4.66		
1137				4.66		
1138				4.66		
1139				4.66		
1140				4.67		
1141				4.68		
1142				4.68		
1143				4.68		
1144				4.69		
1145				4.70		
1146				4.71		
1147				4.71		
1148				4.72		
1149				4.72		
1150				4.76		
1151				4.77		
1152				4.78		
1153				4.79		
1154				4.79		
1155				4.80		
1156				4.81		
1157				4.82		
1158				4.82		
1159				4.83		
1160				4.85		
1161				4.86		
1162				4.87		
1163				4.87		
1164				4.87		
1165				4.88		
1166				4.89		
1167				4.91		
1168				4.92		

Table B6: cont.

1169				4.92		
1170				4.93		
1171				4.94		
1172				4.94		
1173				4.96		
1174				4.96		
1175				4.98		
1176				5.00		
1177				5.01		
1178				5.01		
1179				5.04		
1180				5.05		
1181				5.06		
1182				5.10		
1183				5.10		
1184				5.12		
1185				5.13		
1186				5.14		
1187				5.18		
1188				5.19		
1189				5.22		
1190				5.24		
1191				5.24		
1192				5.28		
1193				5.30		
1194				5.31		
1195				5.34		
1196				5.34		
1197				5.35		
1198				5.38		
1199				5.39		
1200				5.44		
1201				5.46		
1202				5.46		
1203				5.47		
1204				5.48		
1205				5.48		
1206				5.50		
1207				5.51		
1208				5.55		
1209				5.56		
1210				5.56		
1211				5.59		
1212				5.59		
1213				5.61		
1214				5.61		
1215				5.63		
1216				5.70		
1217				5.70		
1218				5.72		
1219				5.72		
1220				5.73		
1221				5.79		
1222				5.80		
1223				5.86		
1224				5.91		
1225				5.93		
1226				5.95		
1227				5.99		
1228				5.99		
1229				6.00		
1230				6.01		
1231				6.18		
1232				6.18		
1233				6.18		
1234				6.19		
1235				6.21		
1236				6.26		
1237				6.26		

Table B6: cont.

1238				6.27		
1239				6.29		
1240				6.30		
1241				6.31		
1242				6.37		
1243				6.41		
1244				6.43		
1245				6.46		
1246				6.46		
1247				6.53		
1248				6.53		
1249				6.56		
1250				6.61		
1251				6.67		
1252				6.70		
1253				6.79		
1254				6.82		
1255				6.92		
1256				7.03		
1257				7.25		
1258				7.33		
1259				7.39		
1260				7.69		
1261				7.75		
1262				7.96		
1263				9.22		
1264				10.38		
1265				10.71		