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# GRADUAL TRANSITION OF NUCLEATE BOILING FROM DISCRETE-BUBBLE REGIME TO MULTIBUBBLE REGIME

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## SUMMARY

A photographic study was made of over 5000 bubbles in the nucleate boiling of methanol and water on a narrow heating strip at various heat fluxes and degrees of subcooling. The results showed that transition from the discrete-bubble regime to the multibubble regime was gradual. The fraction of heating area covered by multibubbles increases with increasing heat flux and is predictable. The area fraction is a Poisson function of the product of the mean area of influence of single bubbles and the instantaneous population density.

## INTRODUCTION

Because nucleate boiling is recognized as a very effective means of heat transfer, a tremendous amount of effort has been directed toward the understanding of this interesting phenomenon. Among such efforts, a good part has been devoted to the study of bubbles. To facilitate observation, studies usually were made on discrete bubbles. Thus, the formulation of theories on nucleate boiling was on the basis of the information derived from discrete bubbles (refs. 1 to 3). These theories were generally applied to the entire regime of nucleate boiling. Recently, however, it has been becoming more and more clear that there actually exist several subdivisions in nuclear boiling, namely, a discrete bubble regime, a merging bubble regime, and perhaps a vapor-patch regime (refs. 4 to 7). It is evident that theories should be developed to deal with each region individually, as well as to predict the transition from one region to another.

It is the purpose of this report to study the transition of the discrete-bubble regime to the merging-bubble regime. In reference 8, an abrupt transition point was proposed, while in reality the transition is gradual and continuous. This report will show how the area covered by merging bubbles gradually increases with increasing heat flux and that the area fractions for merging bubbles can be related with other parameters such as bubble size and instantaneous bubble population. The hope is that, if the area fractions covered by the merging bubbles and the discrete bubbles at a given condition are known, the overall heat-transfer coefficient can be synthesized by weighing the contributions due to the two bubbling mechanisms according to their respective area fractions.

The experimental phase of this work consisted of a photographic study of nucleate boiling of methanol and water on a 1/16- by 3/4-inch heating strip under 1 atmosphere pressure. The resulting data were then analyzed by assuming a Poisson distribution of bubbles.

## SYMBOLS

| | |
|---|---|
| $A$ | area |
| $a$ | empirical area parameter used in equation (1) |
| $a,b$ | empirical parameters used for bubble growth rate $R = at^b$ |
| $D$ | bubble diameter |
| $f$ | bubble generating frequency |
| $\mathcal{F}$ | bubble fraction |
| $g$ | gravitational acceleration |
| $h$ | total number of all single bubbles studied in one roll of film |
| $K$ | thermal conductivity |
| $k$ | number of sample frames |
| $L$ | length of heating strip |
| $M$ | average number of sites per cell |
| $N$ | site population |
| $n$ | instantaneous bubble population |
| $P$ | probability according to Poisson function |
| $q$ | heat flux |
| $R$ | bubble radius |
| $\dot{R}$ | bubble growth rate, dR/dt |
| $s$ | standard deviation associated with average area fraction of merging bubbles |
| $\Delta T_{sub}$ | subcooling temperature difference between saturation and bulk temperatures |

| | |
|---|---|
| $\Delta T_w$ | temperature difference between surface and bulk |
| $t$ | time |
| $t_g$ | bubble growth period |
| $t_w$ | waiting period |
| $W$ | half-width of heating strip |
| $X$ | number of bubble sites per cell |
| $x$ | number of bubbles in a cell |
| $\beta$ | contact angle, radians |
| $\gamma$ | surface tension |
| $\delta$ | thermal layer thickness |
| $\lambda$ | latent heat of vaporization |
| $\mu$ | average number of bubbles per cell |
| $\rho$ | density |
| $\sigma$ | theoretical standard deviation |
| $\varphi$ | area fraction |

Subscripts:

| | |
|---|---|
| av | average |
| B | bubble |
| b | bubble base |
| calc | calculated |
| d | departure |
| exp | experimental |
| F | Fritz equation of bubble departure, equation (9) |
| $l$ | liquid |
| m | merging bubbles or multibubbles |
| s | single bubble |

sub subcooling

t total

v vapor

Superscript:

$\overline{\phantom{x}}$ average

## LITERATURE SURVEY

As mentioned in the INTRODUCTION, bubble interference has been reported previously. The earliest mention of it was probably that found in reference 9. More recent experimental findings have been reported since then. In general, the bubble interference can be classified as one of two types, vertical interference and lateral interference. The vertical interference occurs between consecutive bubbles emitted from the same nucleation site in rapid succession. This type of bubble interference is called chain-bubble interference in reference 9. It is also reported in references 6, 8, 10, and 11. This type of bubble coalescence was the model utilized in reference 8 to derive the criterion for the transition from the discrete-bubble regime to the merging-bubble regime. Deissler used a similar model for an analysis of burnout heat flux (ref. 12). The lateral type of bubble coalescence (or mushroom bubbles according to ref. 4) is the interference between the neighboring bubbles due to close proximity. As observed in references 3, 4, and 13, a growing bubble, while still attached to the heating surface, merges with a neighboring bubble. This merging can be caused either by contact of two growing bubbles or by the up draft of a departing bubble. The area of influence of each bubble is roughly 2 bubble radii away from the nucleation center (refs. 3 to 5). In either case, the lateral-merging bubbles can be pictured as mushrooms with two or more stems. These stems are the places where vaporization occurs. This type of coalescence has been included in the boiling models postulated in references 3 to 5. As will be shown in the section RESULTS AND DISCUSSION, mushroom bubbles are far more frequently observed than chain bubbles. Therefore, the mushroom bubbles will be the ones discussed in this report.

Since the lateral coalescence is due to the interference of neighbors, the distribution of bubbles should be known. In the work of reference 14, it was found from the distribution of the sites on a boiling surface that the site population was distributed according to Poisson's equation

$$P_M(X) = \frac{e^{-M}(M)^X}{X!} \tag{1}$$

where $M = \overline{N}a/A$ and $X = Na/A$, but no attempt was made to predict the population distribution a priori; instead, the cell area $a$ was used strictly as an empirical parameter to fit the data with Poisson curves.

## APPARATUS AND PROCEDURE

The test was carried on inside a 6-inch-diameter by 4-inch-high cylindrical tank made of stainless steel and provided with viewing windows. The tank had provisions for a fill, a drain, a pressure gage, electrical connections, thermocouple leads, and auxiliary heaters. The heater was a thin, electrically conductive, transparent coating 1/16-inch wide, and 1-inch long deposited on a 1- by 1- by 1/8-inch heat-resisting glass plate. The plate was mounted horizontally on a small bench with a mirror situated beneath the plate and inclined 45°. Thus, the camera aiming from a front window saw simultaneously a front view and a bottom view (through the mirror) of the image of any bubble generated on the heating surface. The plate was clamped down with two copper clamps, which also served as electrical leads. The actual heating area was 1/16 by 3/4 inch, since the two end areas were covered by the copper clamps (fig. 1).

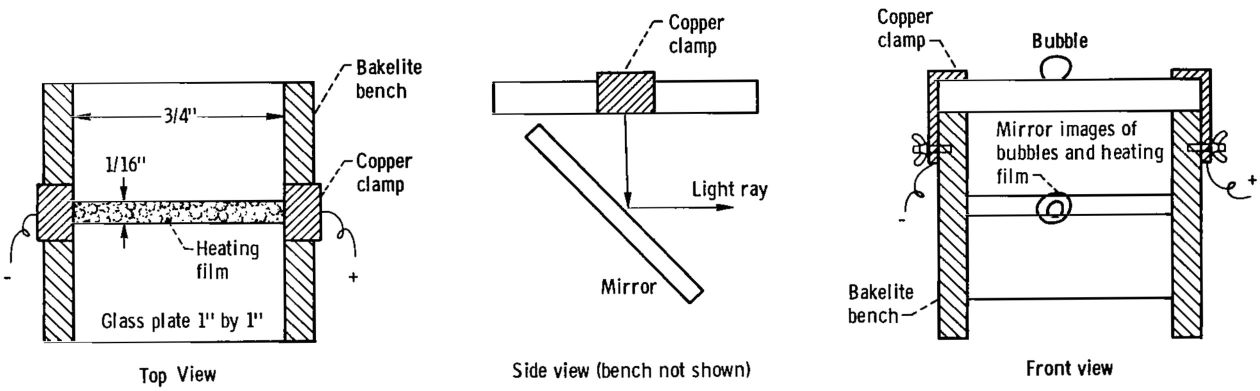


Figure 1. - Setup of heating element.

The 1/16-inch-wide strip was used instead of a wider heating area to ensure that no more than two rows of bubbles were generated. This arrangement was necessary to avoid confusion in the front view due to the presence of overlapping rows of bubbles. Originally, an alternating-current source was used, but because of the low heat capacity of the heating film, there were 120 cps temperature fluctuations on the heating surface. At lower heat flux, when bubble frequencies were low, this 120 cps fluctuation apparently did not have a serious effect. As the heat flux was increased and bubble frequency fell in the vicinity of 120 cps, however, the alternating-current fluctuation began to dictate the bubble frequency, and the bubbles began to grow in unison. Thus, only those runs where there was no apparent synchronization between bubbles and current waves were retained. Later, a direct-current source was used. Because of the high voltage applied to the electrodes (60 to 120 v), electrolysis would take place if water were used. Thus, only methanol was used for direct-current runs. At the beginning of a series of runs, the tank was loaded with a fresh batch of pure methanol or distilled water. The liquid was preheated to a desired temperature by the auxiliary heater. The bulk temperature was constantly monitored through thermocouple readings, and the temperature level was controlled by turning the auxiliary heaters on and off. The auxiliary heaters were always off while actual test runs were being carried out. The test heater would be turned on and set at a desired heat flux by varying the applied voltage, and then high-speed motion pictures (up to 5000 frames/sec) were taken.

The simultaneous viewing of bubble activities from front and bottom (mirror image) was deemed necessary to get the true picture of bubble interaction. Because of the difference in optical distance of the two views, however, it was extremely difficult to keep both views in sharp focus. Thus, the optical qualities of pictures were somewhat sacrificed. Because of such difficulties, studies were limited to those runs with a moderate amount of merging to maintain the accuracy of reading. The high-speed motion pictures were analyzed on a motion-picture analyzer. A total of 14 rolls were examined. For each roll, 50 to 100 frames were studied. The sample frames were selected by arbitrarily stopping the film 50 to 100 times at irregular intervals.

For each frame, information about each bubble present on the entire 3/4- by 1/16-inch heating surface was recorded. The raw data include

(1) The location and size of each bubble. The size or diameter of a bubble is defined as the width of a bubble at its widest part. In a few instances, a mushroom bubble could be a very wide hovering bubble overcasting a large area. In such cases, the bubble size is defined as the width of the bubble stem below the height of an average single bubble (see fig. 2).

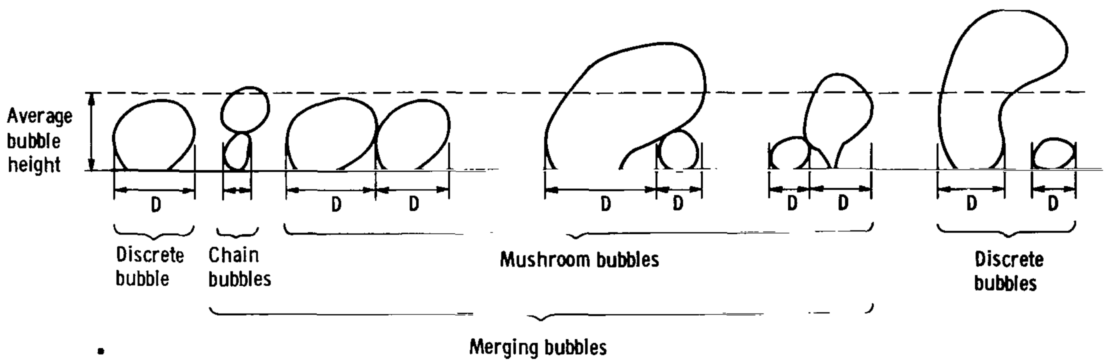


Figure 2. - Various configurations of bubbles.

(2) The classification of bubbles, namely, whether the bubble was a single bubble, or was merging with other bubbles. The criterion for the merging bubbles was the physical contact of two or more bubbles while at least one bubble was still attached to the heating surface.

(3) The number of active bubbles involved in a merging bubble.

(4) The total number of active bubbles $n$ on that frame.

From the aforementioned raw data, calculations were made, and the following information was obtained:

(1) The average size of all the single bubbles recorded in the sample frames was determined. This average was expressed in terms of the area fraction of influence of single bubbles, averaged as a function of the total area or $\varphi_s$. The area of influence of the bubble $\varphi_s$ was computed by the equations

$$\varphi_s = \frac{\pi D_s^2}{A_t} \qquad \text{for} \quad D_s < W \tag{2a}$$

and

$$\varphi_s = \frac{2\left[W\sqrt{D_s^2 - W^2} + D_s^2 \sin^{-1} \frac{W}{D_s}\right]}{A_t} \qquad \text{for} \quad D_s > W \tag{2b}$$

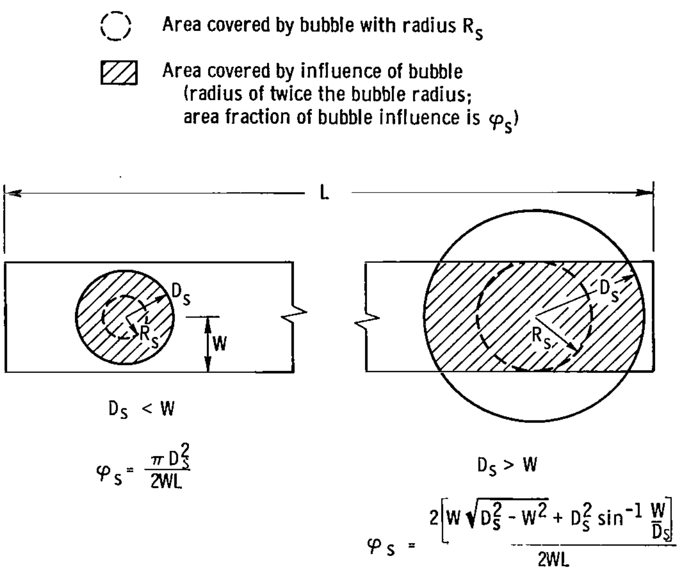


Figure 3. - Calculation of area fraction of heating strip covered by influence of bubble.

The shaded area in figure 3 are the areas of influence of single bubbles. Note that equation (2b) represents the area of a part of a circle with two segments cut off. The mean area fraction averaged over all the single bubbles is

$$\varphi_{s,av} = \frac{\sum_{i=1}^{h} \varphi_{s,i}}{h} \tag{2c}$$

where $h$ is the total number of single bubbles studied in the roll.

(2) The average size of the area covered by a merging bubble in a frame was expressed as the area fraction $\varphi_m$, and was calculated by summing all the area fractions covered by each merging bubble in the same frame. The area fraction of each merging bubble was also computed from equations (2a) and (2b), except that $D_m/2$ was used instead of $D_s$. The average area fraction of merging bubbles was computed over all the frames, or

$$\varphi_{m,av} = \frac{\sum_{i=1}^{k} \varphi_{m,i}}{k}$$

where $k$ is the number of sample frames and $\varphi_{m,i}$ is the sum of all the area fractions of merging bubbles in the frame $i$. Also computed for each roll of film was the standard deviation $s$ associated with the $\varphi_{m,av}$

$$s = \sqrt{\frac{\sum_{i=1}^{k} (\varphi_{m,av} - \varphi_{m,i})^2}{k}}$$

(3) The average instantaneous bubble population density $n_{av}$ was taken for the total number of sample frames $k$.

The total number of active sites $N$ seen in a given roll of film was also studied. The movie was projected on a paper and all the sites where bubbles had ever been generated were marked down. The range of conditions and the data are given in table I.

## RESULTS AND DISCUSSION

### General Description of Photographic Observation

Before the quantitative study of bubble interferences is discussed, the following qualitative descriptions should be given:

(1) The merging of bubbles was predominately due to lateral coalescence. The merging took place when one growing bubble got into the area of influence of a neighboring bubble. A detailed listing of bubble classification and raw data is contained in table II.

(2) The number of merging bubbles and the area covered by these merging bubbles increased with increases in both bubble size and instantaneous bubble population. With pressure and degrees of subcooling held constant, both the bubble size and the instantaneous bubble population increased with heat flux. Thus, increasing the heat flux means increasing the area of merging bubbles.

(3) The location of merging bubbles appeared to be random. For a given location, at one moment there could be no bubbles, one bubble, several discrete bubbles, or merging bubbles; however, the probability of having merging bubbles increased with increasing heat flux.

### Analysis

Based on the general qualitative description of bubble interference observed photographically, a model will be postulated to account quantitatively for the area fraction covered by the merging bubbles. The analysis will be carried out in two steps: The first step will be to seek the relation between the area of a merging bubble and quantities such as the mean area of influence of a bubble and the instantaneous bubble population, provided the latter two are given. The second step will be to estimate the area of influence and the instantaneous bubble population from the more basic information such as heat flux, subcooling, and total bubble population (or site population). The purpose is to estimate the area of merging bubbles from the aforementioned basic information.

Basic model. - The basic model for bubble interference is described in the following manner:

(1) Each bubble has an area of influence, which is the area within 1 bubble diameter of the nucleation center. This assumption is based on the observations made in reference 3.

(2) Since each bubble grows, the area of influence is based on the time-mean bubble size. This mean area of influence of a single bubble is considered as a cell. The heating surface is divided into such cells.

(3) Two bubbles will merge if one is located within the area of influence of the other.

(4) The bubbles are assumed to have a Poisson distribution.[1] This distribution is assumed to apply not only to site population as found in reference 14, but also to the instantaneous bubble population. Note that, at any moment, only part of the sites are actively occupied by bubbles, while the rest are in the waiting period.

Poisson distribution. - The following equation is used to express the previously postulated model in mathematical form:

$$P_\mu(x) = \frac{e^{-\mu}\mu^x}{x!} \tag{3}$$

where $P_\mu(x)$ is the percentage of cells each of which has $x$ bubbles in it and the cell is defined as the mean area of influence of a single bubble. The average number of bubbles per cell is

$$\mu = \frac{n_{av}}{\dfrac{A_t}{A_s}} = \frac{n_{av}}{A_t} A_s = n_{av}\varphi_s \tag{4}$$

where $A_s$ is the mean area of influence of a single bubble or the area of a cell, $n_{av}$ is the average instantaneous bubble population on a total heating area $A_t$, and $\varphi_s$ is the area fraction $A_s/A_t$. Note that equations (1) and (3) are similar in form except that the site population $N$ is used in equation (1), while the instantaneous bubble population $n$ is used in equa-

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[1]The assumption of Poisson distribution for the spatial distribution of bubbles makes possible the calculation of the area fraction for merging bubbles. If one is interested in the fraction of bubble population that is merging, however, an analysis of the clustering of bubbles can be found in appendix A.

tion (3) and that in equation (3) the cell area is defined as the area of influence of a bubble.

Since it is assumed that bubbles will merge when two or more bubbles are present in one cell, the percentage of cells that contain merging bubbles is

$$P_\mu(x > 2) = \sum_{x=2}^{\infty} P_\mu(x) \tag{5a}$$

or

$$P_\mu(x > 2) = 1 - P_\mu(0) - P_\mu(1) = 1 - e^{-n_{av}\varphi_s}(1 + n_{av}\varphi_s) \tag{5b}$$

Since $P_\mu(x > 2)$ is by definition the percentage of cells covered by two or more bubbles or merging bubbles, it is the area fraction covered by merging bubbles

$$\varphi_m = P_\mu(x > 2) = 1 - e^{-n_{av}\varphi_s}(1 + n_{av}\varphi_s) \tag{6}$$

This equation will give the area fraction of merging bubbles if the mean instantaneous bubble population $n_{av}$ and mean area of influence of a single bubble are known. These two terms can either be obtained experimentally or analytically. The next two sections constitute the second step of analysis, namely, determination of $n_{av}$ and $A_s$ analytically.

<u>Mean area of influence of a single bubble</u>. - According to the assumed basic model, the mean area of influence is the area within 1 bubble diameter of the nucleation center, and the bubble diameter is the time average of a growing bubble

$$D_{av} = \frac{1}{t_g}\int_0^{t_g} D(t)dt \tag{7a}$$

or

$$R_{av} = \frac{1}{t_g}\int_0^{t_g} R(t)dt \tag{7b}$$

The term bubble radius $R(t)$ can be obtained through bubble growth information. Although many theoretical equations are available, it is more convenient to use the empirical expression $R = at^b$, where $b = 0.4$ (ref. 15). Since the process of computing the time-average radius $R_{av}$ involves integration of $R(t)$, small deviations in $R(t)$ usually will be evened out. Thus

$$R_{av} = \frac{a}{t_g} \int_0^{t_g} t^b dt = \frac{a t_g^b}{b + 1} = \frac{R_d}{1 + b} = \frac{R_d}{1.4} \qquad \text{for} \quad b = 0.4 \tag{7c}$$

As to the departure radius $R_d$, Staniszewski's empirical expression will be used

$$R_d = R_F(1 + 10.44\ \dot{R}_d) \tag{8}$$

where $\dot{R}_d$ is in feet per second, and $R_d$ and $R_F$ are in feet; $R_F$ is the departure radius according to Fritz' equation

$$R_F = 0.4215\ \beta \sqrt{\frac{2\gamma}{g(\rho_l - \rho_v)}} \tag{9}$$

in which $\beta$ is the contact angle in radians.

Unfortunately the growth rate at departure $\dot{R}_d$ involved in equation (8) can no longer be calculated from the expression $R = at^b$, partly because the exponent $b$ actually varies with time and partly because the coefficient $a$ should be a function of an experimental condition such as heat flux, subcooling, pressure, or cavity size. Thus, an expression for the growth rate $\dot{R}$ as a function of the test condition should be used.

Although many bubble growth equations are available, only a few consider the effect of the bulk turbulence by including terms that describe the thermal layer or the heat dissipation to the bulk. Among such equations are those proposed in references 3, 16, and 17. The equation in reference 16 would be quite convenient to use if both $\Delta T_w$ and $q_w$ were known. Unfortunately, the growth expressions in references 3 and 17 are rather clumsy to use. If only the bubble growth rate at departure is of interest, however, the situation is somewhat simpler because of the fact that in the later stage of bubble growth the sensible heat stored in the superheated layer enveloping the bubble should have already been exhausted. Therefore, the bubble is losing heat to the surrounding bulk and receiving heat from the bubble base. (This heat may be in the form of evaporation of microlayer, as shown in ref. 18.) The bubble growth rate at departure can be easily derived, by following the procedure in reference 3, as

$$\dot{R} = \frac{1}{\lambda\rho_v}\left(\frac{A_b}{A_B}\, q - \frac{K\ \Delta T_{sub}}{\delta}\right) \tag{10}$$

where $A_b/A_B \simeq 0.25$ if the bubble at departure can be assumed to be a truncated sphere with a contact angle between $45^\circ$ to $60^\circ$ (cf., ref. 3) and $\delta$ is the thermal-layer thickness. The information about thermal layer thickness of a boiling fluid is very meager, but there are a few measurements (refs. 6 and 19). Therefore, if the thermal layer thickness $\delta$ is known, by using equations (8) to (10), the bubble departure size can be determined.

Instantaneous bubble population. - The instantaneous bubble population should be differentiated from the commonly used term "bubble population." The latter is actually a misnomer. When the bubble columns during the boiling or the number of aureoles left on a plate after boiling are counted, only the population of the bubble nucleation sites is determined, not the bubble population at any moment. The relation between site population $N$ and the instantaneous bubble population $n$ can be likened to that between the number of houses in a block and the number of families at home at a given moment. It is easy to see that these two populations can be related by the equation

$$n_{av} = \frac{t_{g,av}}{t_{g,av} + t_{w,av}} N = t_{g,av} f_{av} N \tag{11}$$

The variation of $N$ as function of $q$ has been reported in many places, and, unfortunately, the result varies widely. The difficulty stems from the diversity of surface condition and hysteresis (refs. 2, 6, and 20). Unless some characteristic parameter other than root-mean-square roughness of a surface can be found to account for cavity size distribution, it is futile to try to correlate $N$ against $q$; however, the site population $N$ is still a quantity much easier to determine experimentally than the instantaneous bubble population $n$. Thus, it is still worthwhile to obtain $n$ through $N$.

The mean frequency $f_{av}$ can easily be determined through the expression in reference 16

$$fD = 0.59 \left[ \frac{(\rho_l - \rho_v) g \gamma}{\rho_l^2} \right]^{1/4} \tag{12}$$

which yields

$$f_{av} = \frac{0.59}{D_{d,av}} \left[ \frac{(\rho_l - \rho_v) g \gamma}{\rho_l} \right]^{1/4} \tag{13}$$

The time of growth period $t_g$ can readily be calculated through

$$R_d = \int_0^{t_g} \dot{R}\, dt \tag{14}$$

provided $\dot{R}(t)$ and $R_d$ are known. As mentioned before, an empirical expression can be used, namely,

$$R_d = at^b \tag{15}$$

$$\dot{R}_d = abt_g^{b-1} \tag{16}$$

$$\frac{R_d}{\dot{R}_d} = \frac{t_g}{b}$$

or

$$t_g = \frac{bR_d}{\dot{R}_d} \tag{17}$$

Thus from equations (8), (10), and (17) the growth period $t_g$ can be calculated. Strictly speaking, equation (10) can be used to replace equation (16), only when the empirical form (eq. (16)) is identical to the analytical form (eq. (10)); however, an underestimated growth rate $\dot{R}$ tends to give an overestimated growth period $t_g$ and an underestimated departure diameter $D_d$. The result is that the two errors tend to compensate each other in the product of mean bubble population and mean area of influence

$$n_{av}A_s = t_g \frac{(fD)_d}{D_d} \pi D_d^2 \tag{18}$$

Calculation of area fraction covered by influence of a single bubble (calculation of $\varphi_{s,av,calc}$ from $D_{av,calc}$). - The mean influence area fraction covered by a single bubble can be computed from the time-averaged diameter of a bubble $D_{av}$ by using equations (2a) and (2b), except that $D_{av}$ will be used in the place of D. The $\varphi_s$ thus computed will be $\varphi_{s,av,calc}$. Strictly speaking, $\varphi_{s,av,calc}$ should be an average of $\varphi_{s,calc}$ which, in turn, should be computed from $D(t)$ as shown in equation (2c). Since only an estimation was intended, $\varphi_{s,av,calc}$ can be directly computed from $D_{av,calc}$.

## Comparison of Experimental Data with Analysis

The quantitative result will be compared with the model derived in the section Analysis in two steps also. The first step will be to check whether the area fraction of merging bubbles $\varphi_m$ based on the Poisson distribution (eq. (6)) can be used to relate $\varphi_m$ with the experimental values of the mean area of influence of a single bubble $\varphi_{s,exp}$ and the mean instantaneous bubble population $n_{av,exp}$. The second step will be to test whether equations (8) and (11) can be used to predict $\varphi_{s,exp}$ and $n_{av,exp}$, respectively, and whether the calculated product $(\varphi_s n_{av})_{calc}$ can be used to predict the merging bubble area fraction $\varphi_{m,exp}$.

Relation between area fraction of merging bubbles $\varphi_m$ against product of measured values of mean area of influence of single bubble and mean instantaneous bubble population $(n_{av}\varphi_s)_{exp}$. - To test equation (6), $\varphi_{m,av,exp}$ was

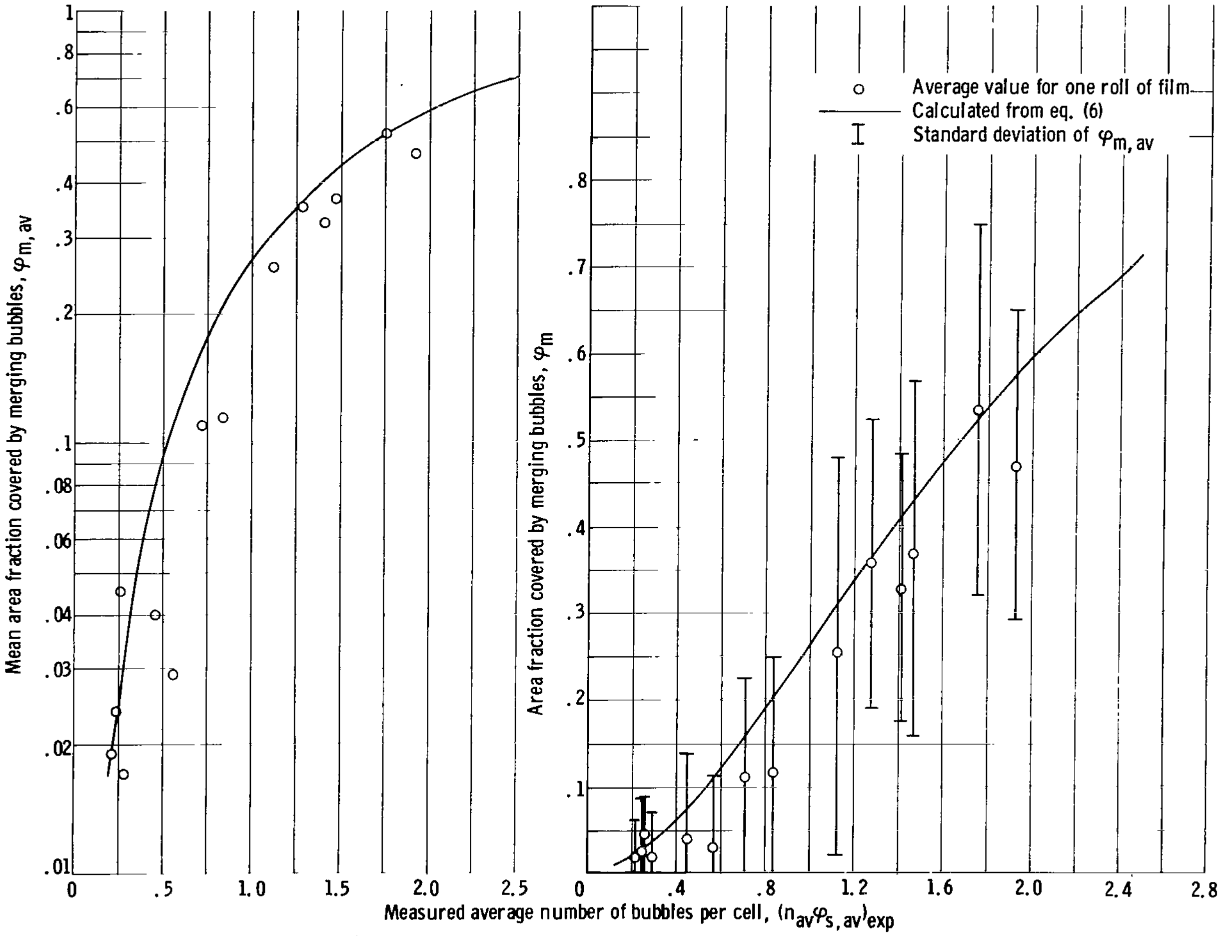


Figure 4. - Area fraction of merging bubbles as function of measured average number of bubbles per cell.

plotted against $(n_{av}\varphi_{s,av})_{exp}$ (fig. 4(a)). The solid curve represents equation (6). Each circle represents the mean values obtained from one roll of film. Figure 4(b) shows a similar plot on rectangular coordinates to show the standard deviations associated with each average area fraction of merging bubbles for the samples studied. (The experimental values of standard deviation are compared with the theoretically expected values in appendix B.) Judging from the figures, the model is fairly close. Thus, if the mean bubble population $n_{av}$ and the mean area of influence of single bubbles $\varphi_s$ are given, the area covered by merging bubbles can be calculated. The values of $n_{av}$ and $\varphi_{s,av}$ can either be obtained experimentally in the same way that figure 4 was constructed, or they can be estimated from test conditions through bubble departure size, bubble growth rate, and frequency by using the available equations.

Comparison of calculated and measured bubble departure diameters $D_{d,cal}$ and $D_{d,exp}$. - To estimate $\varphi_{s,av}$, it is necessary to know the departure diameter $D_d$. Equations (8) and (9) were used to compute $D_d$ with departure growth rate $\dot{R}_d$ computed from equation (10). The thermal layer thickness $\delta$ used in equation (10) was determined from the experimental measurement of reference 10 by matching the heat-transfer coefficient for the case of water ($\delta \approx 10^{-3}$ ft). For the case of methanol, the thermal layer thickness was assumed to be $2\times10^{-3}$ feet. The calculated values of $D_d$ are then compared with the experimental ones derived through equation (7a). The comparison is shown in figure 5. It can be seen that most points are within a ±20 percent error limit, which is about the same as the 25 percent error limit of equation (8).

Comparison of calculated and measured mean instantaneous bubble population $n_{av,calc}$ and $n_{av,exp}$. - To test equation (11), the mean instantaneous bubble population $n_{av}$ was calculated from the experimentally determined site population N together with the calculated frequency $f_{av}$ and growth period $t_{g,av}$. The bubble frequency $f_{av}$ was calculated from equation (13) by using the calculated departure diameter $D_{d,cal}$. The growth period $t_{g,av}$ was calculated from equation (17) by using $\dot{D}_{d,calc}$ and $R_{d,calc}$ (from eq. (10)). The comparison with $n_{av,exp}$ is shown in figure 6. The ±60 percent error limits are also shown in the figure, which are the error limits associated with equation (12).

Comparison of measured merging bubble area fraction $\varphi_{m,exp}$ with that obtained from the calculated average instantaneous bubbles per cell $(n_{av}\varphi_s)_{calc}$. - By using equations (2a) and (2b), $\varphi_{s,av}$ was computed from $D_{av,calc}$. In figure 7, the product $(\varphi_{s,av}n_{av})_{calc}$ was plotted with the average area fraction of merging bubbles $\varphi_{m,av}$. Also shown in figure 7 is the theoretical curve from equation (6). Although there is scattering, the result is still

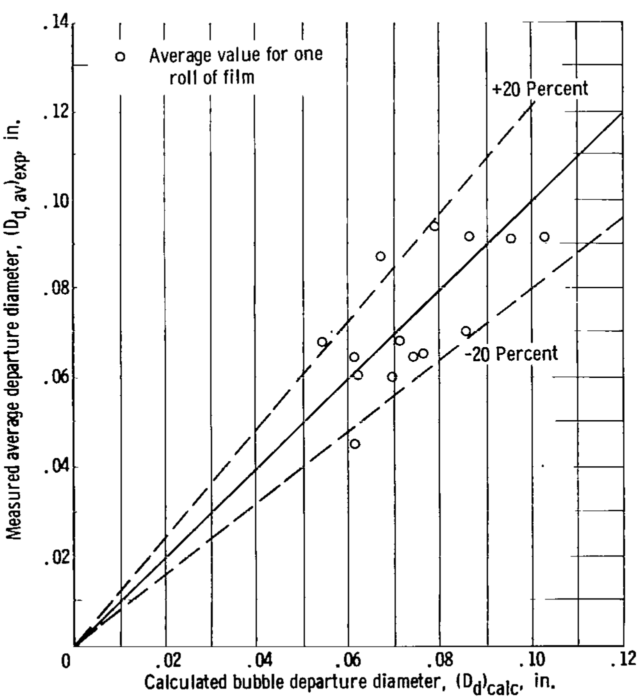


Figure 5. - Comparison of calculated and measured bubble departure diameters.

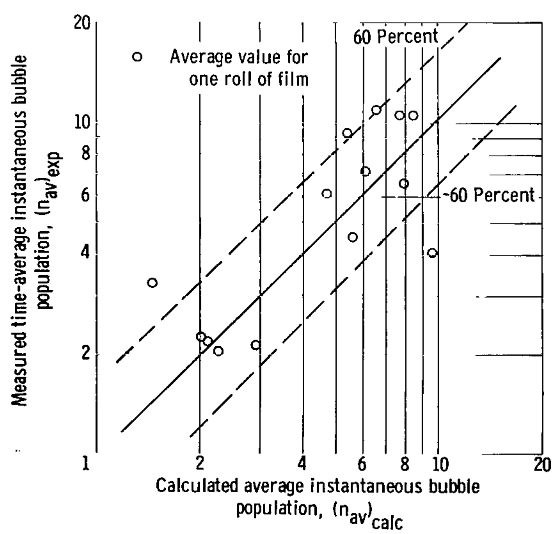


Figure 6. - Comparison of calculated and experimental values of average instantaneous bubble population.

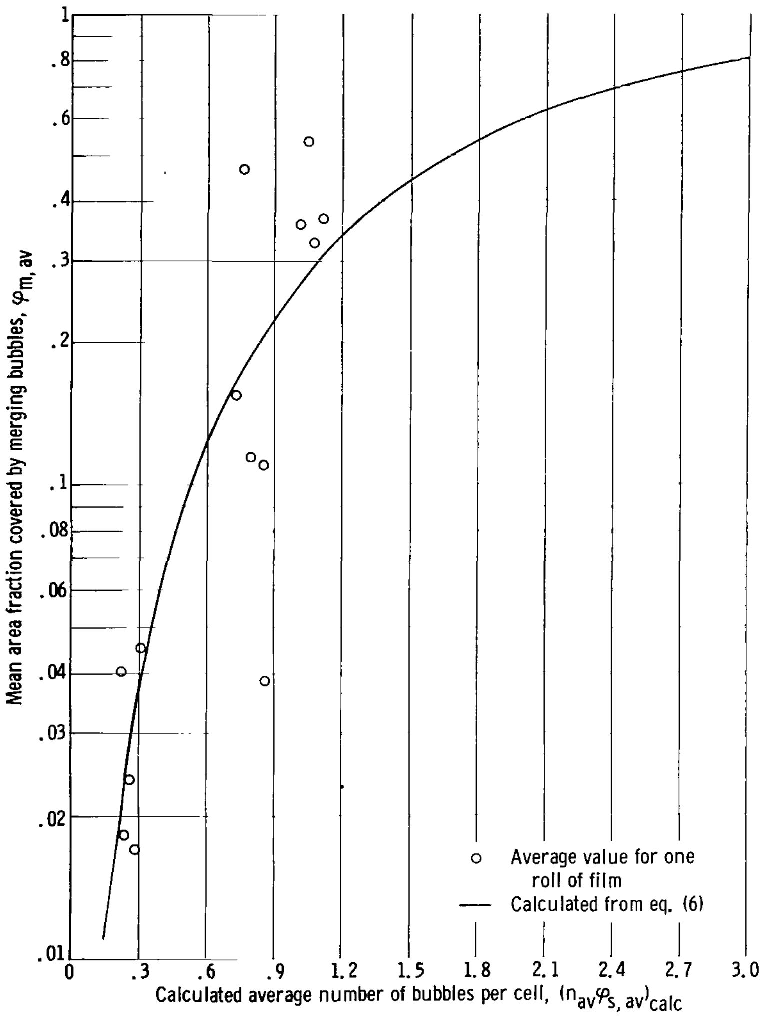


Figure 7. - Area fraction of merging bubbles as a function of calculated average number of bubbles per cell.

quite gratifying considering all the crude assumptions being made and the large error limits associated with the empiricism of equations (8) and (12). Thus, it is shown that an estimate of the area covered by merging bubbles can be based on the test conditions (heat flux, pressure, subcooling, etc.) provided that the site population is known.

## CONCLUDING REMARKS

In the nucleate-boiling regime, if both discrete bubbles and merging bubbles are present, the overall heat-transfer coefficient will have to be determined by considering the contribution due to both bubbling mechanisms. Even if the heat-transfer process of each mechanism were known, a weighting factor would be needed to determine the relative contribution of each mechanism.

One possible weighting factor would be the area fractions of merging bubbles and discrete bubbles. Based on the result obtained from the boiling of methanol and water on a narrow heating strip, it is found that the transition from the discrete-bubble regime to the merging-bubble regime is gradual. Furthermore, the results showed that the area fraction of merging bubbles can be predicted satisfactorily from the Poisson distribution if the average number of bubbles per cell is known. (The cell is defined as the average area of influence of a single bubble.)

It is desirable to be able to determine the average number of bubbles per cell a priori. A method of estimating this item based on crude assumptions and empirical equations was proposed in this report. The maximum error associated with the estimated values was roughly 100 percent; this percentage might be due to the large errors introduced into the basic empirical equations. If a better method is available for estimating the bubble size and bubble population, more accurate estimations of the number of bubbles per cell and, thus, of the area fraction of merging bubbles might be possible.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, September 14, 1964

## APPENDIX A

### PROBABILITY FOR FORMATION OF BUBBLE CLUSTERS

The analysis in the text assumed the Poisson distribution of bubbles over the cells. Such an assumption implies the division of the heating surface into cells and the existence of artificial boundaries between the cells. Thus, when there are two bubbles falling into two neighboring cells but within each other's area of influence, they are not considered to be merging. Such an assumption tends to underestimate the fraction of merging bubbles. The underestimation might have been somewhat compensated for, however, by a slightly overestimated area of influence. Besides, if there are many empty cells surrounding the cells occupied by the bubbles, the cell boundary can be shifted to fit the bubbles without causing much error.

Nevertheless, a more rigorous treatment of bubble merging can be proposed by considering the probability for the clustering of bubbles.

Consider $n$ bubbles on a heating surface $A$, each bubble having an area of influence $a_s$. The probability that another bubble will fall into the area of influence of a given bubble is $a_s/A$, while the probability that another bubble will not fall in the vicinity of a given bubble is $1 - a_s/A$. Therefore, the probability of having a single bubble in its area of influence is $(1 - a_s/A)^{n-1}$. The number of single bubbles is then

$$n_1 = n\left(1 - \frac{a_s}{A}\right)^{n-1} \tag{A1}$$

By the same reasoning, the probability of having only one bubble fall within the area of influence of a given bubble is

$$\frac{(n - 1)!}{(n - 2)!1!} \frac{a_s}{A} \left(1 - \frac{a_s}{A}\right)^{n-2}$$

The number of bubble pairs is

$$n_2 = \frac{n}{2} \frac{(n - 1)!}{(n - 2)!1!} \frac{a_s}{A} \left(1 - \frac{a_s}{A}\right)^{n-2} \tag{A2}$$

The general expression for the number of clusters of $i$ bubbles is

$$n_i = \frac{n}{i} \frac{(n - 1)!}{(n - i)!(i - 1)!} \left(\frac{a_s}{A}\right)^{i-1} \left(1 - \frac{a_s}{A}\right)^{n-i} \tag{A3}$$

The total number of bubbles involved $n$ should be obtained by summing all the bubbles in clusters of various sizes:

$$\sum_{i=1}^{n} in_i = \sum_{i=1}^{n} \frac{n(n-1)!}{(n-i)!(i-1)!} \left(\frac{a_s}{A}\right)^{i-1} \left(1 - \frac{a_s}{A}\right)^{n-i}$$

$$= n \sum_{i=1}^{n} \frac{(n-1)!}{(n-i)!(i-1)!} \left(\frac{a_s}{A}\right)^{i-1} \left(1 - \frac{a_s}{A}\right)^{n-i} \qquad \text{(A4)}$$

Since the terms within the summation sign in equation (A4) are nothing more than the binomial expression $(p + q)^{n-1}$, this term should be unity. Thus

$$\sum_{i=1}^{n} in_i = n$$

Hence, the fraction of bubbles that are single is, from equation (A1),

$$\mathscr{F}_1 = \frac{n_1}{n} = \left(1 - \frac{a_s}{A}\right)^{n-1} \qquad \text{(A5)}$$

while the fraction of clustering bubbles is

$$\mathscr{F}_{i>1} = 1 - \mathscr{F}_1 = 1 - \left(1 - \frac{a_s}{A}\right)^{n-1} \qquad \text{(A6)}$$

It is interesting to note that $\mathscr{F}_1$ and $\mathscr{F}_{i>1}$ are functions of the total number of bubbles involved. In other words, even if the bubble population density is the same, the clustering fraction should change when the heating area is increased, and thus the total number $n$ will be increased. However, the functions $\mathscr{F}_1$ and $\mathscr{F}_{i>1}$ should reach a limit when $n$ approaches infinity:

$$\lim_{n\to\infty} \mathscr{F}_1 = \lim_{n\to\infty} \left(1 - \frac{a_s}{A}\right)^{n-1} = \lim_{n\to\infty} [1 - (n-1)\frac{a_s}{A} + \frac{(n-1)(n-2)}{2}\left(\frac{a_s}{A}\right)^2$$

$$- \frac{(n-1)(n-2)(n-3)}{3!}\left(\frac{a_s}{A}\right)^3 + \ldots \qquad \text{(A7)}$$

Since $n\, a_s/A = \mu$ and

$$\frac{a_s}{A} = \varphi_s = \frac{\mu}{n}$$

then

$$\lim_{n\to\infty} \mathscr{F}_1 = 1 - \frac{(n-1)\mu}{n} + \left[\frac{(n-1)(n-2)}{2}\left(\frac{\mu}{n}\right)^2\right]\left[1 - \frac{(n-3)}{3}\frac{\mu}{n}\right] + \ldots = 1 - \mu + \frac{\mu^2}{2!} - \frac{\mu^3}{3!} + \ldots$$

Therefore,

$$\lim_{n\to\infty} \mathscr{F}_1 = 1 - \mu + \frac{\mu^2}{2!} - \frac{\mu^3}{3!} + \ldots \tag{A8}$$

$$\lim_{n\to\infty} \mathscr{F}_{i>1} = 1 - \mathscr{F}_i = \mu - \frac{\mu^2}{2!} + \frac{\mu^3}{3!} + \ldots \tag{A9}$$

Note that $\mu = na_s/A$ is independent of the size of the heating area.

The comparison of theoretical (eq. (A5)) and experimental values of $\mathscr{F}_1$ is shown in figure 8.

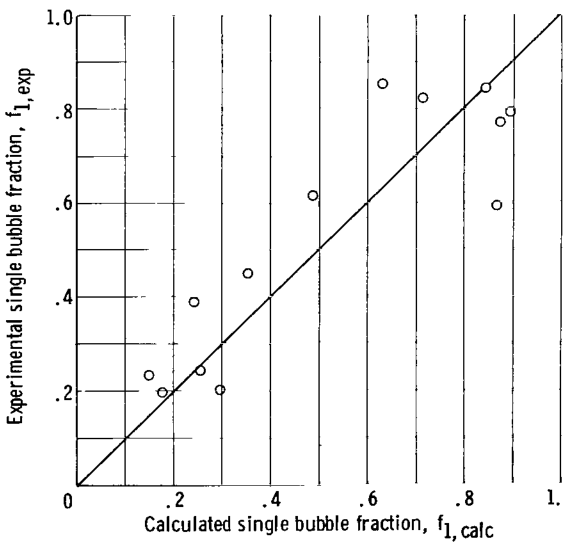


Figure 8. - Comparison of theoretical and experimental values of single bubble fractions.

To determine the area fraction covered by merging bubbles from the fraction of bubble clusters, the area occupied by each cluster $a_i$ must be given; for example,

$$\varphi_n = \sum_{i=2}^{n} a_i f_i \tag{A10}$$

Since $a_i$ is not readily known, however, $\varphi_n$ cannot be obtained from $\mathscr{F}_i$ by using equation (A10).

Of course, assumptions can be made about $a_i$ as a function of $a_s$, but such assumptions involve uncertainties. Consequently, although the analysis in the test, which assumes a Poisson distribution of bubbles over the cells, is less rigorous, it does provide the advantage of circumventing the difficulty of determining $a_i$.

# APPENDIX B

## ESTIMATION OF VARIATION ASSOCIATED WITH AVERAGE AREA FRACTION OF MERGING BUBBLES

Consider a heating strip with area $A$ that is divided into $n_t$ cells, each cell being equal to the mean area of influence of a single bubble $a_s$.

If there are $n_m$ cells found to be occupied by two or more bubbles and causing the coalescence of bubbles, there will be a fraction of area $\varphi_m = n_m/n_t$ occupied by the merging bubbles.

When $k$ motion picture frames were studied, it was found that there was an average value of $\varphi_m$

$$\varphi_{m,av} = \frac{1}{k}\sum_{i=1}^{k} \varphi_{m_i}$$

and a deviation

$$s^2 = \frac{\sum_{i=1}^{k} (\varphi_{m_i} - \varphi_{m,av})^2}{k}$$

The problem is whether or not the deviation $s$ is theoretically expected.

If $k$ is large (say 50 to 100), it can be assumed that $\varphi_{m,av} = \mu_{\varphi_m}$ is the probability of finding the merging bubble cells. Now consider the problem as that of finding the theoretical deviation $\sigma$ for a binomial distribution.

$$\sigma = \sqrt{pq/n}$$

$$= \sqrt{\varphi_{m,av}(1 - \varphi_{m,av})/n_t}$$

$$n_t = \frac{A}{a_s} = \frac{1}{\varphi_{s,av}}$$

or

$$\sigma = \sqrt{\frac{a_s}{A}\varphi_{m,av}(1 - \varphi_{m,av})} = \sqrt{\varphi_{s,av}\varphi_{m,av}(1 - \varphi_{m,av})}$$

The comparison between $s$ and $\sigma$ is shown in table III.

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TABLE I. - EXPERIMENTAL DATA

| Run | Test fluid | Bulk temperature, °F | Heat flux, q, $\frac{\text{Btu}}{(\text{hr})(\text{sq ft})}$ | Subcooling temperature difference between saturation and bulk, $\Delta T_{sub}$, °F | Total number of frames studied, k | Total number of single bubbles studied in roll, h | Number of merging bubbles studied | Average instantaneous bubble population, $n_{av}$ | Average area fraction of influence of bubble, $\varphi_{s,av}$ (a) | Average area fraction of merging bubbles, $\varphi_{m,av}$ | Standard deviation associated with $\varphi_{m,av}$ | Total number of bubble sites, N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 62-12-4-1 | Water | 201 | 21,150 | 11 | 101 | 128 | 87 | 2.13 | 0.121 | 0.0451 | 0.0929 | 13 |
| 62-12-4-2 | | 197 | 23,950 | 15 | 100 | 162 | 43 | 2.05 | .102 | .0182 | .0451 | 10 |
| 62-12-4-3 | | 198 | 32,000 | 14 | 102 | 172 | 51 | 2.19 | .109 | .0240 | .0649 | 15 |
| 62-12-4-5 | | 199 | 49,500 | 13 | 99 | 268 | 57 | 3.28 | .138 | .0402 | .0936 | 18 |
| 62-12-4-6 | | 196 | 41,500 | 16 | 102 | 193 | 35 | 2.24 | .128 | .0171 | .0533 | 19 |
| 63-1-14-6 | Methanol | 132 | 48,300 | 16 | 96 | 328 | 57 | 4.01 | 0.143 | 0.0291 | 0.0702 | 18 |
| 63-2-6-1 | | 137 | 92,900 | 11 | 50 | 139 | 86 | 4.50 | .186 | .115 | .135 | 21 |
| 63-2-6-2 | | 137 | 104,900 | 11 | 56 | 155 | 187 | 6.11 | .185 | .255 | .225 | 20 |
| 63-2-6-3 | | 140 | 120,700 | 8 | 47 | 130 | 202 | 7.06 | .208 | .3695 | .214 | 30 |
| 63-2-6-4 | | 139 | 135,000 | 9 | 50 | 92 | 373 | 9.30 | .189 | .535 | .216 | 30 |
| 63-7-2-2 | | 128 | 73,100 | 20 | 55 | 135 | 447 | 10.58 | .182 | .470 | .183 | 19 |
| 63-7-8-1 | | 111 | 68,400 | 37 | 70 | 263 | 196 | 6.56 | .109 | .110 | .117 | 20 |
| 63-7-8-4 | | 119 | 88,200 | 29 | 56 | 119 | 472 | 10.55 | .121 | .358 | .167 | 26 |
| 63-7-8-5 | | 119 | 82,600 | 29 | 49 | 124 | 385 | 10.39 | .136 | .327 | .152 | 27 |

[a]Values for methanol in this column are changed from those reported in ref. 21 because the calculation of $\varphi_{s,av}$ is based on eq. (2c) in this report, while $\varphi_{s,av}$ was calculated for $D_{av}$ by using eqs. (2a) and (2b); but the changes are not large enough to alter the result.

TABLE II. - BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(a) Test fluid, water; run 62-12-4-1[a]

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (b) | Single bubbles: Bubble width (b) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (b) | Merging bubbles: Site width (b) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 3 | 5.640 | 0.384 | 0.198 | 0 | | | | |
| | | 6.445 | 0.877 | 0.464 | | | | | |
| | | 7.072 | 0.162 | 0.070 | | | | | |
| 30 | 1 | 7.072 | 0.162 | 0.070 | 0 | | | | |
| 80 | 1 | 7.067 | 0.172 | 0.079 | 0 | | | | |
| 120 | 1 | 7.074 | 0.158 | 0.066 | 0 | | | | |
| 160 | 1 | 7.081 | 0.143 | 0.054 | 1 | 3 | 5.653 | 1.066 | 0.279 |
| 195 | 0 | | | | 1 | 2 | 6.906 | 0.493 | 0.122 |
| 240 | 1 | 7.076 | 0.153 | 0.062 | 0 | | | | |
| 270 | 1 | 7.086 | 0.133 | 0.047 | 0 | | | | |
| 325 | 1 | 7.070 | 0.166 | 0.073 | 0 | | | | |
| 365 | 3 | 3.603 | 0.427 | 0.222 | 0 | | | | |
| | | 4.477 | 1.099 | 0.582 | | | | | |
| | | 7.079 | 0.148 | 0.058 | | | | | |
| 400 | 1 | 5.988 | 0.245 | 0.160 | 2 | 3 | 4.350 | 1.398 | 0.377 |
| | | | | | | 2 | 7.074 | 0.157 | |
| 443 | 2 | 5.698 | 0.179 | 0.085 | 1 | 2 | 7.067 | 0.171 | 0.010 |
| | | 5.998 | 0.220 | 0.129 | | | | | |
| 489 | 1 | 5.705 | 0.176 | 0.082 | 1 | 2 | 7.056 | 0.193 | 0.012 |
| 519 | 1 | 7.068 | 0.169 | 0.076 | 0 | | | | |
| 564 | 2 | 5.985 | 0.287 | 0.219 | 0 | | | | |
| | | 7.068 | 0.170 | 0.077 | | | | | |
| 601 | 1 | 7.074 | 0.158 | 0.066 | 0 | | | | |
| 653 | 2 | 5.709 | 0.343 | 0.176 | 0 | | | | |
| | | 7.080 | 0.146 | 0.057 | | | | | |
| 685 | 1 | 7.072 | 0.162 | 0.070 | 0 | | | | |
| 715 | 2 | 5.849 | 0.358 | 0.184 | 0 | | | | |
| | | 7.066 | 0.173 | 0.080 | | | | | |
| 754 | 2 | 3.674 | 0.460 | 0.240 | 1 | 2 | 7.051 | 0.204 | 0.028 |
| | | 6.001 | 0.325 | 0.166 | | | | | |
| 799 | 3 | 4.954 | 0.848 | 0.448 | 1 | 2 | 6.816 | 0.674 | 0.172 |
| | | 5.643 | 0.275 | 0.201 | | | | | |
| | | 5.987 | 0.364 | 0.187 | | | | | |
| 833 | 1 | 4.985 | 0.499 | 0.261 | 1 | 3 | 6.808 | 0.689 | 0.177 |
| 883 | 0 | | | | 1 | 2 | 7.047 | 0.211 | 0.030 |
| 927 | 4 | 3.685 | 0.398 | 0.206 | 0 | | | | |
| | | 5.712 | 0.156 | 0.065 | | | | | |

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (b) | Single bubbles: Bubble width (b) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (b) | Merging bubbles: Site width (b) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 7.042 | 0.221 | 0.130 | | | | | |
| 1927 | 0 | | | | 1 | 2 | 7.035 | 0.235 | 0.037 |
| 1965 | 1 | 7.047 | 0.211 | 0.119 | 1 | 2 | 5.828 | 0.580 | 0.146 |
| 2000 | 1 | 7.060 | 0.185 | 0.091 | 0 | | | | |
| 2029 | 1 | 7.058 | 0.189 | 0.095 | 1 | 2 | 5.816 | 0.559 | 0.140 |
| 2069 | 1 | 7.051 | 0.203 | 0.110 | 0 | | | | |
| 2117 | 2 | 5.734 | 0.357 | 0.183 | 0 | | | | |
| | | 7.067 | 0.171 | 0.078 | | | | | |
| 2192 | 1 | 7.062 | 0.181 | 0.087 | 0 | | | | |
| 2237 | 1 | 7.065 | 0.176 | 0.082 | 0 | | | | |
| 2274 | 2 | 6.003 | 0.304 | 0.246 | 0 | | | | |
| | | 7.056 | 0.194 | 0.100 | | | | | |
| 2317 | 2 | 5.733 | 0.343 | 0.176 | 0 | | | | |
| | | 7.073 | 0.160 | 0.068 | | | | | |
| 2347 | 1 | 7.063 | 0.180 | 0.086 | 0 | | | | |
| 2397 | 1 | 7.063 | 0.180 | 0.086 | 0 | | | | |
| 2437 | 0 | | | | 1 | 3 | 6.815 | 0.676 | 0.173 |
| 2473 | 2 | 3.651 | 0.341 | 0.175 | 2 | 3 | 5.467 | 0.656 | 0.281 |
| | | 6.030 | 0.296 | 0.233 | | 2 | 6.919 | 0.467 | |
| 2516 | 0 | | | | 1 | 2 | 7.052 | 0.201 | 0.027 |
| 2551 | 2 | 5.964 | 0.182 | 0.088 | 0 | | | | |
| | | 7.057 | 0.192 | 0.098 | | | | | |
| 2584 | 1 | 7.053 | 0.200 | 0.106 | 0 | | | | |
| 2624 | 1 | 7.066 | 0.174 | 0.081 | 0 | | | | |
| 2705 | 1 | 7.071 | 0.164 | 0.072 | 0 | | | | |
| 2745 | 2 | 5.720 | 0.149 | 0.059 | 0 | | | | |
| | | 7.073 | 0.160 | 0.068 | | | | | |
| 2790 | 1 | 7.088 | 0.129 | 0.044 | 0 | | | | |
| 2826 | 2 | 3.700 | 0.405 | 0.210 | 1 | 2 | 5.892 | 0.492 | 0.121 |
| | | 7.079 | 0.148 | 0.058 | | | | | |
| 2864 | 1 | 7.074 | 0.157 | 0.066 | 0 | | | | |
| 2907 | 1 | 7.086 | 0.133 | 0.047 | 0 | | | | |
| 2953 | 2 | 5.698 | 0.276 | 0.203 | 0 | | | | |
| | | 7.067 | 0.171 | 0.078 | | | | | |
| 2993 | 1 | 7.064 | 0.178 | 0.084 | 0 | | | | |
| 3025 | 2 | 5.695 | 0.288 | 0.221 | 0 | | | | |
| | | 6.006 | 0.273 | 0.198 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5.979 | 0.089 | 0.021 | | | | | |
| | | 7.061 | 0.184 | 0.090 | | | | | |
| 958 | 1 | 7.075 | 0.155 | 0.064 | 0 | | | | |
| 1001 | 2 | 5.991 | 0.143 | 0.054 | 0 | | | | |
| | | 7.065 | 0.176 | 0.082 | | | | | |
| 1033 | 2 | 5.722 | 0.199 | 0.105 | 0 | | | | |
| | | 7.073 | 0.160 | 0.068 | | | | | |
| 1063 | 1 | 7.054 | 0.198 | 0.104 | 0 | | | | |
| 1095 | 0 | | | | 2 | 2 | 5.883 | 0.640 | 0.20[a] |
| | | | | | | 2 | 7.035 | 0.235 | |
| 1140 | 3 | 3.663 | 0.358 | 0.184 | 0 | | | | |
| | | 5.970 | 0.271 | 0.196 | | | | | |
| | | 7.072 | 0.162 | 0.070 | | | | | |
| 1180 | 1 | 7.072 | 0.162 | 0.070 | 0 | | | | |
| 1223 | 3 | 5.687 | 0.242 | 0.156 | 0 | | | | |
| | | 5.970 | 0.221 | 0.130 | | | | | |
| | | 7.046 | 0.214 | 0.122 | | | | | |
| 1261 | 1 | 7.057 | 0.192 | 0.098 | 0 | | | | |
| 1311 | 1 | 7.070 | 0.166 | 0.073 | 0 | | | | |
| 1359 | 2 | 3.675 | 0.415 | 0.215 | 1 | 2 | 5.503 | 0.808 | 0.209 |
| | | 7.066 | 0.174 | 0.081 | | | | | |
| 1411 | 1 | 7.065 | 0.176 | 0.082 | 0 | | | | |
| 1441 | 1 | 7.057 | 0.191 | 0.097 | 0 | | | | |
| 1486 | 1 | 7.059 | 0.187 | 0.093 | 0 | | | | |
| 1521 | 2 | 3.644 | 0.509 | 0.266 | 1 | 4 | 6.528 | 1.250 | 0.329 |
| | | 5.615 | 0.231 | 0.142 | | | | | |
| 1571 | 0 | | | | 1 | 4 | 6.398 | 1.510 | 0.398 |
| 1600 | 1 | 4.173 | 0.642 | 0.338 | 1 | 2 | 7.044 | 0.217 | 0.031 |
| 1640 | 1 | 7.040 | 0.226 | 0.136 | 0 | | | | |
| 1690 | 1 | 7.039 | 0.227 | 0.137 | 0 | | | | |
| 1733 | 1 | 5.708 | 0.257 | 0.176 | 1 | 2 | 7.049 | 0.208 | 0.029 |
| 1766 | 0 | | | | 1 | 3 | 7.044 | 0.218 | 0.032 |
| 1813 | 1 | 7.057 | 0.191 | 0.097 | 0 | | | | |
| 1858 | 2 | 5.995 | 0.258 | 0.177 | 0 | | | | |
| | | 7.045 | 0.215 | 0.123 | | | | | |
| 1890 | 2 | 5.713 | 0.295 | 0.232 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3063 | 1 | 7.082 | 0.141 | 0.053 | 0 | | | | |
| 3103 | 2 | 5.982 | 0.316 | 0.161 | 0 | | | | |
| | | 7.070 | 0.166 | 0.073 | | | | | |
| 3146 | 2 | 3.657 | 0.534 | 0.280 | 0 | | | | |
| | | 4.060 | 0.161 | 0.069 | | | | | |
| 3193 | 2 | 5.997 | 0.185 | 0.091 | 0 | | | | |
| | | 7.084 | 0.138 | 0.051 | | | | | |
| 3228 | 1 | 5.718 | 0.182 | 0.088 | 1 | 2 | 7.097 | 0.112 | 0.004 |
| 3273 | 0 | | | | 1 | 2 | 6.800 | 0.706 | 0.181 |
| 3313 | 2 | 5.744 | 0.226 | 0.136 | 1 | 2 | 6.814 | 0.678 | 0.174 |
| | | 6.047 | 0.316 | 0.161 | | | | | |
| 3359 | 1 | 7.106 | 0.094 | 0.024 | 0 | | | | |
| 3393 | 1 | 7.102 | 0.101 | 0.027 | 0 | | | | |
| 3423 | 1 | 7.110 | 0.086 | 0.020 | 0 | | | | |
| 3473 | 2 | 5.712 | 0.105 | 0.029 | 0 | | | | |
| | | 7.095 | 0.116 | 0.036 | | | | | |
| 3513 | 0 | | | | 1 | 2 | 7.091 | 0.123 | 0.005 |
| 3548 | 0 | | | | 1 | 2 | 7.056 | 0.193 | 0.012 |
| 3593 | 1 | 5.715 | 0.348 | 0.178 | 1 | 2 | 6.996 | 0.313 | 0.065 |
| 3636 | 0 | | | | 1 | 2 | 7.056 | 0.193 | 0.012 |
| 3674 | 2 | 5.983 | 0.331 | 0.169 | 0 | | | | |
| | | 7.086 | 0.134 | 0.048 | | | | | |
| 3705 | 1 | 7.093 | 0.120 | 0.038 | 1 | 3 | 5.571 | 0.927 | 0.242 |
| 3743 | 0 | | | | 2 | 2 | 5.454 | 0.641 | 0.176 |
| | | | | | | 2 | 7.054 | 0.197 | |
| 3776 | 1 | 7.095 | 0.116 | 0.036 | 0 | | | | |
| 3820 | 1 | 7.125 | 0.055 | 0.008 | 0 | | | | |
| 3858 | 1 | 7.110 | 0.086 | 0.020 | 0 | | | | |
| 3906 | 1 | 7.092 | 0.122 | 0.040 | 0 | | | | |
| 3944 | 2 | 6.009 | 0.136 | 0.049 | 0 | | | | |
| | | 7.093 | 0.119 | 0.038 | | | | | |
| 3987 | 3 | 3.796 | 0.356 | 0.183 | 0 | | | | |
| | | 5.731 | 0.182 | 0.088 | | | | | |
| | | 7.098 | 0.109 | 0.032 | | | | | |
| 4025 | 0 | | | | 1 | 4 | 6.542 | 1.221 | 0.321 |

Total number of sample frames, k, 101.
Total number of single bubbles, h, 128.
Total number of merging bubbles, 87.
Average instantaneous bubble population, $n_{av}$, 2.13.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.121.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.0451.
Standard deviation associated with $\varphi_{m,av}$, 0.0929.

[a]This run was handled in a special manner: For each merging bubble group, the center of its width of influence is indicated. Depending on the comparison between this width of influence and the given base value of 0.20, one of two methods of computation was used in evaluating the average area fraction of merging bubbles. If the width was greater than the base value, the area of influence at each site was evaluated as one single area. If the width was less than or equal to the base value, the area of influence was evaluated by dividing the width by the number of merging bubbles at each site and summing the resulting areas.

[b]3.763 movie analyzer units equal 0.75 inch; left end reading, 3.390; right end reading, 7.153.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(b) Test fluid, water; run 62-12-4-2

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2 | 5.216 | 0.170 | 0.074 | 0 | | | | |
| | | 6.379 | 0.130 | 0.043 | | | | | |
| 30 | 3 | 4.153 | 0.386 | 0.195 | 2 | 2 | 2.661 | 0.375 | 0.202 |
| | | 6.187 | 0.136 | 0.047 | | | 2.833 | 0.217 | |
| | | 6.282 | 0.106 | 0.029 | | 2 | 4.839 | 0.315 | |
| | | | | | | | 5.119 | 0.195 | |
| 80 | 2 | 4.934 | 0.382 | 0.193 | 0 | | | | |
| | | 6.396 | 0.121 | 0.038 | | | | | |
| 120 | 1 | 6.324 | 0.164 | 0.069 | 0 | | | | |
| 160 | 1 | 5.096 | 0.082 | 0.017 | 1 | 2 | 6.160 | 0.129 | 0.018 |
| | | | | | | | 6.280 | 0.110 | |
| 195 | 2 | 5.190 | 0.176 | 0.079 | 0 | | | | |
| | | 6.393 | 0.084 | 0.018 | | | | | |
| 240 | 1 | 4.496 | 0.326 | 0.163 | 1 | 2 | 6.212 | 0.100 | 0.011 |
| | | | | | | | 6.295 | 0.087 | |
| 270 | 3 | 2.895 | 0.148 | 0.056 | 0 | | | | |
| | | 5.216 | 0.158 | 0.064 | | | | | |
| | | 6.405 | 0.060 | 0.009 | | | | | |
| 325 | 1 | 4.254 | 0.499 | 0.256 | 0 | | | | |
| 365 | 2 | 4.229 | 0.341 | 0.171 | 0 | | | | |
| | | 6.405 | 0.092 | 0.022 | | | | | |
| 400 | 1 | 6.220 | 0.247 | 0.156 | 1 | 2 | 4.858 | 0.240 | 0.085 |
| | | | | | | | 5.115 | 0.274 | |
| 443 | 3 | 4.948 | 0.210 | 0.113 | 0 | | | | |
| | | 5.230 | 0.288 | 0.213 | | | | | |
| | | 6.349 | 0.148 | 0.056 | | | | | |
| 489 | 1 | 6.268 | 0.118 | 0.036 | 1 | 2 | 4.850 | 0.240 | 0.103 |
| | | | | | | | 5.130 | 0.321 | |
| 519 | 1 | 6.340 | 0.109 | 0.030 | 0 | | | | |
| 564 | 1 | 6.289 | 0.250 | 0.160 | 0 | | | | |
| 601 | 1 | 6.293 | 0.122 | 0.038 | 1 | 2 | 4.992 | 0.383 | 0.134 |
| | | | | | | | 5.191 | 0.271 | |
| 653 | 2 | 2.846 | 0.348 | 0.175 | 1 | 2 | 6.238 | 0.126 | 0.014 |
| | | 5.105 | 0.277 | 0.197 | | | 6.325 | 0.080 | |
| 685 | 1 | 5.862 | 1.246 | 0.648 | 0 | | | | |
| 715 | 1 | 6.029 | 0.082 | 0.017 | 0 | | | | |
| 754 | 1 | 6.337 | 0.202 | 0.105 | 0 | | | | |
| 799 | 1 | 6.235 | 0.112 | 0.032 | 1 | 2 | 4.176 | 0.597 | 0.157 |
| | | | | | | | 4.162 | 0.116 | |
| 833 | 1 | 6.307 | 0.125 | 0.040 | 1 | 2 | 4.146 | 0.458 | 0.128 |
| | | | | | | | 4.128 | 0.173 | |
| 883 | 2 | 4.648 | 0.614 | 0.317 | 0 | | | | |
| | | 6.392 | 0.185 | 0.088 | | | | | |
| 927 | 1 | 4.703 | 0.366 | 0.185 | 0 | | | | |

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 1965 | 2 | 4.977 | 0.216 | 0.120 | 0 | | | | |
| | | 6.387 | 0.084 | 0.018 | | | | | |
| 2000 | 1 | 4.288 | 0.499 | 0.256 | 0 | | | | |
| 2029 | 3 | 4.295 | 0.289 | 0.214 | 0 | | | | |
| | | 4.954 | 0.193 | 0.095 | | | | | |
| | | 6.413 | 0.065 | 0.011 | | | | | |
| 2069 | 2 | 2.937 | 0.319 | 0.261 | 0 | | | | |
| | | 6.352 | 0.104 | 0.028 | | | | | |
| 2117 | 2 | 5.224 | 0.185 | 0.088 | 0 | | | | |
| | | 6.421 | 0.077 | 0.015 | | | | | |
| 2152 | 1 | 6.413 | 0.088 | 0.020 | 0 | | | | |
| 2192 | 1 | 6.192 | 0.143 | 0.052 | 1 | 2 | 4.875 | 0.294 | 0.089 |
| | | | | | | | 5.137 | 0.230 | |
| 2274 | 1 | 6.265 | 0.110 | 0.031 | 1 | 2 | 4.746 | 0.238 | 0.116 |
| | | | | | | | 5.045 | 0.361 | |
| 2317 | 4 | 2.905 | 0.155 | 0.062 | 0 | | | | |
| | | 6.121 | 0.070 | 0.013 | | | | | |
| | | 6.272 | 0.177 | 0.080 | | | | | |
| | | 6.401 | 0.071 | 0.013 | | | | | |
| 2347 | 1 | 6.425 | 0.070 | 0.013 | 0 | | | | |
| 2397 | 1 | 6.344 | 0.185 | 0.088 | 0 | | | | |
| 2437 | 1 | 6.316 | 0.176 | 0.079 | 0 | | | | |
| 2473 | 2 | 5.966 | 0.351 | 0.177 | 0 | | | | |
| | | 6.289 | 0.258 | 0.171 | | | | | |
| 2516 | 2 | 5.215 | 0.137 | 0.048 | 0 | | | | |
| | | 6.425 | 0.062 | 0.010 | | | | | |
| 2551 | 3 | 2.922 | 0.214 | 0.117 | 0 | | | | |
| | | 4.945 | 0.083 | 0.018 | | | | | |
| | | 6.387 | 0.110 | 0.031 | | | | | |
| 2584 | 2 | 5.237 | 0.210 | 0.113 | 0 | | | | |
| | | 6.399 | 0.091 | 0.021 | | | | | |
| 2624 | 3 | 4.242 | 0.636 | 0.328 | 0 | | | | |
| | | 4.950 | 0.245 | 0.154 | | | | | |
| | | 6.384 | 0.083 | 0.018 | | | | | |
| 2673 | 2 | 4.295 | 0.322 | 0.161 | 0 | | | | |
| | | 6.341 | 0.121 | 0.038 | | | | | |
| 2705 | 1 | 4.254 | 0.532 | 0.273 | 0 | | | | |
| 2790 | 4 | 2.913 | 0.102 | 0.027 | 0 | | | | |
| | | 4.670 | 0.299 | 0.229 | | | | | |
| | | 5.238 | 0.208 | 0.111 | | | | | |
| | | 6.418 | 0.077 | 0.015 | | | | | |
| 2826 | 3 | 4.921 | 0.233 | 0.139 | 0 | | | | |
| | | 5.228 | 0.175 | 0.079 | | | | | |
| | | 6.406 | 0.074 | 0.014 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 958 | 4 | 2.921 | 0.309 | 0.245 | 0 | | | | |
| | | 3.689 | 0.379 | 0.192 | | | | | |
| | | 4.220 | 0.554 | 0.285 | | | | | |
| | | 6.382 | 0.079 | 0.016 | | | | | |
| 1001 | 1 | 4.298 | 0.249 | 0.159 | 0 | | | | |
| 1033 | 2 | 5.231 | 0.249 | 0.159 | 0 | | | | |
| | | 6.398 | 0.077 | 0.015 | | | | | |
| 1063 | 2 | 4.963 | 0.126 | 0.041 | 0 | | | | |
| | | 6.375 | 0.101 | 0.026 | | | | | |
| 1095 | 1 | 5.139 | 0.164 | 0.069 | 1 | 2 | 6.246 | 0.125 | 0.014 |
| | | | | | | | 6.332 | 0.078 | |
| 1140 | 1 | 6.398 | 0.081 | 0.017 | 0 | | | | |
| 1180 | 2 | 4.959 | 0.403 | 0.205 | 0 | | | | |
| | | 6.388 | 0.107 | 0.029 | | | | | |
| 1261 | 0 | | | | 2 | 2 | 4.828 | 0.381 | 0.121 |
| | | | | | | | 5.108 | 0.178 | |
| | | | | | | 2 | 6.206 | 0.105 | |
| | | | | | | | 6.302 | 0.107 | |
| 1311 | 1 | 5.211 | 0.093 | 0.022 | 0 | | | | |
| 1359 | 1 | 6.252 | 0.100 | 0.026 | 1 | 2 | 4.838 | 0.341 | 0.085 |
| | | | | | | | 4.871 | 0.138 | |
| 1411 | 3 | 4.250 | 0.234 | 0.140 | 0 | | | | |
| | | 5.204 | 0.196 | 0.098 | | | | | |
| | | 6.366 | 0.092 | 0.022 | | | | | |
| 1441 | 2 | 2.876 | 0.452 | 0.231 | 0 | | | | |
| | | 6.344 | 0.112 | 0.032 | | | | | |
| 1486 | 1 | 3.916 | 2.350 | 1.225 | 1 | 3 | 5.894 | 0.370 | 0.107 |
| | | | | | | | 5.866 | 0.089 | |
| | | | | | | | 6.135 | 0.176 | |
| 1521 | 1 | 6.344 | 0.126 | 0.041 | 0 | | | | |
| 1571 | 1 | 6.363 | 0.070 | 0.013 | 0 | | | | |
| 1600 | 1 | 6.317 | 0.114 | 0.033 | 0 | | | | |
| 1640 | 2 | 5.211 | 0.138 | 0.049 | 0 | | | | |
| | | 6.275 | 0.134 | 0.046 | | | | | |
| 1690 | 2 | 4.254 | 0.260 | 0.173 | 0 | | | | |
| | | 4.613 | 0.306 | 0.240 | | | | | |
| 1733 | 1 | 6.319 | 0.095 | 0.023 | 0 | | | | |
| 1766 | 1 | 2.798 | 0.091 | 0.021 | 1 | 2 | 6.234 | 0.073 | 0.008 |
| | | | | | | | 6.312 | 0.083 | |
| 1813 | 1 | 6.338 | 0.102 | 0.027 | 0 | | | | |
| 1858 | 2 | 5.217 | 0.117 | 0.035 | 0 | | | | |
| | | 6.325 | 0.090 | 0.021 | | | | | |
| 1890 | 3 | 4.947 | 0.047 | 0.006 | 0 | | | | |
| | | 6.296 | 0.120 | 0.037 | | | | | |
| | | 6.434 | 0.068 | 0.012 | | | | | |
| 1927 | 2 | 5.225 | 0.104 | 0.028 | 0 | | | | |
| | | 6.360 | 0.100 | 0.026 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2864 | 2 | 4.686 | 0.419 | 0.213 | 0 | | | | |
| | | 6.404 | 0.089 | 0.020 | | | | | |
| 2907 | 1 | 6.387 | 0.100 | 0.026 | 0 | | | | |
| 2953 | 1 | 6.364 | 0.071 | 0.013 | 0 | | | | |
| 2993 | 1 | 6.370 | 0.078 | 0.016 | 0 | | | | |
| 3025 | 2 | 2.928 | 0.430 | 0.219 | 0 | | | | |
| | | 6.359 | 0.111 | 0.032 | | | | | |
| 3103 | 2 | 5.229 | 0.120 | 0.037 | 0 | | | | |
| | | 6.430 | 0.057 | 0.008 | | | | | |
| 3146 | 4 | 4.941 | 0.233 | 0.139 | 0 | | | | |
| | | 5.217 | 0.140 | 0.050 | | | | | |
| | | 5.954 | 0.235 | 0.142 | | | | | |
| | | 6.375 | 0.071 | 0.013 | | | | | |
| 3193 | 1 | 2.909 | 0.443 | 0.226 | 0 | | | | |
| 3228 | 1 | 6.387 | 0.063 | 0.010 | 0 | | | | |
| 3273 | 1 | 6.381 | 0.076 | 0.015 | 0 | | | | |
| 3313 | 4 | 2.870 | 0.440 | 0.224 | 0 | | | | |
| | | 5.201 | 0.152 | 0.059 | | | | | |
| | | 5.685 | 0.771 | 0.399 | | | | | |
| | | 6.256 | 0.161 | 0.066 | | | | | |
| 3359 | 1 | 6.413 | 0.102 | 0.027 | 0 | | | | |
| 3393 | 4 | 2.950 | 0.354 | 0.178 | 0 | | | | |
| | | 4.957 | 0.193 | 0.095 | | | | | |
| | | 5.226 | 0.136 | 0.047 | | | | | |
| | | 6.421 | 0.083 | 0.018 | | | | | |
| 3473 | 2 | 4.190 | 0.552 | 0.284 | 1 | 2 | 4.984 | 0.466 | 0.126 |
| | | 6.301 | 0.085 | 0.019 | | | 5.230 | 0.153 | |
| 3513 | 3 | 3.438 | 0.720 | 0.372 | 0 | | | | |
| | | 4.337 | 0.402 | 0.204 | | | | | |
| | | 6.351 | 0.128 | 0.042 | | | | | |
| 3548 | 3 | 4.222 | 0.511 | 0.262 | 0 | | | | |
| | | 4.977 | 0.374 | 0.189 | | | | | |
| | | 6.439 | 0.077 | 0.015 | | | | | |
| 3593 | 1 | 6.425 | 0.068 | 0.012 | 0 | | | | |
| 3636 | 2 | 4.838 | 0.111 | 0.032 | 1 | 2 | 4.569 | 0.524 | 0.136 |
| | | 6.278 | 0.108 | 0.030 | | | 4.558 | 0.112 | |
| 3674 | 1 | 6.346 | 0.089 | 0.020 | 1 | 2 | 4.168 | 0.356 | 0.170 |
| | | | | | | | 4.545 | 0.399 | |
| 3743 | 1 | 6.288 | 0.166 | 0.071 | 0 | | | | |
| 3776 | 1 | 6.014 | 0.265 | 0.180 | 0 | | | | |
| 3820 | 3 | 4.954 | 0.139 | 0.050 | 0 | | | | |
| | | 5.228 | 0.252 | 0.163 | | | | | |
| | | 6.442 | 0.074 | 0.014 | | | | | |
| 3858 | 1 | 6.424 | 0.071 | 0.013 | 0 | | | | |
| 3906 | 2 | 5.247 | 0.185 | 0.088 | 0 | | | | |
| | | 6.394 | 0.072 | 0.013 | | | | | |
| 3944 | 1 | 6.357 | 0.119 | 0.036 | 0 | | | | |

Total number of sample frames, k, 100.
Total number of single bubbles, h, 162.
Total number of merging bubbles, 43.
Average instantaneous bubble population, $n_{av}$, 2.05.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.102.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.0182.
Standard deviation associated with $\varphi_{m,av}$, 0.0451.

[a]3.835 movie analyzer units equal 0.75 inch; left end reading, 2.650; right end reading 6.485.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(c) Test fluid, water; run 62-12-4-3[a]

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (b) | Single bubbles: Bubble width (b) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (b) | Merging bubbles: Site width (b) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 6.873 | 0.080 | 0.016 | 0 | | | | |
| 30 | 1 | 6.840 | 0.109 | 0.030 | 0 | | | | |
| 80 | 2 | 5.401 | 0.166 | 0.069 | 0 | | | | |
| | | 6.863 | 0.157 | 0.062 | | | | | |
| 120 | 2 | 4.606 | 0.255 | 0.162 | 1 | 2 | 5.229 | 0.781 | 0.175 |
| | | 6.895 | 0.113 | 0.032 | | | | | |
| 160 | 2 | 6.189 | 0.391 | 0.195 | 0 | | | | |
| | | 6.889 | 0.136 | 0.046 | | | | | |
| 195 | 1 | 6.883 | 0.100 | 0.025 | 0 | | | | |
| 240 | 1 | 3.170 | 0.174 | 0.076 | 0 | | | | |
| 270 | 1 | 6.888 | 0.132 | 0.043 | 0 | | | | |
| 325 | 2 | 4.477 | 0.313 | 0.245 | 0 | | | | |
| | | 5.421 | 0.299 | 0.223 | | | | | |
| 365 | 1 | 6.935 | 0.074 | 0.014 | 1 | 3 | 6.307 | 0.656 | 0.090 |
| 400 | 2 | 3.331 | 0.078 | 0.015 | 0 | | | | |
| | | 6.925 | 0.102 | 0.026 | | | | | |
| 489 | 1 | 6.928 | 0.103 | 0.026 | 0 | | | | |
| 519 | 2 | 4.031 | 0.321 | 0.257 | 0 | | | | |
| | | 6.875 | 0.210 | 0.110 | | | | | |
| 564 | 1 | 6.876 | 0.207 | 0.107 | 1 | 4 | 5.361 | 1.008 | 0.159 |
| 601 | 2 | 4.494 | 0.139 | 0.048 | 0 | | | | |
| | | 6.902 | 0.155 | 0.060 | | | | | |
| 653 | 1 | 6.924 | 0.112 | 0.031 | 0 | | | | |
| 685 | 1 | 5.750 | 0.086 | 0.018 | 1 | 2 | 6.901 | 0.177 | 0.010 |
| 715 | 1 | 4.511 | 0.273 | 0.186 | 2 | 2 | 3.332 | 0.392 | 0.072 |
| | | | | | | 2 | 6.854 | 0.280 | |
| 754 | 3 | 3.833 | 0.218 | 0.119 | 2 | 2 | 4.458 | 0.189 | 0.025 |
| | | 5.468 | 0.291 | 0.211 | | 2 | 6.897 | 0.214 | |
| | | 5.744 | 0.099 | 0.024 | | | | | |
| 799 | 2 | 6.836 | 0.101 | 0.025 | 0 | | | | |
| | | 6.962 | 0.095 | 0.023 | | | | | |
| 833 | 2 | 5.764 | 0.136 | 0.046 | 0 | | | | |
| | | 6.968 | 0.097 | 0.023 | | | | | |
| 883 | 2 | 5.484 | 0.249 | 0.155 | 0 | | | | |
| | | 6.965 | 0.104 | 0.027 | | | | | |
| 958 | 2 | 4.547 | 0.098 | 0.024 | 0 | | | | |
| | | 5.784 | 0.116 | 0.034 | | | | | |
| 1001 | 1 | 6.609 | 0.303 | 0.229 | 0 | | | | |
| 1033 | 1 | 4.208 | 0.663 | 0.338 | 1 | 2 | 6.958 | 0.133 | 0.006 |
| 1063 | 3 | 4.202 | 0.432 | 0.217 | 0 | | | | |
| | | 5.207 | 0.582 | 0.296 | | | | | |
| | | 6.956 | 0.062 | 0.010 | | | | | |
| 1095 | 1 | 5.167 | 0.393 | 0.196 | 1 | 2 | 6.924 | 0.196 | 0.012 |
| 1180 | 1 | 6.888 | 0.263 | 0.173 | 0 | | | | |
| 1223 | 1 | 6.994 | 0.081 | 0.016 | 1 | 2 | 6.491 | 0.850 | 0.195 |

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (b) | Single bubbles: Bubble width (b) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (b) | Merging bubbles: Site width (b) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 4.741 | 0.412 | 0.206 | | | | | |
| | | 7.000 | 0.103 | 0.026 | | | | | |
| 2274 | 2 | 4.228 | 0.655 | 0.334 | 0 | | | | |
| | | 6.999 | 0.112 | 0.031 | | | | | |
| 2317 | 1 | 4.208 | 0.390 | 0.195 | 0 | | | | |
| 2347 | 2 | 3.425 | 0.414 | 0.208 | 0 | | | | |
| | | 6.972 | 0.102 | 0.026 | | | | | |
| 2397 | 3 | 3.259 | 0.192 | 0.092 | 0 | | | | |
| | | 5.776 | 0.152 | 0.058 | | | | | |
| | | 7.009 | 0.075 | 0.014 | | | | | |
| 2437 | 4 | 3.411 | 0.347 | 0.172 | 0 | | | | |
| | | 5.476 | 0.280 | 0.196 | | | | | |
| | | 5.787 | 0.225 | 0.126 | | | | | |
| | | 6.989 | 0.074 | 0.014 | | | | | |
| 2473 | 1 | 6.970 | 0.091 | 0.021 | 1 | 4 | 6.127 | 1.497 | 0.329 |
| 2624 | 2 | 6.868 | 0.069 | 0.012 | 0 | | | | |
| | | 7.007 | 0.055 | 0.008 | | | | | |
| 2673 | 3 | 4.569 | 0.714 | 0.364 | 0 | | | | |
| | | 5.534 | 0.254 | 0.161 | | | | | |
| | | 6.986 | 0.100 | 0.025 | | | | | |
| 2705 | 4 | 3.436 | 0.332 | 0.164 | 0 | | | | |
| | | 4.609 | 0.087 | 0.019 | | | | | |
| | | 5.810 | 0.157 | 0.062 | | | | | |
| | | 6.982 | 0.094 | 0.022 | | | | | |
| 2745 | 4 | 3.245 | 0.181 | 0.082 | 1 | 2 | 5.673 | 0.512 | 0.082 |
| | | 3.909 | 0.657 | 0.335 | | | | | |
| | | 4.626 | 0.382 | 0.191 | | | | | |
| | | 7.003 | 0.097 | 0.023 | | | | | |
| 2790 | 3 | 3.862 | 0.351 | 0.174 | 0 | | | | |
| | | 4.572 | 0.189 | 0.089 | | | | | |
| | | 6.995 | 0.127 | 0.040 | | | | | |
| 2826 | 3 | 4.670 | 0.188 | 0.088 | 0 | | | | |
| | | 5.211 | 0.498 | 0.252 | | | | | |
| | | 7.017 | 0.111 | 0.031 | | | | | |
| 2864 | 2 | 5.328 | 0.333 | 0.164 | 0 | | | | |
| | | 6.973 | 0.128 | 0.041 | | | | | |
| 2907 | 4 | 3.278 | 0.232 | 0.134 | 0 | | | | |
| | | 4.572 | 0.168 | 0.070 | | | | | |
| | | 5.801 | 0.149 | 0.055 | | | | | |
| | | 7.019 | 0.087 | 0.019 | | | | | |
| 2953 | 4 | 3.407 | 0.371 | 0.185 | 0 | | | | |
| | | 4.227 | 0.315 | 0.248 | | | | | |
| | | 5.809 | 0.193 | 0.093 | | | | | |
| | | 6.981 | 0.118 | 0.035 | | | | | |
| 2993 | 1 | 6.958 | 0.142 | 0.050 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1261 | 1 | 6.930 | 0.073 | 0.013 | 0 | | | | |
| 1311 | 1 | 6.948 | 0.073 | 0.013 | 0 | | | | |
| 1359 | 3 | 3.411 | 0.245 | 0.150 | 1 | 2 | 5.565 | 0.391 | 0.048 |
| | | 5.817 | 0.071 | 0.013 | | | | | |
| | | 6.958 | 0.077 | 0.015 | | | | | |
| 1411 | 2 | 5.779 | 0.142 | 0.050 | 1 | 2 | 5.251 | 0.832 | 0.190 |
| | | 7.011 | 0.065 | 0.011 | | | | | |
| 1441 | 3 | 3.885 | 0.717 | 0.366 | 0 | | | | |
| | | 5.790 | 0.066 | 0.011 | | | | | |
| | | 6.934 | 0.109 | 0.030 | | | | | |
| 1486 | 3 | 3.778 | 0.422 | 0.212 | 0 | | | | |
| | | 4.719 | 0.811 | 0.415 | | | | | |
| | | 6.928 | 0.124 | 0.038 | | | | | |
| 1521 | 2 | 4.732 | 0.319 | 0.254 | 0 | | | | |
| | | 6.931 | 0.081 | 0.016 | | | | | |
| 1571 | 1 | 3.400 | 0.289 | 0.209 | 0 | | | | |
| 1600 | 2 | 5.793 | 0.228 | 0.130 | 0 | | | | |
| | | 6.929 | 0.153 | 0.058 | | | | | |
| 1640 | 1 | 4.226 | 0.597 | 0.303 | 1 | 3 | 6.717 | 0.679 | 0.096 |
| 1690 | 4 | 3.275 | 0.198 | 0.098 | 0 | | | | |
| | | 4.203 | 0.419 | 0.210 | | | | | |
| | | 5.808 | 0.260 | 0.169 | | | | | |
| | | 7.024 | 0.076 | 0.014 | | | | | |
| 1733 | 1 | 5.584 | 0.314 | 0.246 | 0 | | | | |
| 1766 | 1 | 7.020 | 0.075 | 0.014 | 0 | | | | |
| 1813 | 1 | 5.511 | 0.156 | 0.061 | 0 | | | | |
| 1858 | 2 | 3.304 | 0.248 | 0.154 | 0 | | | | |
| | | 7.001 | 0.075 | 0.014 | | | | | |
| 1890 | 1 | 7.022 | 0.083 | 0.017 | 0 | | | | |
| 1965 | 1 | 6.968 | 0.082 | 0.017 | 1 | 2 | 3.727 | 1.095 | 0.264 |
| 2000 | 3 | 3.866 | 0.379 | 0.189 | 0 | | | | |
| | | 5.504 | 0.180 | 0.081 | | | | | |
| | | 6.980 | 0.091 | 0.021 | | | | | |
| 2029 | 3 | 3.931 | 0.418 | 0.210 | 0 | | | | |
| | | 5.789 | 0.177 | 0.078 | | | | | |
| | | 6.996 | 0.116 | 0.034 | | | | | |
| 2069 | 3 | 5.172 | 0.148 | 0.055 | 1 | 2 | 5.734 | 0.644 | 0.129 |
| | | 6.218 | 0.240 | 0.144 | | | | | |
| | | 6.901 | 0.145 | 0.052 | | | | | |
| 2152 | 1 | 6.992 | 0.063 | 0.010 | 1 | 2 | 6.905 | 0.077 | 0.002 |
| 2192 | 1 | 4.748 | 0.763 | 0.390 | 0 | | | | |
| 2237 | 3 | 3.418 | 0.364 | 0.181 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3025 | 3 | 5.519 | 0.272 | 0.185 | 0 | | | | |
| | | 6.608 | 0.514 | 0.260 | | | | | |
| | | 7.015 | 0.099 | 0.024 | | | | | |
| 3063 | 2 | 6.614 | 0.365 | 0.181 | 0 | | | | |
| | | 6.988 | 0.154 | 0.059 | | | | | |
| 3146 | 1 | 7.031 | 0.079 | 0.016 | 0 | | | | |
| 3193 | 2 | 4.555 | 0.336 | 0.166 | 1 | 2 | 5.554 | 0.447 | 0.062 |
| | | 6.949 | 0.125 | 0.039 | | | | | |
| 3228 | 2 | 5.804 | 0.284 | 0.201 | 0 | | | | |
| | | 7.026 | 0.096 | 0.023 | | | | | |
| 3273 | 1 | 6.965 | 0.143 | 0.051 | 0 | | | | |
| 3313 | 1 | 6.989 | 0.091 | 0.021 | 1 | 2 | 5.295 | 0.944 | 0.222 |
| 3359 | 2 | 4.555 | 0.254 | 0.161 | 0 | | | | |
| | | 5.113 | 0.304 | 0.231 | | | | | |
| 3393 | 1 | 4.499 | 0.289 | 0.209 | 0 | | | | |
| 3423 | 0 | | | | 1 | 3 | 6.446 | 1.232 | 0.280 |
| 3473 | 2 | 5.489 | 0.129 | 0.042 | 0 | | | | |
| | | 6.990 | 0.079 | 0.016 | | | | | |
| 3513 | 4 | 3.297 | 0.270 | 0.182 | 0 | | | | |
| | | 3.885 | 0.626 | 0.319 | | | | | |
| | | 5.486 | 0.150 | 0.056 | | | | | |
| | | 6.972 | 0.084 | 0.018 | | | | | |
| 3548 | 4 | 3.809 | 0.157 | 0.062 | 0 | | | | |
| | | 4.527 | 0.604 | 0.307 | | | | | |
| | | 5.495 | 0.218 | 0.119 | | | | | |
| | | 6.969 | 0.099 | 0.024 | | | | | |
| 3593 | 2 | 4.548 | 0.353 | 0.175 | 0 | | | | |
| | | 6.968 | 0.086 | 0.018 | | | | | |
| 3743 | 2 | 3.220 | 0.139 | 0.048 | 0 | | | | |
| | | 4.169 | 0.571 | 0.290 | | | | | |
| 3776 | 2 | 4.175 | 0.386 | 0.193 | 0 | | | | |
| | | 6.954 | 0.099 | 0.024 | | | | | |
| 3820 | 3 | 4.558 | 0.099 | 0.024 | 0 | | | | |
| | | 5.691 | 0.088 | 0.019 | | | | | |
| | | 6.993 | 0.076 | 0.014 | | | | | |
| 3906 | 4 | 5.464 | 0.185 | 0.085 | 0 | | | | |
| | | 5.768 | 0.272 | 0.185 | | | | | |
| | | 6.584 | 0.307 | 0.235 | | | | | |
| | | 6.967 | 0.127 | 0.040 | | | | | |
| 3944 | 1 | 3.247 | 0.200 | 0.100 | 0 | | | | |
| 3987 | 1 | 4.536 | 0.395 | 0.197 | 0 | | | | |
| 4025 | 1 | 6.923 | 0.122 | 0.037 | 0 | | | | |

Total number of sample frames, k, 102.
Total number of single bubbles, h, 172.
Total number of merging bubbles, 51.
Average instantaneous bubble population, $n_{av}$, 2.19.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.109.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.0240.
Standard deviation associated with $\varphi_{m,av}$, 0.0649.

[a]This run was handled in a special manner: For each merging bubble group, the center of its width of influence is indicated. Depending on the comparison between this width of influence and the given base value of 100.00, one of two methods of computation was used in evaluating the average area fraction of merging bubbles. If the width was greater than the base value, the area of influence at each site was evaluated as one single area. If the width was less than or equal to the base value, the area of influence was evaluated by dividing the width by the number of merging bubbles at each site and summing the resulting areas.

[b]3.886 movie analyzer units equal 0.75 inch; left end reading, 3.146; right end reading, 7.032.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(d) Test fluid, water; run 62-12-4-5

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 5 | 3.324 | 0.387 | 0.192 | 0 | | | | |
| | | 4.492 | 0.316 | 0.247 | | | | | |
| | | 5.448 | 0.214 | 0.113 | | | | | |
| | | 5.746 | 0.253 | 0.158 | | | | | |
| | | 6.922 | 0.135 | 0.045 | | | | | |
| 30 | 4 | 3.352 | 0.541 | 0.273 | 0 | | | | |
| | | 4.519 | 0.348 | 0.171 | | | | | |
| | | 5.178 | 0.243 | 0.146 | | | | | |
| | | 6.931 | 0.117 | 0.034 | | | | | |
| 80 | 3 | 3.891 | 0.303 | 0.227 | 0 | | | | |
| | | 5.728 | 0.298 | 0.219 | | | | | |
| | | 6.852 | 0.133 | 0.044 | | | | | |
| 160 | 3 | 3.750 | 0.548 | 0.276 | 1 | 2 | 3.081 | 0.140 | 0.034 |
| | | 6.448 | 0.622 | 0.315 | | | 3.198 | 0.188 | |
| | | 6.854 | 0.143 | 0.051 | | | | | |
| 195 | 4 | 3.092 | 0.173 | 0.074 | 1 | 2 | 5.348 | 0.400 | 0.104 |
| | | 3.271 | 0.264 | 0.172 | | | 5.623 | 0.151 | |
| | | 4.397 | 0.428 | 0.214 | | | | | |
| | | 6.851 | 0.144 | 0.051 | | | | | |
| 240 | 2 | 4.404 | 0.560 | 0.283 | 1 | 3 | 5.006 | 0.572 | 0.232 |
| | | 6.821 | 0.202 | 0.101 | | | 5.456 | 0.329 | |
| | | | | | | | 5.725 | 0.209 | |
| 270 | 3 | 3.160 | 0.166 | 0.068 | 0 | | | | |
| | | 4.582 | 0.341 | 0.168 | | | | | |
| | | 6.960 | 0.049 | 0.006 | | | | | |
| 325 | 2 | 3.248 | 0.186 | 0.085 | 1 | 4 | 5.702 | 0.361 | 0.276 |
| | | 5.367 | 0.170 | 0.071 | | | 6.083 | 0.401 | |
| | | | | | | | 6.501 | 0.435 | |
| | | | | | | | 6.779 | 0.120 | |
| 365 | 3 | 3.134 | 0.118 | 0.034 | 0 | | | | |
| | | 4.465 | 0.629 | 0.318 | | | | | |
| | | 6.582 | 0.287 | 0.204 | | | | | |
| 400 | 4 | 3.870 | 0.912 | 0.464 | 0 | | | | |
| | | 4.538 | 0.425 | 0.212 | | | | | |
| | | 5.136 | 0.493 | 0.248 | | | | | |
| | | 6.833 | 0.128 | 0.040 | | | | | |
| 443 | 3 | 3.200 | 0.301 | 0.224 | 0 | | | | |
| | | 5.408 | 0.390 | 0.194 | | | | | |
| | | 6.889 | 0.143 | 0.051 | | | | | |
| 489 | 2 | 5.474 | 0.366 | 0.181 | 0 | | | | |
| | | 6.843 | 0.085 | 0.018 | | | | | |
| 519 | 1 | 5.637 | 0.255 | 0.161 | 1 | 2 | 6.426 | 0.520 | 0.156 |
| | | | | | | | 6.713 | 0.228 | |
| 601 | 4 | 3.110 | 0.113 | 0.032 | 0 | | | | |
| | | 4.504 | 0.430 | 0.215 | | | | | |
| | | 5.491 | 0.206 | 0.105 | | | | | |
| | | 6.036 | 0.243 | 0.146 | | | | | |
| 653 | 1 | 3.817 | 0.118 | 0.034 | 0 | | | | |
| 685 | 1 | 6.725 | 0.171 | 0.072 | 1 | 2 | 4.432 | 0.612 | 0.286 |
| | | | | | | | 5.022 | 0.569 | |
| 715 | 2 | 4.540 | 0.282 | 0.197 | 0 | | | | |
| | | 5.423 | 0.132 | 0.043 | | | | | |
| 754 | 4 | 3.843 | 0.680 | 0.345 | 0 | | | | |
| | | 5.688 | 0.243 | 0.146 | | | | | |
| | | 6.190 | 0.760 | 0.386 | | | | | |
| | | 6.906 | 0.119 | 0.035 | | | | | |
| 799 | 5 | 3.768 | 0.277 | 0.190 | 0 | | | | |
| | | 4.481 | 0.272 | 0.183 | | | | | |
| | | 5.719 | 0.123 | 0.037 | | | | | |
| | | 6.444 | 0.367 | 0.182 | | | | | |
| | | 6.916 | 0.100 | 0.025 | | | | | |
| 833 | 3 | 3.308 | 0.457 | 0.229 | 0 | | | | |
| | | 6.581 | 0.296 | 0.216 | | | | | |
| | | 6.826 | 0.195 | 0.094 | | | | | |
| 883 | 2 | 4.065 | 0.307 | 0.233 | 1 | 2 | 5.029 | 0.453 | 0.158 |
| | | 6.775 | 0.119 | 0.035 | | | 5.402 | 0.292 | |
| 927 | 4 | 3.308 | 0.250 | 0.154 | 0 | | | | |
| | | 4.513 | 0.292 | 0.211 | | | | | |
| | | 5.734 | 0.319 | 0.251 | | | | | |
| | | [illegible] | [illegible] | [illegible] | | | | | |

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 1 | 6.865 | 0.192 | 0.091 | 0 | | | | |
| 2029 | 5 | 3.315 | 0.407 | 0.203 | 0 | | | | |
| | | 3.787 | 0.536 | 0.270 | | | | | |
| | | 4.508 | 0.418 | 0.208 | | | | | |
| | | 5.133 | 0.391 | 0.194 | | | | | |
| | | 6.924 | 0.091 | 0.020 | | | | | |
| 2069 | 1 | 6.902 | 0.145 | 0.052 | 0 | | | | |
| 2117 | 4 | 3.139 | 0.158 | 0.062 | 0 | | | | |
| | | 3.325 | 0.214 | 0.113 | | | | | |
| | | 5.450 | 0.257 | 0.163 | | | | | |
| | | 6.548 | 0.423 | 0.211 | | | | | |
| 2152 | 3 | 3.839 | 0.224 | 0.124 | 0 | | | | |
| | | 4.536 | 0.377 | 0.187 | | | | | |
| | | 6.534 | 0.185 | 0.085 | | | | | |
| 2192 | 1 | 6.796 | 0.139 | 0.048 | 1 | 2 | 5.409 | 0.278 | 0.062 |
| | | | | | | | 5.623 | 0.151 | |
| 2237 | 0 | | | | 1 | 2 | 3.146 | 0.273 | 0.108 |
| | | | | | | | 3.300 | 0.316 | |
| 2274 | 1 | 5.022 | 0.193 | 0.092 | 1 | 2 | 5.369 | 0.294 | 0.068 |
| | | | | | | | 5.648 | 0.155 | |
| 2317 | 3 | 3.073 | 0.134 | 0.044 | 1 | 2 | 6.433 | 0.635 | 0.176 |
| | | 4.416 | 0.474 | 0.238 | | | 6.842 | 0.183 | |
| | | 5.368 | 0.221 | 0.121 | | | | | |
| 2347 | 3 | 5.452 | 0.268 | 0.177 | 0 | | | | |
| | | 5.771 | 0.260 | 0.167 | | | | | |
| | | 6.532 | 0.784 | 0.399 | | | | | |
| 2397 | 2 | 6.118 | 0.497 | 0.250 | 0 | | | | |
| | | 6.904 | 0.131 | 0.042 | | | | | |
| 2437 | 1 | 3.870 | 0.551 | 0.278 | 0 | | | | |
| 2473 | 3 | 3.797 | 0.271 | 0.181 | 0 | | | | |
| | | 4.494 | 0.455 | 0.228 | | | | | |
| | | 5.152 | 0.695 | 0.353 | | | | | |
| 2516 | 5 | 4.490 | 0.290 | 0.208 | 0 | | | | |
| | | 5.052 | 0.352 | 0.174 | | | | | |
| | | 5.746 | 0.145 | 0.052 | | | | | |
| | | 6.538 | 0.160 | 0.063 | | | | | |
| | | 6.921 | 0.097 | 0.023 | | | | | |
| 2551 | 3 | 3.541 | 0.342 | 0.168 | 0 | | | | |
| | | 6.486 | 0.236 | 0.138 | | | | | |
| | | 6.935 | 0.069 | 0.012 | | | | | |
| 2584 | 4 | 3.260 | 0.302 | 0.225 | 0 | | | | |
| | | 5.754 | 0.181 | 0.081 | | | | | |
| | | 6.517 | 0.186 | 0.085 | | | | | |
| | | 6.953 | 0.058 | 0.008 | | | | | |
| 2624 | 1 | 6.935 | 0.093 | 0.021 | 0 | | | | |
| 2673 | 2 | 5.435 | 0.108 | 0.029 | 0 | | | | |
| | | 6.830 | 0.137 | 0.046 | | | | | |
| 2745 | 3 | 5.436 | 0.083 | 0.017 | 0 | | | | |
| | | 6.003 | 0.543 | 0.274 | | | | | |
| | | 6.546 | 0.542 | 0.273 | | | | | |
| 2790 | 4 | 3.769 | 0.246 | 0.150 | 0 | | | | |
| | | 4.470 | 0.556 | 0.281 | | | | | |
| | | 6.518 | 0.077 | 0.015 | | | | | |
| | | 6.914 | 0.083 | 0.017 | | | | | |
| 2826 | 6 | 3.310 | 0.496 | 0.249 | 0 | | | | |
| | | 3.801 | 0.200 | 0.099 | | | | | |
| | | 4.493 | 0.230 | 0.131 | | | | | |
| | | 5.427 | 0.302 | 0.225 | | | | | |
| | | 5.723 | 0.189 | 0.088 | | | | | |
| | | 6.924 | 0.076 | 0.014 | | | | | |
| 2864 | 5 | 3.171 | 0.218 | 0.117 | 0 | | | | |
| | | 4.458 | 0.390 | 0.194 | | | | | |
| | | 5.429 | 0.443 | 0.222 | | | | | |
| | | 5.793 | 0.284 | 0.199 | | | | | |
| | | 6.901 | 0.122 | 0.037 | | | | | |
| 2907 | 1 | 6.904 | 0.116 | 0.033 | 0 | | | | |
| 2953 | 4 | 3.127 | 0.130 | 0.042 | 0 | | | | |
| | | 4.499 | 0.390 | 0.194 | | | | | |
| | | 5.117 | 0.242 | 0.145 | | | | | |
| | | 6.764 | 0.137 | 0.046 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | |
| | | 6.919 | 0.098 | 0.024 | | | | | |
| 1001 | 3 | 4.386 | 0.283 | 0.198 | 1 | 2 | 6.424 | 0.506 | 0.166 |
| | | 5.357 | 0.244 | 0.147 | | | 6.700 | 0.274 | |
| | | 5.637 | 0.185 | 0.085 | | | | | |
| 1033 | 4 | 3.248 | 0.281 | 0.195 | 1 | 3 | 5.362 | 0.265 | 0.181 |
| | | 3.738 | 0.588 | 0.297 | | | 5.619 | 0.248 | |
| | | 4.429 | 0.259 | 0.166 | | | 5.960 | 0.434 | |
| | | 6.539 | 0.326 | 0.160 | | | | | |
| 1063 | 3 | 3.177 | 0.217 | 0.116 | 0 | | | | |
| | | 3.781 | 0.262 | 0.170 | | | | | |
| | | 5.452 | 0.179 | 0.079 | | | | | |
| 1095 | 3 | 3.103 | 0.069 | 0.012 | 0 | | | | |
| | | 5.744 | 0.297 | 0.218 | | | | | |
| | | 6.891 | 0.157 | 0.061 | | | | | |
| 1140 | 3 | 4.596 | 0.240 | 0.142 | 0 | | | | |
| | | 5.448 | 0.194 | 0.093 | | | | | |
| | | 5.748 | 0.101 | 0.025 | | | | | |
| 1180 | 3 | 3.301 | 0.311 | 0.239 | 0 | | | | |
| | | 6.732 | 0.120 | 0.036 | | | | | |
| | | 6.921 | 0.109 | 0.029 | | | | | |
| 1223 | 3 | 4.079 | 0.766 | 0.389 | 1 | 2 | 3.048 | 0.111 | 0.042 |
| | | 5.357 | 0.109 | 0.029 | | | 3.221 | 0.235 | |
| | | 5.650 | 0.114 | 0.032 | | | | | |
| 1261 | 2 | 5.241 | 0.272 | 0.183 | 1 | 4 | 5.573 | 0.247 | 0.256 |
| | | 6.823 | 0.194 | 0.093 | | | 5.971 | 0.549 | |
| | | | | | | | 6.245 | 0.149 | |
| | | | | | | | 6.493 | 0.346 | |
| 1311 | 4 | 3.808 | 0.362 | 0.179 | 0 | | | | |
| | | 4.496 | 0.282 | 0.197 | | | | | |
| | | 5.468 | 0.226 | 0.126 | | | | | |
| | | 5.732 | 0.135 | 0.045 | | | | | |
| 1359 | 2 | 3.809 | 0.318 | 0.250 | 0 | | | | |
| | | 4.440 | 0.380 | 0.188 | | | | | |
| 1411 | 3 | 5.059 | 0.395 | 0.196 | 0 | | | | |
| | | 5.442 | 0.371 | 0.184 | | | | | |
| | | 6.932 | 0.080 | 0.016 | | | | | |
| 1486 | 2 | 5.705 | 0.154 | 0.059 | 0 | | | | |
| | | 6.509 | 0.597 | 0.302 | | | | | |
| 1521 | 3 | 3.822 | 0.281 | 0.195 | 0 | | | | |
| | | 5.723 | 0.235 | 0.136 | | | | | |
| | | 6.479 | 0.211 | 0.110 | | | | | |
| 1571 | 2 | 4.508 | 0.614 | 0.311 | 0 | | | | |
| | | 6.790 | 0.164 | 0.066 | | | | | |
| 1600 | 1 | 4.493 | 0.395 | 0.196 | 0 | | | | |
| 1640 | 1 | 6.707 | 0.166 | 0.068 | 3 | 2 | 3.129 | 0.251 | 0.529 |
| | | | | | | | 3.532 | 0.555 | |
| | | | | | | 2 | 4.069 | 0.355 | |
| | | | | | | | 4.414 | 0.335 | |
| | | | | | | 3 | 5.386 | 0.123 | |
| | | | | | | | 5.611 | 0.327 | |
| | | | | | | | 6.058 | 0.567 | |
| 1733 | 1 | 3.319 | 0.210 | 0.109 | 0 | | | | |
| 1766 | 3 | 3.824 | 0.114 | 0.032 | 0 | | | | |
| | | 4.497 | 0.287 | 0.204 | | | | | |
| | | 5.454 | 0.436 | 0.218 | | | | | |
| 1813 | 4 | 3.812 | 0.105 | 0.027 | 0 | | | | |
| | | 5.057 | 0.368 | 0.182 | | | | | |
| | | 5.415 | 0.348 | 0.171 | | | | | |
| | | 6.881 | 0.131 | 0.042 | | | | | |
| 1858 | 3 | 3.241 | 0.231 | 0.132 | 1 | 2 | 4.057 | 0.322 | 0.130 |
| | | 5.670 | 0.223 | 0.123 | | | 4.428 | 0.328 | |
| | | 6.887 | 0.074 | 0.014 | | | | | |
| 1890 | 5 | 4.266 | 0.231 | 0.132 | 0 | | | | |
| | | 5.444 | 0.192 | 0.091 | | | | | |
| | | 5.721 | 0.132 | 0.043 | | | | | |
| | | 6.530 | 0.244 | 0.147 | | | | | |
| | | 6.927 | 0.084 | 0.017 | | | | | |
| 1927 | 2 | 5.303 | 0.269 | 0.179 | 1 | 2 | 5.647 | 0.324 | 0.169 |
| | | 6.846 | 0.126 | 0.039 | | | 6.034 | 0.450 | |
| 1965 | 5 | 3.820 | 0.345 | 0.170 | 0 | | | | |
| | | 4.481 | 0.281 | 0.195 | | | | | |
| | | 5.473 | 0.347 | 0.171 | | | | | |
| | | 6.087 | 0.168 | 0.070 | | | | | |
| | | 6.920 | 0.097 | 0.023 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2993 | 1 | 3.209 | 0.400 | 0.199 | 1 | 2 | 4.218 | 0.724 | 0.326 |
| | | | | | | | 4.883 | 0.606 | |
| 3025 | 3 | 3.823 | 0.357 | 0.176 | 0 | | | | |
| | | 4.196 | 0.389 | 0.193 | | | | | |
| | | 4.995 | 0.301 | 0.224 | | | | | |
| 3063 | 2 | 3.841 | 0.224 | 0.124 | 0 | | | | |
| | | 4.475 | 0.218 | 0.117 | | | | | |
| 3103 | 1 | 3.161 | 0.179 | 0.079 | 0 | | | | |
| 3146 | 4 | 4.489 | 0.572 | 0.289 | 0 | | | | |
| | | 6.091 | 0.547 | 0.276 | | | | | |
| | | 6.574 | 0.419 | 0.209 | | | | | |
| | | 6.895 | 0.119 | 0.035 | | | | | |
| 3193 | 3 | 3.843 | 0.504 | 0.254 | 0 | | | | |
| | | 4.469 | 0.243 | 0.146 | | | | | |
| | | 5.739 | 0.187 | 0.086 | | | | | |
| 3228 | 3 | 3.815 | 0.317 | 0.248 | 0 | | | | |
| | | 5.735 | 0.224 | 0.124 | | | | | |
| | | 6.823 | 0.167 | 0.069 | | | | | |
| 3273 | 5 | 4.459 | 0.250 | 0.154 | 0 | | | | |
| | | 5.114 | 0.363 | 0.179 | | | | | |
| | | 5.425 | 0.162 | 0.065 | | | | | |
| | | 5.751 | 0.210 | 0.109 | | | | | |
| | | 6.928 | 0.079 | 0.015 | | | | | |
| 3313 | 3 | 3.318 | 0.364 | 0.180 | 0 | | | | |
| | | 6.447 | 0.377 | 0.187 | | | | | |
| | | 6.937 | 0.077 | 0.015 | | | | | |
| 3359 | 3 | 6.035 | 0.403 | 0.201 | 0 | | | | |
| | | 6.476 | 0.240 | 0.142 | | | | | |
| | | 6.889 | 0.174 | 0.075 | | | | | |
| 3393 | 2 | 3.335 | 0.529 | 0.267 | 0 | | | | |
| | | 6.923 | 0.105 | 0.027 | | | | | |
| 3473 | 1 | 5.707 | 0.206 | 0.105 | 0 | | | | |
| 3513 | 4 | 4.468 | 0.118 | 0.034 | 0 | | | | |
| | | 5.124 | 0.187 | 0.086 | | | | | |
| | | 5.420 | 0.287 | 0.204 | | | | | |
| | | 5.713 | 0.151 | 0.056 | | | | | |
| 3548 | 4 | 3.840 | 0.130 | 0.042 | 0 | | | | |
| | | 5.742 | 0.244 | 0.147 | | | | | |
| | | 6.456 | 0.391 | 0.194 | | | | | |
| | | 6.842 | 0.204 | 0.103 | | | | | |
| 3593 | 3 | 3.832 | 0.233 | 0.134 | 0 | | | | |
| | | 5.747 | 0.122 | 0.037 | | | | | |
| | | 6.579 | 0.199 | 0.098 | | | | | |
| 3636 | 6 | 3.307 | 0.277 | 0.190 | 0 | | | | |
| | | 4.496 | 0.464 | 0.233 | | | | | |
| | | 5.377 | 0.391 | 0.194 | | | | | |
| | | 5.699 | 0.252 | 0.157 | | | | | |
| | | 6.126 | 0.602 | 0.304 | | | | | |
| | | 6.910 | 0.146 | 0.053 | | | | | |
| 3674 | 1 | 6.745 | 0.189 | 0.088 | 2 | 2 | 4.009 | 0.449 | 0.354 |
| | | | | | | | 4.450 | 0.433 | |
| | | | | | | 2 | 5.049 | 0.472 | |
| | | | | | | | 5.412 | 0.255 | |
| 3705 | 2 | 3.234 | 0.319 | 0.251 | 1 | 2 | 4.212 | 0.164 | 0.036 |
| | | 6.858 | 0.145 | 0.052 | | | 4.383 | 0.179 | |
| 3743 | 2 | 3.144 | 0.180 | 0.080 | 0 | | | | |
| | | 3.824 | 0.631 | 0.319 | | | | | |
| 3776 | 5 | 3.304 | 0.254 | 0.159 | 0 | | | | |
| | | 3.795 | 0.221 | 0.121 | | | | | |
| | | 4.467 | 0.153 | 0.058 | | | | | |
| | | 5.436 | 0.179 | 0.079 | | | | | |
| | | 6.921 | 0.117 | 0.034 | | | | | |
| 3820 | 2 | 5.433 | 0.191 | 0.090 | 0 | | | | |
| | | 6.860 | 0.136 | 0.046 | | | | | |
| 3858 | 1 | 6.823 | 0.149 | 0.055 | 1 | 2 | 4.346 | 0.292 | 0.132 |
| | | | | | | | 4.674 | 0.365 | |
| 3906 | 2 | 3.280 | 0.238 | 0.140 | 0 | | | | |
| | | 5.708 | 0.206 | 0.105 | | | | | |
| 3944 | 2 | 5.709 | 0.125 | 0.039 | 0 | | | | |
| | | 6.539 | 0.110 | 0.030 | | | | | |
| 3987 | 5 | 3.327 | 0.404 | 0.201 | 0 | | | | |
| | | 5.063 | 0.219 | 0.119 | | | | | |
| | | 5.456 | 0.255 | 0.161 | | | | | |
| | | 5.756 | 0.193 | 0.092 | | | | | |
| | | 6.929 | 0.110 | 0.030 | | | | | |

Total number of sample frames, k, 99.
Total number of single bubbles, h, 268.
Total number of merging bubbles, 57.
Average instantaneous bubble population, $n_{av}$, 3.28.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.138.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.0402.
Standard deviation associated with $\varphi_{m,av}$, 0.0936.

[a]3.906 movie analyzer units equal 0.75 inch; left end reading, 3.070; right end reading, 6.976.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(e) Test fluid, water; run 62-12-4-6

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 0 | 1 | 6.886 | 0.064 | 0.010 | 0 | | | | |
| 30 | 0 | | | | 1 | 2 | 6.712 | 0.116 | 0.014 |
| | | | | | | | 6.782 | 0.097 | |
| 80 | 2 | 3.651 | 0.297 | 0.217 | 0 | | | | |
| | | 6.824 | 0.144 | 0.051 | | | | | |
| 120 | 3 | 3.089 | 0.204 | 0.102 | 0 | | | | |
| | | 5.378 | 0.222 | 0.121 | | | | | |
| | | 6.890 | 0.069 | 0.012 | | | | | |
| 160 | 1 | 6.877 | 0.095 | 0.022 | 0 | | | | |
| 195 | 2 | 3.161 | 0.449 | 0.224 | 0 | | | | |
| | | 6.753 | 0.097 | 0.023 | | | | | |
| 240 | 1 | 6.835 | 0.103 | 0.026 | 0 | | | | |
| 270 | 1 | 6.878 | 0.107 | 0.028 | 0 | | | | |
| 325 | 1 | 6.343 | 0.250 | 0.154 | 1 | 2 | 5.258 | 0.238 | 0.053 |
| | | | | | | | 5.528 | 0.172 | |
| 365 | 8 | 3.221 | 0.308 | 0.234 | 0 | | | | |
| | | 3.626 | 0.502 | 0.252 | | | | | |
| | | 4.114 | 0.475 | 0.238 | | | | | |
| | | 5.363 | 0.343 | 0.168 | | | | | |
| | | 5.685 | 0.174 | 0.075 | | | | | |
| | | 5.984 | 0.424 | 0.211 | | | | | |
| | | 6.402 | 0.326 | 0.262 | | | | | |
| | | 6.816 | 0.179 | 0.079 | | | | | |
| 400 | 3 | 3.065 | 0.166 | 0.068 | 0 | | | | |
| | | 6.694 | 0.126 | 0.039 | | | | | |
| | | 6.814 | 0.114 | 0.032 | | | | | |
| 443 | 2 | 3.241 | 0.412 | 0.205 | 0 | | | | |
| | | 6.876 | 0.072 | 0.013 | | | | | |
| 489 | 1 | 3.245 | 0.465 | 0.233 | 0 | | | | |
| 519 | 1 | 5.670 | 0.099 | 0.024 | 0 | | | | |
| 564 | 2 | 6.419 | 0.297 | 0.217 | 0 | | | | |
| | | 6.870 | 0.093 | 0.021 | | | | | |
| 601 | 1 | 4.417 | 0.410 | 0.204 | 0 | | | | |
| 653 | 2 | 4.537 | 0.519 | 0.261 | 1 | 2 | 5.379 | 0.130 | 0.190 |
| | | 6.721 | 0.190 | 0.089 | | | 5.870 | 0.729 | |
| 685 | 2 | 6.012 | 0.235 | 0.136 | 0 | | | | |
| | | 6.845 | 0.150 | 0.055 | | | | | |
| 715 | 2 | 4.450 | 0.354 | 0.174 | 0 | | | | |
| | | 5.398 | 0.309 | 0.235 | | | | | |
| 799 | 2 | 4.123 | 0.520 | 0.261 | 0 | | | | |
| | | 6.934 | 0.070 | 0.012 | | | | | |
| 833 | 1 | 6.918 | 0.102 | 0.026 | 0 | | | | |
| 883 | 2 | 4.305 | 0.346 | 0.170 | 2 | 3 | 4.669 | 0.288 | 0.181 |
| | | 6.428 | 0.226 | 0.126 | | | 4.881 | 0.136 | |
| | | | | | | | 5.186 | 0.474 | |
| | | | | | | 2 | 6.744 | 0.083 | |
| | | | | | | | 6.823 | 0.074 | |
| 927 | 2 | 3.279 | 0.238 | 0.139 | 0 | | | | |
| | | 6.869 | 0.135 | 0.045 | | | | | |
| 2000 | 1 | 6.895 | 0.128 | 0.040 | 0 | | | | |
| 2029 | 1 | 3.769 | 0.606 | 0.306 | 0 | | | | |
| 2069 | 1 | 3.692 | 0.285 | 0.200 | 2 | 2 | 5.432 | 0.204 | 0.296 |
| | | | | | | | 5.651 | 0.234 | |
| | | | | | | 2 | 5.938 | 0.341 | |
| | | | | | | | 6.447 | 0.677 | |
| 2117 | 2 | 4.414 | 0.383 | 0.190 | 0 | | | | |
| | | 5.378 | 0.191 | 0.090 | | | | | |
| 2192 | 3 | 3.098 | 0.146 | 0.052 | 0 | | | | |
| | | 3.299 | 0.256 | 0.161 | | | | | |
| | | 5.080 | 0.324 | 0.258 | | | | | |
| 2237 | 1 | 6.841 | 0.115 | 0.033 | 0 | | | | |
| 2274 | 2 | 4.090 | 0.152 | 0.057 | 0 | | | | |
| | | 5.684 | 0.116 | 0.033 | | | | | |
| 2317 | 4 | 5.068 | 0.483 | 0.242 | 0 | | | | |
| | | 5.427 | 0.234 | 0.135 | | | | | |
| | | 5.712 | 0.162 | 0.065 | | | | | |
| | | 6.925 | 0.066 | 0.011 | | | | | |
| 2347 | 3 | 3.253 | 0.198 | 0.097 | 0 | | | | |
| | | 5.389 | 0.199 | 0.098 | | | | | |
| | | 5.697 | 0.271 | 0.181 | | | | | |
| 2397 | 1 | 3.145 | 0.238 | 0.139 | 0 | | | | |
| 2437 | 1 | 3.773 | 0.229 | 0.129 | 0 | | | | |
| 2473 | 1 | 5.385 | 0.167 | 0.069 | 0 | | | | |
| 2516 | 4 | 3.297 | 0.435 | 0.217 | 0 | | | | |
| | | 5.389 | 0.271 | 0.181 | | | | | |
| | | 5.680 | 0.311 | 0.238 | | | | | |
| | | 6.743 | 0.134 | 0.044 | | | | | |
| 2551 | 3 | 5.354 | 0.294 | 0.213 | 0 | | | | |
| | | 5.674 | 0.346 | 0.170 | | | | | |
| | | 6.458 | 0.506 | 0.254 | | | | | |
| 2584 | 4 | 4.468 | 0.325 | 0.260 | 0 | | | | |
| | | 5.403 | 0.167 | 0.069 | | | | | |
| | | 6.498 | 0.178 | 0.078 | | | | | |
| | | 6.934 | 0.075 | 0.014 | | | | | |
| 2624 | 2 | 3.055 | 0.207 | 0.105 | 1 | 2 | 3.155 | 0.378 | 0.232 |
| | | 4.601 | 0.450 | 0.225 | | | 3.703 | 0.615 | |
| 2673 | 1 | 3.729 | 0.331 | 0.162 | 0 | | | | |
| 2790 | 1 | 6.921 | 0.099 | 0.024 | 0 | | | | |
| 2826 | 1 | 5.411 | 0.315 | 0.244 | 0 | | | | |
| 2864 | 1 | 4.373 | 0.316 | 0.246 | 1 | 2 | 3.027 | 0.158 | 0.040 |
| | | | | | | | 3.163 | 0.199 | |
| 2907 | 2 | 6.385 | 0.432 | 0.215 | 1 | 2 | 5.076 | 0.341 | 0.118 |
| | | 6.788 | 0.115 | 0.033 | | | 5.385 | 0.277 | |
| 2953 | 3 | 3.236 | 0.140 | 0.048 | 0 | | | | |
| | | 4.436 | 0.168 | 0.069 | | | | | |
| | | 6.471 | 0.229 | 0.129 | | | | | |
| 2993 | 2 | 5.390 | 0.188 | 0.087 | 0 | | | | |
| | | 5.683 | 0.126 | 0.039 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1001 | 1 | 5.692 | 0.229 | 0.129 | 0 | | | | |
| 1033 | 3 | 3.014 | 0.143 | 0.050 | 1 | 2 | 5.300 | 0.198 | 0.072 |
| | | 6.377 | 0.548 | 0.276 | | | 5.589 | 0.279 | |
| | | 6.803 | 0.102 | 0.026 | | | | | |
| 1063 | 6 | 3.265 | 0.263 | 0.170 | 0 | | | | |
| | | 3.804 | 0.345 | 0.170 | | | | | |
| | | 4.445 | 0.179 | 0.079 | | | | | |
| | | 5.105 | 0.442 | 0.221 | | | | | |
| | | 5.699 | 0.240 | 0.142 | | | | | |
| | | 6.514 | 0.208 | 0.107 | | | | | |
| 1095 | 3 | 3.827 | 0.198 | 0.097 | 0 | | | | |
| | | 6.510 | 0.103 | 0.026 | | | | | |
| | | 6.923 | 0.091 | 0.020 | | | | | |
| 1140 | 2 | 4.335 | 0.273 | 0.184 | 2 | 2 | 3.046 | 0.229 | 0.168 |
| | | 6.803 | 0.132 | 0.043 | | | 3.213 | 0.230 | |
| | | | | | | 3 | 5.246 | 0.137 | |
| | | | | | | | 5.529 | 0.225 | |
| | | | | | | | 5.881 | 0.314 | |
| 1180 | 2 | 4.096 | 0.629 | 0.318 | 0 | | | | |
| | | 6.915 | 0.086 | 0.018 | | | | | |
| 1223 | 4 | 3.789 | 0.224 | 0.124 | 0 | | | | |
| | | 5.391 | 0.215 | 0.114 | | | | | |
| | | 6.452 | 0.080 | 0.016 | | | | | |
| | | 6.937 | 0.064 | 0.010 | | | | | |
| 1261 | 3 | 5.413 | 0.261 | 0.168 | 0 | | | | |
| | | 6.632 | 0.088 | 0.019 | | | | | |
| | | 6.920 | 0.097 | 0.023 | | | | | |
| 1311 | 1 | 5.386 | 0.291 | 0.208 | 0 | | | | |
| 1359 | 3 | 3.309 | 0.551 | 0.277 | 0 | | | | |
| | | 3.820 | 0.470 | 0.235 | | | | | |
| | | 5.118 | 0.601 | 0.303 | | | | | |
| 1411 | 1 | 6.445 | 0.600 | 0.303 | 0 | | | | |
| 1441 | 1 | 6.485 | 0.258 | 0.164 | 0 | | | | |
| 1486 | 2 | 5.670 | 0.107 | 0.028 | 0 | | | | |
| | | 6.852 | 0.072 | 0.013 | | | | | |
| 1521 | 3 | 3.743 | 0.163 | 0.065 | 0 | | | | |
| | | 5.375 | 0.196 | 0.095 | | | | | |
| | | 5.651 | 0.162 | 0.065 | | | | | |
| 1640 | 2 | 3.101 | 0.198 | 0.097 | 1 | 3 | 5.198 | 0.204 | 0.196 |
| | | 4.284 | 0.262 | 0.169 | | | 5.508 | 0.317 | |
| | | | | | | | 5.900 | 0.466 | |
| 1733 | 1 | 6.884 | 0.100 | 0.025 | 0 | | | | |
| 1766 | 2 | 3.229 | 0.328 | 0.160 | 0 | | | | |
| | | 6.474 | 0.305 | 0.229 | | | | | |
| 1813 | 1 | 6.866 | 0.106 | 0.028 | 0 | | | | |
| 1858 | 2 | 3.150 | 0.417 | 0.208 | 1 | 2 | 5.305 | 0.242 | 0.063 |
| | | 6.774 | 0.141 | 0.049 | | | 5.583 | 0.209 | |
| 1890 | 6 | 3.207 | 0.271 | 0.181 | 0 | | | | |
| | | 3.751 | 0.313 | 0.241 | | | | | |
| | | 4.391 | 0.200 | 0.098 | | | | | |
| | | 5.055 | 0.403 | 0.200 | | | | | |
| | | 5.401 | 0.288 | 0.204 | | | | | |
| | | 5.691 | 0.188 | 0.087 | | | | | |
| 1927 | 1 | 6.874 | 0.112 | 0.031 | 0 | | | | |
| 1965 | 1 | 6.800 | 0.137 | 0.046 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3025 | 3 | 5.388 | 0.110 | 0.030 | 0 | | | | |
| | | 5.682 | 0.115 | 0.033 | | | | | |
| | | 5.988 | 0.108 | 0.029 | | | | | |
| 3063 | 2 | 3.195 | 0.215 | 0.114 | 1 | 2 | 4.061 | 0.394 | 0.122 |
| | | 5.333 | 0.165 | 0.067 | | | 4.427 | 0.237 | |
| 3103 | 4 | 3.129 | 0.213 | 0.112 | 0 | | | | |
| | | 4.084 | 0.300 | 0.222 | | | | | |
| | | 5.098 | 0.333 | 0.163 | | | | | |
| | | 5.430 | 0.219 | 0.118 | | | | | |
| 3273 | 6 | 3.767 | 0.263 | 0.170 | 0 | | | | |
| | | 4.429 | 0.268 | 0.177 | | | | | |
| | | 5.052 | 0.323 | 0.257 | | | | | |
| | | 5.396 | 0.268 | 0.177 | | | | | |
| | | 5.689 | 0.087 | 0.019 | | | | | |
| | | 6.498 | 0.200 | 0.098 | | | | | |
| 3313 | 2 | 3.788 | 0.114 | 0.032 | 0 | | | | |
| | | 6.887 | 0.121 | 0.036 | | | | | |
| 3393 | 1 | 6.844 | 0.101 | 0.025 | 0 | | | | |
| 3423 | 2 | 3.267 | 0.352 | 0.173 | 0 | | | | |
| | | 4.460 | 0.424 | 0.211 | | | | | |
| 3513 | 1 | 5.463 | 0.093 | 0.021 | 0 | | | | |
| 3548 | 2 | 3.749 | 0.786 | 0.399 | 0 | | | | |
| | | 6.873 | 0.143 | 0.050 | | | | | |
| 3593 | 2 | 5.058 | 0.355 | 0.175 | 0 | | | | |
| | | 6.480 | 0.276 | 0.188 | | | | | |
| 3636 | 3 | 4.438 | 0.203 | 0.101 | 0 | | | | |
| | | 6.011 | 0.583 | 0.294 | | | | | |
| | | 6.792 | 0.312 | 0.240 | | | | | |
| 3674 | 1 | 6.874 | 0.094 | 0.022 | 0 | | | | |
| 3705 | 2 | 4.653 | 0.197 | 0.096 | 0 | | | | |
| | | 5.408 | 0.308 | 0.234 | | | | | |
| 3743 | 4 | 3.129 | 0.175 | 0.075 | 0 | | | | |
| | | 3.331 | 0.229 | 0.129 | | | | | |
| | | 4.677 | 0.237 | 0.138 | | | | | |
| | | 5.411 | 0.284 | 0.199 | | | | | |
| 3776 | 3 | 4.478 | 0.187 | 0.086 | 0 | | | | |
| | | 4.717 | 0.290 | 0.207 | | | | | |
| | | 6.943 | 0.070 | 0.012 | | | | | |
| 3820 | 1 | 6.908 | 0.119 | 0.035 | 0 | | | | |
| 3858 | 1 | 5.443 | 0.323 | 0.257 | 0 | | | | |
| 3906 | 4 | 4.105 | 0.594 | 0.300 | 0 | | | | |
| | | 4.524 | 0.244 | 0.147 | | | | | |
| | | 6.496 | 0.545 | 0.274 | | | | | |
| | | 6.876 | 0.079 | 0.015 | | | | | |
| 3944 | 2 | 4.125 | 0.373 | 0.184 | 0 | | | | |
| | | 6.529 | 0.183 | 0.082 | | | | | |
| 3987 | 3 | 3.281 | 0.130 | 0.042 | 0 | | | | |
| | | 5.385 | 0.202 | 0.100 | | | | | |
| | | 5.690 | 0.152 | 0.057 | | | | | |
| 4025 | 5 | 3.794 | 0.292 | 0.210 | 0 | | | | |
| | | 4.441 | 0.244 | 0.147 | | | | | |
| | | 5.388 | 0.265 | 0.173 | | | | | |
| | | 5.699 | 0.249 | 0.153 | | | | | |
| | | 6.920 | 0.086 | 0.018 | | | | | |

Total number of sample frames, k, 102.
Total number of single bubbles, h, 193.
Total number of merging bubbles, 35.
Average instantaneous bubble population, $n_{av}$, 2.24.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.128.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.0171.
Standard deviation associated with $\varphi_{m,av}$, 0.0533.

[a]3.913 movie analyzer units equal 0.75 inch; left end reading, 3.032; right end reading, 6.945.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(f) Test fluid, methanol; run 63-1-14-6

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 30 | 1 | 6.318 | 0.323 | 0.239 | 1 | 3 | 3.141 | 0.231 | 0.105 |
| | | | | | | | 3.265 | 0.242 | |
| | | | | | | | 3.519 | 0.266 | |
| 80 | 4 | 3.285 | 0.298 | 0.204 | 0 | | | | |
| | | 3.590 | 0.313 | 0.225 | | | | | |
| | | 5.301 | 0.428 | 0.206 | | | | | |
| | | 6.392 | 0.272 | 0.170 | | | | | |
| 120 | 4 | 3.204 | 0.125 | 0.036 | 0 | | | | |
| | | 4.351 | 0.423 | 0.203 | | | | | |
| | | 5.008 | 0.453 | 0.218 | | | | | |
| | | 5.468 | 0.467 | 0.225 | | | | | |
| 160 | 2 | 3.270 | 0.248 | 0.141 | 0 | | | | |
| | | 7.024 | 0.273 | 0.171 | | | | | |
| 195 | 4 | 3.302 | 0.293 | 0.197 | 0 | | | | |
| | | 4.363 | 0.261 | 0.156 | | | | | |
| | | 5.685 | 0.518 | 0.251 | | | | | |
| | | 7.024 | 0.240 | 0.132 | | | | | |
| 240 | 1 | 7.019 | 0.236 | 0.128 | 0 | | | | |
| 270 | 3 | 3.235 | 0.186 | 0.079 | 0 | | | | |
| | | 5.669 | 0.271 | 0.168 | | | | | |
| | | 7.036 | 0.230 | 0.121 | | | | | |
| 325 | 3 | 3.283 | 0.327 | 0.245 | 0 | | | | |
| | | 6.313 | 0.166 | 0.063 | | | | | |
| | | 7.027 | 0.247 | 0.140 | | | | | |
| 365 | 2 | 6.371 | 0.374 | 0.178 | 1 | 3 | 3.159 | 0.283 | 0.113 |
| | | 6.933 | 0.091 | 0.019 | | | 3.341 | 0.202 | |
| | | | | | | | 3.546 | 0.276 | |
| 400 | 3 | 3.272 | 0.277 | 0.176 | 0 | | | | |
| | | 3.780 | 0.488 | 0.236 | | | | | |
| | | 7.036 | 0.116 | 0.031 | | | | | |
| 443 | 2 | 3.270 | 0.251 | 0.145 | 0 | | | | |
| | | 3.819 | 0.104 | 0.025 | | | | | |
| 489 | 3 | 3.282 | 0.224 | 0.115 | 0 | | | | |
| | | 5.395 | 0.507 | 0.245 | | | | | |
| | | 7.030 | 0.168 | 0.065 | | | | | |
| 519 | 4 | 3.278 | 0.263 | 0.159 | 0 | | | | |
| | | 5.395 | 0.325 | 0.242 | | | | | |
| | | 6.295 | 0.264 | 0.160 | | | | | |
| | | 7.026 | 0.126 | 0.036 | | | | | |
| 564 | 3 | 3.289 | 0.277 | 0.176 | 0 | | | | |
| | | 5.483 | 0.427 | 0.205 | | | | | |
| | | 6.308 | 0.223 | 0.114 | | | | | |
| | | 7.061 | 0.234 | 0.126 | | | | | |
| 1180 | 4 | 3.256 | 0.418 | 0.200 | 1 | 2 | 3.601 | 0.273 | 0.131 |
| | | 5.211 | 0.343 | 0.162 | | | 3.759 | 0.409 | |
| | | 5.557 | 0.349 | 0.165 | | | | | |
| | | 6.953 | 0.202 | 0.094 | | | | | |
| 1223 | 6 | 3.263 | 0.165 | 0.062 | 0 | | | | |
| | | 3.835 | 0.396 | 0.189 | | | | | |
| | | 5.700 | 0.311 | 0.222 | | | | | |
| | | 6.097 | 0.279 | 0.179 | | | | | |
| | | 6.419 | 0.188 | 0.081 | | | | | |
| | | 7.061 | 0.217 | 0.108 | | | | | |
| 1261 | 2 | 3.274 | 0.105 | 0.025 | 0 | | | | |
| | | 7.062 | 0.226 | 0.117 | | | | | |
| 1311 | 3 | 4.259 | 0.844 | 0.414 | 1 | 2 | 3.158 | 0.210 | 0.068 |
| | | 6.002 | 0.228 | 0.119 | | | 3.399 | 0.273 | |
| | | 6.949 | 0.277 | 0.176 | | | | | |
| 1359 | 3 | 4.158 | 0.769 | 0.376 | 2 | 3 | 3.207 | 0.271 | 0.461 |
| | | 5.969 | 0.398 | 0.190 | | | 3.325 | 0.323 | |
| | | 6.950 | 0.224 | 0.115 | | | 3.674 | 0.375 | |
| | | | | | | 3 | 4.999 | 0.695 | |
| | | | | | | | 4.915 | 0.329 | |
| | | | | | | | 5.501 | 0.309 | |
| 1411 | 2 | 3.313 | 0.130 | 0.039 | 0 | | | | |
| | | 7.054 | 0.300 | 0.206 | | | | | |
| 1441 | 5 | 3.602 | 0.239 | 0.131 | 0 | | | | |
| | | 4.387 | 0.312 | 0.223 | | | | | |
| | | 6.085 | 0.285 | 0.186 | | | | | |
| | | 6.435 | 0.117 | 0.031 | | | | | |
| | | 7.069 | 0.107 | 0.026 | | | | | |
| 1486 | 3 | 3.347 | 0.366 | 0.174 | 0 | | | | |
| | | 3.626 | 0.193 | 0.085 | | | | | |
| | | 4.512 | 0.646 | 0.315 | | | | | |
| 1521 | 3 | 3.206 | 0.197 | 0.089 | 1 | 3 | 6.008 | 0.316 | 0.149 |
| | | 3.719 | 0.137 | 0.043 | | | 6.175 | 0.260 | |
| | | 6.958 | 0.269 | 0.166 | | | 6.375 | 0.303 | |
| 1600 | 5 | 3.304 | 0.210 | 0.101 | 0 | | | | |
| | | 3.570 | 0.172 | 0.068 | | | | | |
| | | 4.380 | 0.316 | 0.229 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 3.787 | 0.223 | 0.114 | | | | | |
| | | 7.042 | 0.249 | 0.142 | | | | | |
| 601 | 3 | 3.324 | 0.272 | 0.170 | 0 | | | | |
| | | 3.774 | 0.229 | 0.120 | | | | | |
| | | 7.048 | 0.243 | 0.135 | | | | | |
| 653 | 2 | 3.305 | 0.163 | 0.061 | 0 | | | | |
| | | 3.787 | 0.422 | 0.202 | | | | | |
| 685 | 2 | 3.301 | 0.286 | 0.188 | 0 | | | | |
| | | 3.803 | 0.433 | 0.208 | | | | | |
| 715 | 5 | 3.348 | 0.258 | 0.153 | 0 | | | | |
| | | 3.606 | 0.258 | 0.153 | | | | | |
| | | 5.439 | 0.395 | 0.189 | | | | | |
| | | 6.320 | 0.386 | 0.184 | | | | | |
| | | 7.065 | 0.282 | 0.182 | | | | | |
| 754 | 4 | 3.610 | 0.085 | 0.017 | 0 | | | | |
| | | 5.592 | 0.270 | 0.167 | | | | | |
| | | 6.257 | 0.504 | 0.244 | | | | | |
| | | 7.022 | 0.221 | 0.112 | | | | | |
| 799 | 3 | 3.821 | 0.322 | 0.238 | 0 | | | | |
| | | 6.263 | 0.391 | 0.187 | | | | | |
| | | 7.043 | 0.140 | 0.045 | | | | | |
| 833 | 2 | 3.219 | 0.135 | 0.042 | 0 | | | | |
| | | 6.119 | 0.443 | 0.213 | | | | | |
| 883 | 3 | 3.230 | 0.157 | 0.057 | 0 | | | | |
| | | 5.518 | 0.376 | 0.179 | | | | | |
| | | 7.048 | 0.247 | 0.140 | | | | | |
| 927 | 5 | 3.342 | 0.332 | 0.253 | 0 | | | | |
| | | 3.849 | 0.384 | 0.183 | | | | | |
| | | 5.522 | 0.273 | 0.171 | | | | | |
| | | 6.105 | 0.225 | 0.116 | | | | | |
| | | 7.060 | 0.259 | 0.154 | | | | | |
| 958 | 3 | 3.363 | 0.225 | 0.116 | 0 | | | | |
| | | 6.106 | 0.210 | 0.101 | | | | | |
| | | 7.068 | 0.155 | 0.055 | | | | | |
| 1001 | 1 | 6.025 | 0.165 | 0.062 | 1 | 2 | 3.223 | 0.319 | 0.195 |
| | | | | | | | 3.677 | 0.589 | |
| 1063 | 5 | 3.286 | 0.244 | 0.137 | 0 | | | | |
| | | 3.615 | 0.259 | 0.154 | | | | | |
| | | 6.127 | 0.328 | 0.247 | | | | | |
| | | 6.349 | 0.117 | 0.031 | | | | | |
| | | 7.059 | 0.314 | 0.226 | | | | | |
| 1095 | 4 | 3.295 | 0.248 | 0.141 | 0 | | | | |
| | | 3.817 | 0.332 | 0.253 | | | | | |
| | | 6.325 | 0.416 | 0.199 | | | | | |
| | | 7.063 | 0.326 | 0.244 | | | | | |
| 1140 | 4 | 3.274 | 0.221 | 0.112 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 6.122 | 0.230 | 0.121 | | | | | |
| | | 7.065 | 0.254 | 0.148 | | | | | |
| 1640 | 3 | 3.629 | 0.147 | 0.050 | 0 | | | | |
| | | 6.398 | 0.184 | 0.078 | | | | | |
| | | 7.060 | 0.129 | 0.038 | | | | | |
| 1690 | 3 | 3.523 | 0.162 | 0.060 | 1 | 4 | 5.563 | 0.333 | 0.176 |
| | | 4.466 | 0.314 | 0.226 | | | 5.830 | 0.200 | |
| | | 6.963 | 0.144 | 0.048 | | | 6.077 | 0.294 | |
| | | | | | | | 6.302 | 0.265 | |
| 1733 | 4 | 3.321 | 0.190 | 0.083 | 0 | | | | |
| | | 3.825 | 0.260 | 0.155 | | | | | |
| | | 4.478 | 0.474 | 0.229 | | | | | |
| | | 7.068 | 0.162 | 0.060 | | | | | |
| 1766 | 2 | 3.317 | 0.223 | 0.114 | 0 | | | | |
| | | 6.440 | 0.160 | 0.059 | | | | | |
| 1813 | 1 | 3.241 | 0.153 | 0.054 | 2 | 2 | 3.466 | 0.239 | 0.226 |
| | | | | | | | 3.757 | 0.343 | |
| | | | | | | 2 | 5.983 | 0.363 | |
| | | | | | | | 6.316 | 0.302 | |
| 1858 | 2 | 3.333 | 0.131 | 0.039 | 0 | | | | |
| | | 6.308 | 0.163 | 0.061 | | | | | |
| 1890 | 4 | 3.235 | 0.181 | 0.075 | 1 | 2 | 3.541 | 0.244 | 0.046 |
| | | 6.018 | 0.364 | 0.173 | | | 3.712 | 0.143 | |
| | | 6.375 | 0.246 | 0.139 | | | | | |
| | | 6.982 | 0.172 | 0.068 | | | | | |
| 1927 | 5 | 3.284 | 0.220 | 0.111 | 0 | | | | |
| | | 3.560 | 0.203 | 0.095 | | | | | |
| | | 4.360 | 0.270 | 0.167 | | | | | |
| | | 4.588 | 0.186 | 0.079 | | | | | |
| | | 7.058 | 0.221 | 0.112 | | | | | |
| 1965 | 3 | 3.297 | 0.162 | 0.060 | 0 | | | | |
| | | 3.830 | 0.177 | 0.072 | | | | | |
| | | 7.072 | 0.143 | 0.047 | | | | | |
| 2000 | 2 | 3.294 | 0.166 | 0.063 | 0 | | | | |
| | | 4.388 | 0.207 | 0.098 | | | | | |
| 2029 | 4 | 3.320 | 0.181 | 0.075 | 0 | | | | |
| | | 3.839 | 0.318 | 0.232 | | | | | |
| | | 6.111 | 0.319 | 0.233 | | | | | |
| | | 7.083 | 0.243 | 0.135 | | | | | |
| 2069 | 5 | 3.324 | 0.290 | 0.193 | 0 | | | | |
| | | 3.631 | 0.324 | 0.241 | | | | | |
| | | 4.367 | 0.277 | 0.176 | | | | | |
| | | 6.296 | 0.130 | 0.039 | | | | | |
| | | 7.075 | 0.250 | 0.143 | | | | | |
| 2117 | 4 | 3.314 | 0.176 | 0.071 | 0 | | | | |
| | | 3.779 | 0.288 | 0.190 | | | | | |

[a]4.054 movie analyzer units equal 0.75 inch; left end reading, 3.136; right end reading, 7.190.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(f) Concluded. Test fluid, methanol; run 63-1-14-6

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 4.564 | 0.224 | 0.115 | | | | | |
| | | 7.060 | 0.203 | 0.095 | | | | | |
| 2152 | 4 | 3.264 | 0.211 | 0.102 | 0 | | | | |
| | | 6.109 | 0.418 | 0.200 | | | | | |
| | | 6.393 | 0.150 | 0.052 | | | | | |
| | | 7.050 | 0.187 | 0.080 | | | | | |
| 2192 | 1 | 3.248 | 0.121 | 0.034 | 0 | | | | |
| 2237 | 3 | 3.329 | 0.138 | 0.044 | 0 | | | | |
| | | 4.568 | 0.212 | 0.103 | | | | | |
| | | 6.091 | 0.366 | 0.174 | | | | | |
| 2274 | 5 | 3.332 | 0.180 | 0.074 | 0 | | | | |
| | | 3.775 | 0.248 | 0.141 | | | | | |
| | | 4.359 | 0.413 | 0.198 | | | | | |
| | | 6.293 | 0.315 | 0.228 | | | | | |
| | | 7.065 | 0.279 | 0.179 | | | | | |
| 2317 | 5 | 3.321 | 0.326 | 0.244 | 0 | | | | |
| | | 3.809 | 0.359 | 0.170 | | | | | |
| | | 5.164 | 0.480 | 0.232 | | | | | |
| | | 5.849 | 0.395 | 0.189 | | | | | |
| | | 7.085 | 0.265 | 0.161 | | | | | |
| 2347 | 6 | 3.313 | 0.173 | 0.069 | 0 | | | | |
| | | 4.375 | 0.111 | 0.028 | | | | | |
| | | 4.593 | 0.324 | 0.241 | | | | | |
| | | 5.129 | 0.648 | 0.316 | | | | | |
| | | 5.817 | 0.592 | 0.288 | | | | | |
| | | 7.065 | 0.172 | 0.068 | | | | | |
| 2397 | 4 | 3.400 | 0.268 | 0.165 | 0 | | | | |
| | | 3.804 | 0.332 | 0.253 | | | | | |
| | | 6.058 | 0.218 | 0.109 | | | | | |
| | | 6.383 | 0.234 | 0.126 | | | | | |
| 2437 | 4 | 3.268 | 0.202 | 0.094 | 0 | | | | |
| | | 4.346 | 0.317 | 0.231 | | | | | |
| | | 5.138 | 0.276 | 0.175 | | | | | |
| | | 6.405 | 0.280 | 0.180 | | | | | |
| 2473 | 5 | 3.322 | 0.244 | 0.137 | 0 | | | | |
| | | 3.825 | 0.403 | 0.193 | | | | | |
| | | 6.086 | 0.318 | 0.232 | | | | | |
| | | 6.416 | 0.129 | 0.038 | | | | | |
| | | 7.038 | 0.265 | 0.161 | | | | | |
| 2516 | 7 | 3.268 | 0.185 | 0.079 | 0 | | | | |

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 3.615 | 0.212 | 0.103 | | | | | |
| | | 6.479 | 0.231 | 0.122 | | | | | |
| | | 7.043 | 0.219 | 0.110 | | | | | |
| 3025 | 0 | | | | 1 | 2 | 3.191 | 0.220 | 0.053 |
| | | | | | | | 3.405 | 0.208 | |
| 3063 | 5 | 3.310 | 0.153 | 0.054 | 0 | | | | |
| | | 3.813 | 0.325 | 0.242 | | | | | |
| | | 4.366 | 0.112 | 0.029 | | | | | |
| | | 5.867 | 0.372 | 0.177 | | | | | |
| | | 6.465 | 0.273 | 0.171 | | | | | |
| 3103 | 4 | 3.323 | 0.182 | 0.076 | 0 | | | | |
| | | 4.518 | 0.431 | 0.207 | | | | | |
| | | 5.098 | 0.466 | 0.225 | | | | | |
| | | 7.028 | 0.235 | 0.127 | | | | | |
| 3146 | 7 | 3.334 | 0.218 | 0.109 | 0 | | | | |
| | | 3.566 | 0.246 | 0.139 | | | | | |
| | | 3.873 | 0.369 | 0.175 | | | | | |
| | | 4.601 | 0.324 | 0.241 | | | | | |
| | | 5.133 | 0.178 | 0.073 | | | | | |
| | | 6.487 | 0.253 | 0.147 | | | | | |
| | | 7.038 | 0.254 | 0.148 | | | | | |
| 3193 | 4 | 3.291 | 0.280 | 0.180 | 0 | | | | |
| | | 3.536 | 0.210 | 0.101 | | | | | |
| | | 4.363 | 0.419 | 0.201 | | | | | |
| | | 6.070 | 0.189 | 0.082 | | | | | |
| 3228 | 4 | 3.256 | 0.193 | 0.085 | 0 | | | | |
| | | 4.382 | 0.123 | 0.035 | | | | | |
| | | 5.869 | 0.296 | 0.201 | | | | | |
| | | 6.490 | 0.208 | 0.099 | | | | | |
| 3273 | 2 | 3.246 | 0.090 | 0.019 | 0 | | | | |
| | | 6.103 | 0.264 | 0.160 | | | | | |
| 3313 | 2 | 3.203 | 0.179 | 0.073 | 1 | 2 | 3.463 | 0.340 | 0.155 |
| | | 6.510 | 1.059 | 0.520 | | | 3.839 | 0.412 | |
| 3359 | 4 | 3.157 | 0.195 | 0.087 | 2 | 2 | 3.749 | 0.260 | 0.213 |
| | | 3.403 | 0.297 | 0.202 | | | 4.165 | 0.326 | |
| | | 4.457 | 0.224 | 0.115 | | 2 | 5.973 | 0.345 | |
| | | 6.942 | 0.249 | 0.142 | | | 6.287 | 0.282 | |
| 3393 | 3 | 3.312 | 0.430 | 0.207 | 0 | | | | |
| | | 5.901 | 0.383 | 0.183 | | | | | |
| | | 6.306 | 0.426 | 0.205 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4.353 | 0.310 | 0.220 | | | | | |
| | | 4.590 | 0.164 | 0.062 | | | | | |
| | | 5.838 | 0.229 | 0.120 | | | | | |
| | | 6.120 | 0.335 | 0.257 | | | | | |
| | | 6.423 | 0.270 | 0.167 | | | | | |
| | | 7.046 | 0.265 | 0.161 | | | | | |
| 2551 | 3 | 3.219 | 0.291 | 0.194 | 1 | 2 | 3.526 | 0.256 | 0.067 |
| | | 6.283 | 0.454 | 0.219 | | | 3.768 | 0.228 | |
| | | 6.892 | 0.298 | 0.204 | | | | | |
| 2584 | 3 | 3.301 | 0.342 | 0.162 | 0 | | | | |
| | | 4.375 | 0.139 | 0.044 | | | | | |
| | | 6.501 | 0.281 | 0.181 | | | | | |
| 2624 | 1 | 6.932 | 0.239 | 0.131 | 1 | 3 | 3.216 | 0.233 | 0.120 |
| | | | | | | | 3.446 | 0.304 | |
| | | | | | | | 3.723 | 0.250 | |
| 2673 | 4 | 3.317 | 0.238 | 0.130 | 0 | | | | |
| | | 4.373 | 0.315 | 0.228 | | | | | |
| | | 6.466 | 0.362 | 0.172 | | | | | |
| | | 7.026 | 0.268 | 0.165 | | | | | |
| 2705 | 3 | 3.322 | 0.264 | 0.160 | 0 | | | | |
| | | 3.572 | 0.237 | 0.129 | | | | | |
| | | 4.560 | 0.189 | 0.082 | | | | | |
| 2745 | 4 | 3.286 | 0.159 | 0.058 | 0 | | | | |
| | | 4.446 | 0.521 | 0.252 | | | | | |
| | | 6.468 | 0.327 | 0.245 | | | | | |
| | | 7.075 | 0.240 | 0.132 | | | | | |
| 2790 | 3 | 5.790 | 0.330 | 0.250 | 1 | 2 | 3.254 | 0.218 | 0.041 |
| | | 6.118 | 0.201 | 0.093 | | | 3.440 | 0.154 | |
| | | 6.943 | 0.264 | 0.160 | | | | | |
| 2826 | 5 | 3.301 | 0.239 | 0.131 | 0 | | | | |
| | | 3.841 | 0.240 | 0.132 | | | | | |
| | | 4.374 | 0.278 | 0.177 | | | | | |
| | | 6.483 | 0.280 | 0.180 | | | | | |
| | | 7.068 | 0.130 | 0.039 | | | | | |
| 2864 | 2 | 5.998 | 0.217 | 0.108 | 1 | 2 | 3.182 | 0.112 | 0.015 |
| | | 6.302 | 0.231 | 0.122 | | | 3.274 | 0.114 | |
| 2907 | 5 | 3.409 | 0.326 | 0.244 | 0 | | | | |
| | | 3.805 | 0.467 | 0.225 | | | | | |
| | | 4.556 | 0.190 | 0.083 | | | | | |
| | | 6.489 | 0.352 | 0.167 | | | | | |
| | | 7.074 | 0.300 | 0.206 | | | | | |
| 2953 | 4 | 3.203 | 0.188 | 0.081 | 1 | 2 | 5.806 | 0.368 | 0.113 |
| | | 4.082 | 0.294 | 0.198 | | | 5.981 | 0.256 | |
| | | 4.401 | 0.344 | 0.163 | | | | | |
| | | 6.896 | 0.201 | 0.093 | | | | | |
| 2993 | 4 | 3.319 | 0.182 | 0.076 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3423 | 5 | 3.274 | 0.163 | 0.061 | 0 | | | | |
| | | 3.535 | 0.182 | 0.076 | | | | | |
| | | 3.839 | 0.226 | 0.117 | | | | | |
| | | 4.388 | 0.297 | 0.202 | | | | | |
| | | 7.037 | 0.295 | 0.200 | | | | | |
| 3473 | 2 | 3.330 | 0.157 | 0.057 | 0 | | | | |
| | | 7.048 | 0.213 | 0.104 | | | | | |
| 3513 | 3 | 3.261 | 0.136 | 0.042 | 0 | | | | |
| | | 4.352 | 0.203 | 0.095 | | | | | |
| | | 7.040 | 0.170 | 0.066 | | | | | |
| 3548 | 4 | 3.721 | 0.320 | 0.235 | 1 | 3 | 3.230 | 0.125 | 0.052 |
| | | 4.451 | 0.282 | 0.182 | | | 3.339 | 0.180 | |
| | | 6.314 | 0.202 | 0.094 | | | 3.458 | 0.205 | |
| | | 6.966 | 0.219 | 0.110 | | | | | |
| 3593 | 5 | 3.294 | 0.157 | 0.057 | 0 | | | | |
| | | 3.577 | 0.236 | 0.128 | | | | | |
| | | 4.370 | 0.432 | 0.208 | | | | | |
| | | 5.982 | 0.461 | 0.222 | | | | | |
| | | 7.059 | 0.211 | 0.102 | | | | | |
| 3636 | 4 | 3.295 | 0.140 | 0.045 | 0 | | | | |
| | | 3.845 | 0.248 | 0.141 | | | | | |
| | | 6.408 | 0.336 | 0.259 | | | | | |
| | | 7.056 | 0.238 | 0.130 | | | | | |
| 3674 | 4 | 3.286 | 0.158 | 0.057 | 0 | | | | |
| | | 6.060 | 0.263 | 0.159 | | | | | |
| | | 6.427 | 0.471 | 0.227 | | | | | |
| | | 7.069 | 0.123 | 0.035 | | | | | |
| 3705 | 3 | 4.269 | 0.157 | 0.057 | 1 | 2 | 3.311 | 0.420 | 0.158 |
| | | 6.331 | 0.566 | 0.275 | | | 3.692 | 0.342 | |
| | | 6.929 | 0.223 | 0.114 | | | | | |
| 3743 | 5 | 3.305 | 0.144 | 0.048 | 0 | | | | |
| | | 3.543 | 0.160 | 0.059 | | | | | |
| | | 4.537 | 0.380 | 0.181 | | | | | |
| | | 6.570 | 0.274 | 0.172 | | | | | |
| | | 7.048 | 0.285 | 0.186 | | | | | |
| 3776 | 3 | 3.301 | 0.197 | 0.089 | 0 | | | | |
| | | 4.591 | 0.345 | 0.163 | | | | | |
| | | 6.510 | 0.158 | 0.057 | | | | | |
| 3820 | 3 | 3.227 | 0.283 | 0.184 | 1 | 2 | 3.842 | 0.370 | 0.138 |
| | | 3.513 | 0.288 | 0.190 | | | 4.191 | 0.328 | |
| | | 6.001 | 0.181 | 0.075 | | | | | |
| 3858 | 4 | 3.367 | 0.267 | 0.164 | 0 | | | | |
| | | 3.603 | 0.205 | 0.096 | | | | | |
| | | 4.546 | 0.167 | 0.064 | | | | | |
| | | 7.075 | 0.283 | 0.184 | | | | | |

Total number of sample frames, k, 96.
Total number of single bubbles, h, 328.
Number of merging bubbles, 57.
Average instantaneous bubble population, $n_{av}$, 4.01.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.143.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.0291.
Standard deviation associated with $\varphi_{m,av}$, 0.0702.

[a]4.054 movie analyzer units equal 0.75 inch; left end reading, 3.136; right end reading, 7.190.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(g) Test fluid, methanol; run 63-2-6-1

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 0 | 3 | 5.228 | 0.487 | 0.261 | 2 | 2 | 2.756 | 0.219 | 0.209 |
| | | 5.807 | 0.209 | 0.122 | | | 2.898 | 0.121 | |
| | | 6.264 | 0.136 | 0.052 | | 2 | 3.548 | 0.406 | |
| | | | | | | | 3.904 | 0.307 | |
| 30 | 3 | 3.538 | 0.365 | 0.193 | 1 | 2 | 2.708 | 0.134 | 0.020 |
| | | 5.228 | 0.203 | 0.116 | | | 2.809 | 0.104 | |
| | | 6.156 | 0.299 | 0.251 | | | | | |
| 80 | 5 | 2.738 | 0.223 | 0.139 | 1 | 2 | 5.720 | 0.520 | 0.195 |
| | | 3.561 | 0.467 | 0.250 | | | 6.128 | 0.297 | |
| | | 4.694 | 0.293 | 0.241 | | | | | |
| | | 5.232 | 0.286 | 0.229 | | | | | |
| | | 6.288 | 0.075 | 0.016 | | | | | |
| 120 | 2 | 3.527 | 0.535 | 0.288 | 2 | 2 | 2.774 | 0.255 | 0.342 |
| | | 6.111 | 0.402 | 0.214 | | | 3.056 | 0.428 | |
| | | | | | | 2 | 4.494 | 0.479 | |
| | | | | | | | 4.828 | 0.317 | |
| 160 | 2 | 5.260 | 0.461 | 0.247 | 1 | 3 | 2.728 | 0.314 | 0.248 |
| | | 6.223 | 0.219 | 0.134 | | | 2.955 | 0.141 | |
| | | | | | | | 3.342 | 0.632 | |
| 195 | 3 | 3.272 | 0.220 | 0.136 | 1 | 2 | 2.674 | 0.247 | 0.055 |
| | | 5.276 | 0.248 | 0.172 | | | 2.766 | 0.131 | |
| | | 6.216 | 0.195 | 0.107 | | | | | |
| 240 | 5 | 2.767 | 0.220 | 0.136 | 0 | | | | |
| | | 3.270 | 0.376 | 0.199 | | | | | |
| | | 4.675 | 0.200 | 0.112 | | | | | |
| | | 5.474 | 0.774 | 0.419 | | | | | |
| | | 6.231 | 0.188 | 0.099 | | | | | |
| 325 | 4 | 2.767 | 0.227 | 0.144 | 0 | | | | |
| | | 3.560 | 0.201 | 0.113 | | | | | |
| | | 5.261 | 0.408 | 0.217 | | | | | |
| | | 6.141 | 0.366 | 0.194 | | | | | |
| 365 | 2 | 2.738 | 0.175 | 0.086 | 0 | | | | |
| | | 6.110 | 0.407 | 0.217 | | | | | |
| 400 | 3 | 2.779 | 0.264 | 0.195 | 0 | | | | |
| | | 4.675 | 0.279 | 0.218 | | | | | |
| | | 6.144 | 0.307 | 0.160 | | | | | |
| 443 | 4 | 2.763 | 0.229 | 0.147 | 0 | | | | |
| | | 3.541 | 0.504 | 0.271 | | | | | |
| | | 5.200 | 0.196 | 0.108 | | | | | |
| | | 6.265 | 0.097 | 0.026 | | | | | |
| 489 | 4 | 2.754 | 0.215 | 0.130 | 0 | | | | |
| | | 3.549 | 0.497 | 0.267 | | | | | |
| | | 4.658 | 0.540 | 0.291 | | | | | |
| | | 6.105 | 0.393 | 0.209 | | | | | |
| 1033 | 3 | 2.727 | 0.202 | 0.114 | 0 | | | | |
| | | 4.880 | 0.344 | 0.181 | | | | | |
| | | 6.065 | 0.350 | 0.185 | | | | | |
| 1063 | 3 | 2.767 | 0.252 | 0.178 | 0 | | | | |
| | | 4.700 | 0.210 | 0.124 | | | | | |
| | | 6.101 | 0.286 | 0.229 | | | | | |
| 1095 | 1 | 4.018 | 0.575 | 0.310 | 1 | 3 | 2.761 | 0.219 | 0.188 |
| | | | | | | | 2.911 | 0.327 | |
| | | | | | | | 3.116 | 0.350 | |
| 1140 | 5 | 2.768 | 0.200 | 0.112 | 0 | | | | |
| | | 3.877 | 0.309 | 0.161 | | | | | |
| | | 4.697 | 0.788 | 0.427 | | | | | |
| | | 5.665 | 0.677 | 0.366 | | | | | |
| | | 6.201 | 0.246 | 0.170 | | | | | |
| 1180 | 2 | 2.804 | 0.273 | 0.209 | 2 | 2 | 3.303 | 0.545 | 0.404 |
| | | 4.187 | 0.773 | 0.419 | | | 3.691 | 0.320 | |
| | | | | | | 3 | 5.808 | 0.233 | |
| | | | | | | | 6.093 | 0.390 | |
| | | | | | | | 6.166 | 0.294 | |
| 1223 | 2 | 3.299 | 0.452 | 0.242 | 2 | 2 | 2.701 | 0.107 | 0.275 |
| | | 4.214 | 0.549 | 0.296 | | | 2.795 | 0.137 | |
| | | | | | | 2 | 5.716 | 0.718 | |
| | | | | | | | 6.150 | 0.303 | |
| 1261 | 2 | 2.770 | 0.206 | 0.119 | 1 | 4 | 5.719 | 0.299 | 0.206 |
| | | 3.590 | 0.353 | 0.186 | | | 5.862 | 0.316 | |
| | | | | | | | 5.918 | 0.225 | |
| | | | | | | | 6.107 | 0.235 | |
| 1311 | 3 | 2.739 | 0.194 | 0.106 | 1 | 2 | 5.779 | 0.311 | 0.103 |
| | | 3.235 | 0.383 | 0.203 | | | 5.889 | 0.224 | |
| | | 6.223 | 0.163 | 0.074 | | | | | |
| 1359 | 1 | 4.629 | 0.371 | 0.196 | 2 | 2 | 2.788 | 0.278 | 0.268 |
| | | | | | | | 3.030 | 0.506 | |
| | | | | | | 2 | 5.828 | 0.192 | |
| | | | | | | | 6.069 | 0.290 | |
| 1411 | 2 | 2.741 | 0.143 | 0.057 | 1 | 3 | 3.218 | 0.381 | 0.351 |
| | | 6.149 | 0.313 | 0.164 | | | 3.546 | 0.457 | |
| | | | | | | | 4.056 | 0.562 | |
| 1441 | 0 | | | | 1 | 3 | 2.717 | 0.095 | 0.241 |
| | | | | | | | 2.818 | 0.258 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 3.550 | 0.717 | 0.388 | | | | | |
| | | 4.691 | 0.237 | 0.157 | | | | | |
| | | 6.134 | 0.308 | 0.161 | | | | | |
| 519 | 5 | 2.800 | 0.218 | 0.133 | 0 | | | | |
| | | 3.704 | 0.371 | 0.196 | | | | | |
| | | 4.700 | 0.498 | 0.267 | | | | | |
| | | 5.230 | 0.488 | 0.262 | | | | | |
| | | 6.030 | 0.457 | 0.245 | | | | | |
| 564 | 2 | 5.555 | 0.544 | 0.293 | 2 | 2 | 2.783 | 0.190 | 0.173 |
| | | 6.131 | 0.362 | 0.191 | | | 2.806 | 0.157 | |
| | | | | | | 4 | 3.705 | 0.249 | |
| | | | | | | | 3.743 | 0.138 | |
| | | | | | | | 3.865 | 0.143 | |
| | | | | | | | 3.892 | 0.290 | |
| 601 | 3 | 4.012 | 0.640 | 0.346 | 1 | 2 | 2.739 | 0.137 | 0.039 |
| | | 4.760 | 0.832 | 0.451 | | | 2.831 | 0.191 | |
| | | 6.257 | 0.171 | 0.082 | | | | | |
| 653 | 1 | 6.089 | 0.430 | 0.229 | 2 | 2 | 2.699 | 0.144 | 0.210 |
| | | | | | | | 2.725 | 0.158 | |
| | | | | | | 2 | 4.117 | 0.412 | |
| | | | | | | | 4.491 | 0.337 | |
| 685 | 3 | 2.746 | 0.219 | 0.134 | 1 | 2 | 4.345 | 0.635 | 0.190 |
| | | 3.777 | 0.280 | 0.220 | | | 4.703 | 0.186 | |
| | | 6.220 | 0.147 | 0.061 | | | | | |
| 715 | 2 | 4.318 | 0.473 | 0.253 | 1 | 3 | 2.777 | 0.349 | 0.381 |
| | | 6.221 | 0.178 | 0.089 | | | 3.118 | 0.691 | |
| | | | | | | | 3.596 | 0.469 | |
| 754 | 3 | 4.679 | 0.626 | 0.338 | 1 | 2 | 2.718 | 0.205 | 0.159 |
| | | 5.557 | 0.334 | 0.176 | | | 3.060 | 0.509 | |
| | | 6.182 | 0.213 | 0.127 | | | | | |
| 799 | 3 | 2.741 | 0.155 | 0.067 | 1 | 4 | 5.125 | 0.753 | 0.469 |
| | | 3.577 | 0.196 | 0.108 | | | 5.592 | 0.643 | |
| | | 4.129 | 0.576 | 0.310 | | | 6.005 | 0.360 | |
| | | | | | | | 6.262 | 0.155 | |
| 833 | 2 | 2.733 | 0.158 | 0.070 | 0 | | | | |
| | | 6.126 | 0.376 | 0.199 | | | | | |
| 883 | 2 | 3.559 | 0.619 | 0.334 | 1 | 2 | 2.714 | 0.102 | 0.023 |
| | | 6.178 | 0.296 | 0.246 | | | 2.766 | 0.151 | |
| 927 | 4 | 2.718 | 0.139 | 0.054 | 0 | | | | |
| | | 3.231 | 0.531 | 0.286 | | | | | |
| | | 4.894 | 0.651 | 0.352 | | | | | |
| | | 6.228 | 0.154 | 0.066 | | | | | |
| 958 | 4 | 2.758 | 0.203 | 0.116 | 0 | | | | |
| | | 3.233 | 0.395 | 0.210 | | | | | |
| | | 4.925 | 0.259 | 0.188 | | | | | |
| | | 6.150 | 0.235 | 0.155 | | | | | |
| 1001 | 4 | 2.749 | 0.222 | 0.138 | 0 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3.271 | 0.711 | |
| 1486 | 3 | 2.772 | 0.228 | 0.146 | 0 | | | | |
| | | 4.723 | 0.091 | 0.023 | | | | | |
| | | 6.245 | 0.142 | 0.057 | | | | | |
| 1521 | 4 | 2.733 | 0.143 | 0.057 | 0 | | | | |
| | | 3.569 | 0.407 | 0.217 | | | | | |
| | | 4.749 | 0.516 | 0.277 | | | | | |
| | | 6.184 | 0.283 | 0.225 | | | | | |
| 1571 | 4 | 2.754 | 0.209 | 0.122 | 0 | | | | |
| | | 3.553 | 0.415 | 0.221 | | | | | |
| | | 4.933 | 0.150 | 0.063 | | | | | |
| | | 6.155 | 0.294 | 0.242 | | | | | |
| 1600 | 3 | 2.771 | 0.234 | 0.154 | 0 | | | | |
| | | 4.738 | 0.717 | 0.388 | | | | | |
| | | 6.110 | 0.390 | 0.207 | | | | | |
| 1640 | 4 | 2.750 | 0.196 | 0.108 | 0 | | | | |
| | | 3.541 | 0.574 | 0.309 | | | | | |
| | | 4.805 | 0.429 | 0.229 | | | | | |
| | | 6.165 | 0.251 | 0.177 | | | | | |
| 1690 | 2 | 2.792 | 0.232 | 0.151 | 1 | 2 | 4.587 | 0.147 | 0.093 |
| | | 6.162 | 0.238 | 0.159 | | | 4.804 | 0.341 | |
| 1733 | 1 | 6.160 | 0.267 | 0.200 | 1 | 3 | 2.786 | 0.273 | 0.332 |
| | | | | | | | 3.078 | 0.401 | |
| | | | | | | | 3.553 | 0.693 | |
| 1766 | 2 | 2.760 | 0.218 | 0.133 | 1 | 3 | 3.439 | 0.186 | 0.054 |
| | | 6.200 | 0.210 | 0.124 | | | 3.593 | 0.144 | |
| | | | | | | | 3.698 | 0.145 | |
| 1813 | 2 | 2.714 | 0.096 | 0.026 | 1 | 2 | 5.978 | 0.216 | 0.082 |
| | | 4.704 | 0.144 | 0.058 | | | 6.182 | 0.266 | |
| 1858 | 3 | 2.807 | 0.278 | 0.217 | 0 | | | | |
| | | 3.236 | 0.310 | 0.162 | | | | | |
| | | 6.211 | 0.241 | 0.163 | | | | | |
| 1890 | 0 | | | | 2 | 2 | 2.756 | 0.182 | 0.252 |
| | | | | | | | 2.961 | 0.593 | |
| | | | | | | 2 | 6.178 | 0.290 | |
| | | | | | | | 6.141 | 0.151 | |
| 1927 | 3 | 2.740 | 0.151 | 0.064 | 0 | | | | |
| | | 4.687 | 0.361 | 0.191 | | | | | |
| | | 6.286 | 0.113 | 0.036 | | | | | |
| 1965 | 2 | 2.721 | 0.113 | 0.036 | 1 | 2 | 3.195 | 0.274 | 0.170 |
| | | 6.289 | 0.207 | 0.120 | | | 3.565 | 0.467 | |
| 2000 | 4 | 2.819 | 0.263 | 0.194 | 0 | | | | |
| | | 3.172 | 0.337 | 0.177 | | | | | |
| | | 4.315 | 1.037 | 0.564 | | | | | |
| | | 6.124 | 0.397 | 0.211 | | | | | |

Total number of sample frames, k, 50.
Total number of single bubbles, h, 139.
Total number of merging bubbles, 86.
Average instantaneous bubble population, $n_{av}$, 4.50.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.186.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.1147.
Standard deviation associated with $\varphi_{m,av}$, 0.1350.

[a]3.667 movie analyzer units equal 0.75 inch; left end reading, 2.653; right end reading, 6.320.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(h) Test fluid, methanol; run 63-2-6-2

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 30 | 3 | 3.072 | 0.378 | 0.195 | 2 | 3 | 4.697 | 0.637 | 0.640 |
| | | 4.094 | 0.354 | 0.182 | | | 4.884 | 0.273 | |
| | | 6.510 | 0.313 | 0.159 | | | 4.983 | 0.315 | |
| | | | | | | 2 | 5.646 | 1.017 | |
| | | | | | | | 5.400 | 0.402 | |
| 80 | 5 | 3.224 | 0.480 | 0.251 | 1 | 3 | 5.585 | 0.271 | 0.227 |
| | | 4.252 | 0.518 | 0.272 | | | 5.766 | 0.298 | |
| | | 4.674 | 0.328 | 0.168 | | | 5.900 | 0.481 | |
| | | 5.050 | 0.176 | 0.083 | | | | | |
| | | 6.429 | 0.325 | 0.166 | | | | | |
| 120 | 4 | 3.083 | 0.326 | 0.167 | 0 | | | | |
| | | 4.144 | 0.417 | 0.217 | | | | | |
| | | 5.652 | 0.286 | 0.219 | | | | | |
| | | 6.444 | 0.327 | 0.167 | | | | | |
| 160 | 1 | 6.445 | 0.401 | 0.208 | 2 | 3 | 3.118 | 0.367 | 0.724 |
| | | | | | | | 3.460 | 0.929 | |
| | | | | | | | 4.053 | 0.392 | |
| | | | | | | 4 | 4.692 | 0.365 | |
| | | | | | | | 4.959 | 0.218 | |
| | | | | | | | 5.292 | 0.475 | |
| | | | | | | | 5.676 | 0.335 | |
| 195 | 6 | 3.045 | 0.391 | 0.203 | 0 | | | | |
| | | 3.601 | 0.163 | 0.071 | | | | | |
| | | 3.928 | 0.355 | 0.183 | | | | | |
| | | 5.176 | 0.429 | 0.223 | | | | | |
| | | 5.621 | 0.358 | 0.184 | | | | | |
| | | 6.452 | 0.415 | 0.216 | | | | | |
| 240 | 2 | 5.032 | 0.170 | 0.077 | 2 | 2 | 3.076 | 0.282 | 0.341 |
| | | 6.484 | 0.358 | 0.184 | | | 3.120 | 0.371 | |
| | | | | | | 3 | 3.544 | 0.321 | |
| | | | | | | | 3.878 | 0.460 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 3.452 | 0.470 | |
| | | | | | | 2 | 3.949 | 0.238 | |
| | | | | | | | 4.104 | 0.290 | |
| 601 | 4 | 3.033 | 0.387 | 0.200 | 0 | | | | |
| | | 4.066 | 0.449 | 0.234 | | | | | |
| | | 5.012 | 0.101 | 0.027 | | | | | |
| | | 6.431 | 0.393 | 0.204 | | | | | |
| 653 | 4 | 3.055 | 0.434 | 0.226 | 0 | | | | |
| | | 5.008 | 0.103 | 0.028 | | | | | |
| | | 5.635 | 0.342 | 0.176 | | | | | |
| | | 6.472 | 0.351 | 0.181 | | | | | |
| 685 | 4 | 3.016 | 0.304 | 0.247 | 0 | | | | |
| | | 3.907 | 0.492 | 0.258 | | | | | |
| | | 5.000 | 0.251 | 0.168 | | | | | |
| | | 6.398 | 0.540 | 0.284 | | | | | |
| 715 | 4 | 3.028 | 0.347 | 0.178 | 0 | | | | |
| | | 3.833 | 0.292 | 0.228 | | | | | |
| | | 5.051 | 0.732 | 0.387 | | | | | |
| | | 6.551 | 0.200 | 0.107 | | | | | |
| 754 | 2 | 3.090 | 0.370 | 0.191 | 1 | 4 | 4.853 | 0.211 | 0.177 |
| | | 6.350 | 0.367 | 0.189 | | | 4.908 | 0.292 | |
| | | | | | | | 5.183 | 0.278 | |
| | | | | | | | 5.217 | 0.240 | |
| 799 | 3 | 3.044 | 0.441 | 0.230 | 0 | | | | |
| | | 4.994 | 0.130 | 0.045 | | | | | |
| | | 6.376 | 0.481 | 0.252 | | | | | |
| 833 | 3 | 3.034 | 0.361 | 0.186 | 0 | | | | |
| | | 4.987 | 0.093 | 0.023 | | | | | |
| | | 6.462 | 0.301 | 0.242 | | | | | |
| 883 | 1 | 6.392 | 0.383 | 0.198 | 1 | 5 | 3.054 | 0.343 | 0.737 |
| | | | | | | | 3.625 | 0.798 | |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 4.132 | 0.179 | | | | | | | | | 4.347 | 0.646 | |
| 270 | 2 | 5.014 | 0.175 | 0.082 | 1 | 4 | 3.213 | 0.505 | 0.368 | | | | | | | | 4.919 | 0.555 | |
| | | 6.434 | 0.322 | 0.164 | | | 3.573 | 0.339 | | | | | | | | | 5.258 | 0.588 | |
| | | | | | | | 3.780 | 0.319 | | 927 | 3 | 4.932 | 0.183 | 0.090 | 2 | 2 | 3.149 | 0.390 | 0.418 |
| | | | | | | | 3.978 | 0.418 | | | | 5.185 | 0.194 | 0.101 | | | 3.218 | 0.330 | |
| 325 | 3 | 3.995 | 0.402 | 0.209 | 1 | 3 | 3.119 | 0.363 | 0.244 | | | 6.375 | 0.453 | 0.236 | | 4 | 3.656 | 0.259 | |
| | | 4.759 | 0.286 | 0.219 | | | 3.128 | 0.416 | | | | | | | | | 3.728 | 0.403 | |
| | | 6.502 | 0.318 | 0.162 | | | 3.483 | 0.305 | | | | | | | | | 3.948 | 0.371 | |
| 365 | 5 | 3.107 | 0.295 | 0.233 | 0 | | | | | | | | | | | | 4.068 | 0.209 | |
| | | 4.674 | 0.290 | 0.225 | | | | | | 958 | 2 | 5.000 | 0.111 | 0.033 | 2 | 3 | 3.076 | 0.415 | 0.345 |
| | | 4.726 | 0.172 | 0.079 | | | | | | | | 5.320 | 0.403 | 0.209 | | | 3.503 | 0.438 | |
| | | 6.130 | 0.252 | 0.170 | | | | | | | | | | | | | 3.722 | 0.197 | |
| | | 6.514 | 0.318 | 0.162 | | | | | | | | | | | | 2 | 6.203 | 0.280 | |
| 400 | 1 | 6.407 | 0.424 | 0.221 | 2 | 3 | 3.092 | 0.282 | 0.535 | | | | | | | | 6.495 | 0.304 | |
| | | | | | | | 3.100 | 0.260 | | 1001 | 3 | 3.054 | 0.281 | 0.211 | 0 | | | | |
| | | | | | | | 3.439 | 0.474 | | | | 5.317 | 0.521 | 0.273 | | | | | |
| | | | | | | 3 | 4.451 | 0.485 | | | | 6.471 | 0.315 | 0.161 | | | | | |
| | | | | | | | 4.968 | 0.549 | | 1033 | 1 | 6.363 | 0.471 | 0.246 | 2 | 2 | 3.010 | 0.386 | 0.382 |
| | | | | | | | 5.077 | 0.306 | | | | | | | | | 3.491 | 0.577 | |
| 443 | 2 | 5.592 | 0.429 | 0.223 | 2 | 2 | 3.029 | 0.269 | 0.254 | | | | | | | 2 | 5.032 | 0.419 | |
| | | 6.424 | 0.316 | 0.161 | | | 3.277 | 0.219 | | | | | | | | | 5.313 | 0.264 | |
| | | | | | | 2 | 4.889 | 0.397 | | 1063 | 2 | 3.066 | 0.271 | 0.196 | 2 | 2 | 3.464 | 0.241 | 0.298 |
| | | | | | | | 5.129 | 0.355 | | | | 6.461 | 0.386 | 0.200 | | | 3.562 | 0.223 | |
| 489 | 5 | 3.052 | 0.377 | 0.195 | 0 | | | | | | | | | | | 2 | 3.829 | 0.263 | |
| | | 3.524 | 0.776 | 0.410 | | | | | | | | | | | | | 4.137 | 0.698 | |
| | | 4.442 | 0.653 | 0.344 | | | | | | 1095 | 2 | 5.694 | 0.781 | 0.413 | 2 | 3 | 3.045 | 0.251 | 0.340 |
| | | 5.010 | 0.123 | 0.040 | | | | | | | | 6.512 | 0.201 | 0.108 | | | 3.264 | 0.186 | |
| | | 6.408 | 0.477 | 0.249 | | | | | | | | | | | | | 3.774 | 0.882 | |
| 519 | 2 | 5.632 | 0.305 | 0.249 | 1 | 5 | 3.150 | 0.500 | 0.629 | | | | | | | 2 | 4.905 | 0.217 | |
| | | 6.391 | 0.419 | 0.218 | | | 3.667 | 0.534 | | | | | | | | | 5.069 | 0.141 | |
| | | | | | | | 4.025 | 0.618 | | 1140 | 3 | 3.107 | 0.254 | 0.172 | 2 | 2 | 3.850 | 0.311 | 0.397 |
| | | | | | | | 4.501 | 0.335 | | | | 4.978 | 0.091 | 0.022 | | | 4.196 | 0.380 | |
| | | | | | | | 4.948 | 0.559 | | | | 6.421 | 0.328 | 0.168 | | 3 | 5.476 | 0.292 | |
| 564 | 2 | 4.944 | 0.178 | 0.085 | 2 | 3 | 3.050 | 0.333 | 0.317 | | | | | | | | 5.558 | 0.357 | |
| | | 6.476 | 0.335 | 0.172 | | | 3.045 | 0.230 | | | | | | | | | 5.841 | 0.439 | |

Total number of sample frames, k, 56.
Total number of single bubbles, h, 155.
Total number of merging bubbles, 187.
Average instantaneous bubble population, $n_{av}$, 6.11.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.185.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.2548.
Standard deviation associated with $\varphi_{m,av}$, 0.2254.

[a]3.755 movie analyzer units equal 0.75 inch; left end reading, 2.895; right end reading, 6.650.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER.

[1/16- by 3/4-in. heating strip.]

(i) Test fluid, methanol; run 63-2-6-3

| Frame | Single bubbles: Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Merging bubbles: Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 5.008 | 0.153 | 0.063 | 1 | 5 | 3.038 | 0.229 | 0.401 |
| | | | | | | | 3.263 | 0.220 | |
| | | | | | | | 3.535 | 0.550 | |
| | | | | | | | 3.986 | 0.353 | |
| | | | | | | | 4.395 | 0.465 | |
| 30 | 3 | 3.081 | 0.435 | 0.223 | 1 | 4 | 4.117 | 0.446 | 0.485 |
| | | 3.549 | 0.367 | 0.190 | | | 4.501 | 0.322 | |
| | | 6.335 | 0.538 | 0.284 | | | 4.905 | 0.459 | |
| | | | | | | | 5.514 | 0.758 | |
| 80 | 2 | 3.081 | 0.313 | 0.160 | 1 | 4 | 3.840 | 0.791 | 0.471 |
| | | 6.391 | 0.438 | 0.229 | | | 4.435 | 0.399 | |
| | | | | | | | 4.900 | 0.531 | |
| | | | | | | | 5.032 | 0.235 | |
| 120 | 6 | 3.066 | 0.273 | 0.201 | 0 | | | | |
| | | 3.670 | 0.365 | 0.189 | | | | | |
| | | 4.232 | 0.315 | 0.161 | | | | | |
| | | 4.745 | 0.297 | 0.238 | | | | | |
| | | 5.311 | 0.313 | 0.160 | | | | | |
| | | 6.434 | 0.398 | 0.207 | | | | | |
| 160 | 3 | 3.082 | 0.315 | 0.161 | 1 | 3 | 4.363 | 0.326 | 0.207 |
| | | 5.871 | 0.666 | 0.353 | | | 4.612 | 0.464 | |
| | | 6.456 | 0.321 | 0.165 | | | 4.867 | 0.190 | |
| 195 | 2 | 3.083 | 0.380 | 0.193 | 2 | 4 | 4.331 | 0.211 | 0.553 |
| | | 3.858 | 0.334 | 0.172 | | | 4.647 | 0.421 | |
| | | | | | | | 5.038 | 0.361 | |
| | | | | | | | 5.326 | 0.347 | |
| | | | | | | 2 | 5.910 | 0.472 | |
| | | | | | | | 6.328 | 0.570 | |
| 240 | 6 | 3.092 | 0.341 | 0.176 | 1 | 2 | 5.492 | 0.338 | 0.135 |
| | | 3.841 | 0.796 | 0.423 | | | 5.809 | 0.297 | |
| | | 4.412 | 0.192 | 0.100 | | | | | |
| | | 4.794 | 0.235 | 0.149 | | | | | |
| | | 5.119 | 0.131 | 0.046 | | | | | |
| | | 6.516 | 0.302 | 0.246 | | | | | |
| 270 | 5 | 3.110 | 0.281 | 0.213 | 1 | 2 | 4.896 | 0.322 | 0.165 |
| | | 3.715 | 0.293 | 0.232 | | | 5.224 | 0.401 | |
| | | 4.416 | 0.371 | 0.193 | | | | | |
| | | 5.743 | 0.413 | 0.216 | | | | | |
| | | 6.424 | 0.474 | 0.249 | | | | | |
| 325 | 2 | 4.352 | 0.457 | 0.246 | 3 | 3 | 2.987 | 0.273 | 0.487 |
| | | 5.792 | 0.288 | 0.224 | | | 3.198 | 0.266 | |
| | | | | | | | 3.447 | 0.556 | |
| | | | | | | 2 | 5.087 | 0.336 | |
| | | | | | | | 5.367 | 0.342 | |
| | | | | | | 2 | 6.215 | 0.346 | |
| | | | | | | | 6.477 | 0.179 | |
| 365 | 2 | 5.097 | 0.342 | 0.176 | 2 | 2 | 3.838 | 0.427 | 0.465 |
| | | 5.690 | 0.343 | 0.177 | | | 4.372 | 0.640 | |
| | | | | | | 2 | 6.132 | 0.496 | |
| | | | | | | | 6.548 | 0.337 | |
| 400 | 1 | 3.022 | 0.309 | 0.253 | 1 | 6 | 4.054 | 0.250 | 0.691 |
| | | | | | | | 4.463 | 0.568 | |
| | | | | | | | 4.772 | 0.855 | |
| | | | | | | | 5.562 | 0.365 | |
| | | | | | | | 5.946 | 0.366 | |
| | | | | | | | 6.361 | 0.460 | |
| 443 | 2 | 4.421 | 0.254 | 0.174 | 2 | 2 | 3.031 | 0.285 | 0.26 |
| | | 6.413 | 0.502 | 0.264 | | | 3.149 | 0.240 | |

| Frame | Single bubbles: Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Merging bubbles: Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 5.942 | 0.351 | |
| 1001 | 3 | 5.026 | 0.315 | 0.161 | 1 | 5 | 5.026 | 0.205 | 0.217 |
| | | 4.376 | 0.431 | 0.226 | | | 5.135 | 0.234 | |
| | | 6.394 | 0.432 | 0.226 | | | 5.339 | 0.209 | |
| | | | | | | | 5.556 | 0.225 | |
| | | | | | | | 5.858 | 0.378 | |
| 1033 | 2 | 3.078 | 0.302 | 0.246 | 2 | 2 | 4.976 | 0.202 | 0.361 |
| | | 4.341 | 0.230 | 0.143 | | | 5.172 | 0.429 | |
| | | | | | | 2 | 5.953 | 0.372 | |
| | | | | | | | 6.327 | 0.566 | |
| 1095 | 5 | 3.017 | 0.291 | 0.227 | 0 | | | | |
| | | 4.402 | 0.612 | 0.324 | | | | | |
| | | 4.968 | 0.256 | 0.180 | | | | | |
| | | 6.000 | 0.417 | 0.215 | | | | | |
| | | 6.440 | 0.342 | 0.176 | | | | | |
| 1140 | 1 | 6.470 | 0.232 | 0.215 | 1 | 7 | 3.036 | 0.250 | 0.791 |
| | | | | | | | 3.219 | 0.617 | |
| | | | | | | | 3.729 | 0.403 | |
| | | | | | | | 4.061 | 0.549 | |
| | | | | | | | 4.489 | 0.346 | |
| | | | | | | | 4.860 | 0.815 | |
| | | | | | | | 5.295 | 0.312 | |
| 1180 | 1 | 6.333 | 0.433 | 0.227 | 2 | 4 | 3.083 | 0.291 | 0.717 |
| | | | | | | | 3.722 | 0.386 | |
| | | | | | | | 4.401 | 0.409 | |
| | | | | | | | 4.415 | 0.262 | |
| | | | | | | 4 | 4.777 | 0.247 | |
| | | | | | | | 5.052 | 0.302 | |
| | | | | | | | 5.357 | 0.316 | |
| | | | | | | | 5.701 | 0.373 | |
| 1223 | 1 | 4.967 | 0.290 | 0.227 | 2 | 5 | 3.095 | 0.334 | 0.467 |
| | | | | | | | 3.311 | 0.237 | |
| | | | | | | | 3.556 | 0.341 | |
| | | | | | | | 3.880 | 0.306 | |
| | | | | | | | 4.096 | 0.352 | |
| | | | | | | 2 | 5.190 | 0.308 | |
| | | | | | | | 5.483 | 0.279 | |
| 1261 | 5 | 3.066 | 0.315 | 0.161 | 1 | 3 | 3.522 | 0.324 | 0.224 |
| | | 4.730 | 0.285 | 0.219 | | | 3.769 | 0.290 | |
| | | 4.987 | 0.237 | 0.152 | | | 4.074 | 0.406 | |
| | | 5.683 | 0.660 | 0.351 | | | | | |
| | | 6.340 | 0.459 | 0.241 | | | | | |
| 1311 | 6 | 4.424 | 0.209 | 0.113 | 1 | 5 | 3.002 | 0.254 | 0.362 |
| | | 4.794 | 0.135 | 0.047 | | | 3.015 | 0.273 | |
| | | 4.986 | 0.162 | 0.071 | | | 3.346 | [illegible] | |
| | | 5.606 | 0.452 | 0.237 | | | 3.693 | 0.333 | |
| | | 6.164 | 0.283 | 0.216 | | | 4.081 | 0.242 | |
| | | 6.651 | 0.167 | 0.075 | | | | | |
| 1355 | 2 | 5.675 | 0.308 | 0.256 | 2 | 2 | 3.114 | 0.346 | 0.403 |
| | | 6.451 | 0.349 | 0.180 | | | 3.508 | 0.377 | |
| | | | | | | 3 | 4.133 | 0.447 | |
| | | | | | | | 4.224 | 0.301 | |
| | | | | | | | 4.502 | 0.311 | |
| 1411 | 1 | 3.695 | 0.284 | 0.21[illegible] | 2 | 2 | 2.994 | 0.261 | 0.335 |
| | | | | | | | 3.225 | [illegible] | |
| | | | | | | 2 | 5.594 | 0.344 | |
| | | | | | | | 5.915 | 0.709 | |
| 1441 | 5 | 2.991 | 0.262 | 0.135 | 2 | 3 | 4.317 | 0.714 | [illegible] |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2 | 4.933 | 0.300 | |
| | | | | | | | 5.314 | 0.463 | |
| 469 | 3 | 3.034 | 0.363 | 0.186 | 2 | 2 | 4.927 | 0.715 | 0.347 |
| | | 3.718 | 0.684 | 0.363 | | | 5.286 | 0.502 | |
| | | 4.397 | 0.242 | 0.158 | | 2 | 6.231 | 0.363 | |
| | | | | | | | 6.457 | 0.441 | |
| 519 | 1 | 6.516 | 0.181 | 0.083 | 1 | 9 | 3.155 | 0.509 | 0.733 |
| | | | | | | | 3.494 | 0.168 | |
| | | | | | | | 3.651 | 0.147 | |
| | | | | | | | 3.569 | 0.274 | |
| | | | | | | | 3.967 | 0.546 | |
| | | | | | | | 4.448 | 0.416 | |
| | | | | | | | 4.812 | 0.313 | |
| | | | | | | | 5.004 | 0.322 | |
| | | | | | | | 5.302 | 0.585 | |
| 564 | 4 | 4.028 | 0.403 | 0.210 | 1 | 3 | 3.075 | 0.365 | 0.168 |
| | | 4.771 | 0.322 | 0.165 | | | 3.344 | 0.172 | |
| | | 5.309 | 0.301 | 0.245 | | | 3.584 | 0.308 | |
| | | 6.453 | 0.501 | 0.264 | | | | | |
| 601 | 2 | 3.173 | 0.633 | 0.335 | 1 | 4 | 3.975 | 0.271 | 0.483 |
| | | 6.561 | 0.284 | 0.216 | | | 4.334 | 0.533 | |
| | | | | | | | 4.850 | 0.550 | |
| | | | | | | | 5.272 | 0.626 | |
| 653 | 3 | 4.389 | 0.506 | 0.266 | 1 | 2 | 3.065 | 0.331 | 0.141 |
| | | 5.365 | 0.677 | 0.359 | | | 3.296 | 0.319 | |
| | | 6.233 | 0.748 | 0.397 | | | | | |
| 685 | 1 | 4.477 | 0.212 | 0.121 | 2 | 2 | 3.063 | 0.338 | 0.492 |
| | | | | | | | 3.405 | 0.517 | |
| | | | | | | 4 | 5.660 | 0.245 | |
| | | | | | | | 5.955 | 0.345 | |
| | | | | | | | 5.911 | 0.330 | |
| | | | | | | | 6.326 | 0.409 | |
| 715 | 2 | 5.031 | 0.290 | 0.227 | 2 | 2 | 3.829 | 0.356 | 0.422 |
| | | 5.484 | 0.576 | 0.304 | | | 4.353 | 0.693 | |
| | | | | | | 2 | 4.911 | 0.373 | |
| | | | | | | | 4.960 | 0.340 | |
| 754 | 2 | 5.075 | 0.361 | 0.187 | 2 | 3 | 4.371 | 0.635 | 0.420 |
| | | 6.399 | 0.375 | 0.195 | | | 4.883 | 0.388 | |
| | | | | | | | 5.024 | 0.287 | |
| | | | | | | 2 | 5.439 | 0.212 | |
| | | | | | | | 5.447 | 0.354 | |
| 799 | 3 | 3.098 | 0.347 | 0.177 | 1 | 2 | 6.057 | 0.329 | 0.165 |
| | | 3.930 | 0.455 | 0.239 | | | 6.418 | 0.393 | |
| | | 4.919 | 0.261 | 0.184 | | | | | |
| 833 | 3 | 3.060 | 0.287 | 0.222 | 1 | 2 | 3.661 | 0.816 | 0.274 |
| | | 4.356 | 0.382 | 0.199 | | | 3.401 | 0.302 | |
| | | 6.368 | 0.489 | 0.257 | | | | | |
| 863 | 2 | 3.069 | 0.295 | 0.235 | 3 | 3 | 3.631 | 0.265 | 0.619 |
| | | 4.354 | 0.307 | 0.254 | | | 3.895 | 0.311 | |
| | | | | | | | 3.938 | 0.409 | |
| | | | | | | 3 | 4.866 | 0.179 | |
| | | | | | | | 5.039 | 0.167 | |
| | | | | | | | 5.484 | 0.842 | |
| | | | | | | 2 | 6.106 | 0.178 | |
| | | | | | | | 6.448 | 0.506 | |
| 958 | 1 | 6.624 | 0.185 | 0.092 | 2 | 7 | 3.081 | 0.302 | 0.677 |
| | | | | | | | 3.400 | 0.337 | |
| | | | | | | | 3.677 | 0.217 | |
| | | | | | | | 3.875 | 0.178 | |
| | | | | | | | 4.003 | 0.295 | |
| | | | | | | | 4.206 | 0.294 | |
| | | | | | | | 4.379 | 0.275 | |
| | | | | | | 3 | 5.125 | 0.718 | |
| | | | | | | | 5.625 | 0.283 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 3.524 | 0.283 | 0.216 | | | 4.993 | 0.333 | |
| | | 4.087 | 0.441 | 0.231 | | | 5.006 | 0.386 | |
| | | | | | | 2 | 5.861 | 0.793 | |
| | | | | | | | 6.428 | 0.341 | |
| 1486 | 3 | 3.001 | 0.298 | 0.240 | 2 | 2 | 4.115 | 0.549 | 0.256 |
| | | 4.873 | 0.411 | 0.215 | | | 4.432 | 0.285 | |
| | | 6.431 | 0.389 | 0.202 | | 2 | 5.879 | 0.331 | |
| | | | | | | | 5.948 | 0.255 | |
| 1521 | 5 | 3.074 | 0.383 | 0.197 | 0 | | | | |
| | | 3.584 | 0.202 | 0.110 | | | | | |
| | | 4.133 | 0.199 | 0.107 | | | | | |
| | | 4.495 | 0.345 | 0.176 | | | | | |
| | | 6.388 | 0.477 | 0.251 | | | | | |
| 1571 | 4 | 3.061 | 0.395 | 0.206 | 1 | 2 | 4.017 | 0.363 | 0.156 |
| | | 3.496 | 0.383 | 0.199 | | | 4.367 | 0.335 | |
| | | 5.866 | 0.515 | 0.271 | | | | | |
| | | 6.438 | 0.387 | 0.201 | | | | | |
| 1600 | 1 | 5.023 | 0.695 | 0.369 | 2 | 5 | 5.129 | 0.421 | 0.714 |
| | | | | | | | 3.461 | 0.365 | |
| | | | | | | | 3.624 | 0.479 | |
| | | | | | | | 4.058 | 0.389 | |
| | | | | | | | 4.390 | 0.274 | |
| | | | | | | 3 | 5.799 | 0.452 | |
| | | | | | | | 6.179 | 0.307 | |
| | | | | | | | 5.531 | 0.394 | |
| 1640 | 2 | 5.967 | 0.451 | 0.236 | 3 | 2 | 3.072 | 0.311 | 0.543 |
| | | 6.409 | 0.350 | 0.181 | | | 3.386 | 0.429 | |
| | | | | | | 3 | 3.744 | 0.257 | |
| | | | | | | | 4.003 | 0.261 | |
| | | | | | | | 4.376 | 0.484 | |
| | | | | | | 2 | 4.895 | 0.760 | |
| | | | | | | | 5.248 | 0.478 | |
| 1690 | 3 | 3.037 | 0.322 | 0.165 | 1 | 2 | 4.916 | 0.248 | 0.154 |
| | | 3.969 | 0.506 | 0.266 | | | 5.270 | 0.460 | |
| | | 6.318 | 0.555 | 0.293 | | | | | |
| 1733 | 3 | 3.070 | 0.407 | 0.212 | 2 | 2 | 5.122 | 0.272 | 0.383 |
| | | 3.961 | 0.167 | 0.075 | | | 5.329 | 0.328 | |
| | | 4.381 | 0.145 | 0.057 | | 2 | 5.806 | 0.523 | |
| | | | | | | | 6.338 | 0.535 | |
| 1766 | 4 | 3.056 | 0.373 | 0.194 | 0 | | | | |
| | | 3.910 | 0.173 | 0.081 | | | | | |
| | | 4.997 | 0.144 | 0.056 | | | | | |
| | | 6.378 | 0.493 | 0.263 | | | | | |
| 1813 | 4 | 2.980 | 0.182 | 0.089 | 1 | 2 | 3.670 | 0.569 | 0.193 |
| | | 4.387 | 0.294 | 0.233 | | | 3.878 | 0.284 | |
| | | 5.761 | 0.612 | 0.324 | | | | | |
| | | 6.380 | 0.469 | 0.246 | | | | | |
| 1858 | 3 | 3.054 | 0.289 | 0.225 | 2 | 2 | 3.679 | 0.315 | 0.447 |
| | | 5.025 | 0.333 | 0.171 | | | 4.029 | 0.384 | |
| | | 6.384 | 0.477 | 0.251 | | 2 | 5.468 | 0.620 | |
| | | | | | | | 5.810 | 0.523 | |
| 1890 | 2 | 4.964 | 0.256 | 0.177 | 2 | 6 | 3.137 | 0.427 | 0.601 |
| | | 5.536 | 0.600 | 0.317 | | | 3.393 | 0.315 | |
| | | | | | | | 3.646 | 0.378 | |
| | | | | | | | 3.818 | 0.244 | |
| | | | | | | | 4.028 | 0.386 | |
| | | | | | | | 4.406 | 0.371 | |
| | | | | | | 2 | 6.278 | 0.298 | |
| | | | | | | | 6.458 | 0.313 | |
| 1927 | 4 | 3.072 | 0.247 | 0.165 | 1 | 2 | 6.110 | 0.190 | 0.127 |
| | | 4.406 | 0.650 | 0.345 | | | 6.418 | 0.427 | |
| | | 4.896 | 0.237 | 0.152 | | | | | |
| | | 5.376 | 0.488 | 0.257 | | | | | |

[a]3.737 movie analyzer units equal 0.75 inch; left end reading, 2.886; right end reading, 6.623.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(i) Concluded. Test fluid, methanol; run 63-2-6-3

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 1180 | 2 | 4.166 | 0.350 | 0.180 | 2 | 2 | 3.050 | 0.268 | 0.394 |
| | | 4.970 | 0.095 | 0.024 | | | 3.128 | 0.273 | |
| | | | | | | 3 | 5.525 | 0.399 | |
| | | | | | | | 5.927 | 0.405 | |
| | | | | | | | 6.350 | 0.440 | |
| 1223 | 2 | 3.045 | 0.160 | 0.068 | 3 | 3 | 3.449 | 0.499 | 0.660 |
| | | 5.454 | 0.325 | 0.166 | | | 3.858 | 0.318 | |
| | | | | | | | 4.205 | 0.377 | |
| | | | | | | 2 | 4.943 | 0.654 | |
| | | | | | | | 4.855 | 0.231 | |
| | | | | | | 2 | 5.841 | 0.339 | |
| | | | | | | | 6.180 | 0.433 | |
| 1261 | 2 | 3.067 | 0.356 | 0.183 | 1 | 2 | 3.743 | 0.293 | 0.135 |
| | | 4.994 | 0.371 | 0.192 | | | 4.063 | 0.346 | |
| 1311 | 4 | 3.029 | 0.359 | 0.185 | 0 | | | | |
| | | 4.223 | 0.571 | 0.300 | | | | | |
| | | 4.856 | 0.278 | 0.207 | | | | | |
| | | 6.396 | 0.407 | 0.211 | | | | | |
| 1359 | 1 | 4.894 | 0.138 | 0.051 | 3 | 3 | 3.044 | 0.357 | 0.803 |
| | | | | | | | 3.053 | 0.368 | |
| | | | | | | | 3.477 | 0.585 | |
| | | | | | | 2 | 4.389 | 0.396 | |
| | | | | | | | 4.617 | 0.359 | |
| | | | | | | 2 | 5.816 | 0.838 | |
| | | | | | | | 6.425 | 0.411 | |
| 1411 | 0 | | | | 2 | 4 | 3.000 | 0.247 | 0.466 |
| | | | | | | | 3.105 | 0.341 | |
| | | | | | | | 3.202 | 0.286 | |
| | | | | | | | 3.483 | 0.373 | |
| | | | | | | 2 | 5.828 | 0.376 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | 6.044 | 0.303 | 0.245 | | | | | |
| 1813 | 4 | 4.326 | 0.860 | 0.456 | 1 | 2 | 2.950 | 0.195 | 0.052 |
| | | 4.925 | 0.124 | 0.041 | | | 2.985 | 0.199 | |
| | | 5.566 | 0.332 | 0.170 | | | | | |
| | | 6.396 | 0.298 | 0.237 | | | | | |
| 1858 | 2 | 5.569 | 0.333 | 0.171 | 3 | 2 | 3.001 | 0.197 | 0.257 |
| | | 6.502 | 0.216 | 0.125 | | | 3.083 | 0.262 | |
| | | | | | | 4 | 4.165 | 0.176 | |
| | | | | | | | 4.306 | 0.157 | |
| | | | | | | | 4.310 | 0.172 | |
| | | | | | | | 4.563 | 0.334 | |
| | | | | | | 3 | 4.846 | 0.206 | |
| | | | | | | | 4.819 | 0.089 | |
| | | | | | | | 4.953 | 0.179 | |
| 1890 | 2 | 2.918 | 0.288 | 0.222 | 2 | 5 | 4.189 | 0.337 | 0.394 |
| | | 5.203 | 0.611 | 0.322 | | | 4.360 | 0.230 | |
| | | | | | | | 4.324 | 0.256 | |
| | | | | | | | 4.618 | 0.351 | |
| | | | | | | | 4.763 | 0.191 | |
| | | | | | | 2 | 6.039 | 0.324 | |
| | | | | | | | 6.360 | 0.318 | |
| 1927 | 3 | 5.231 | 0.189 | 0.096 | 2 | 2 | 2.954 | 0.243 | 0.307 |
| | | 5.597 | 0.319 | 0.163 | | | 3.038 | 0.211 | |
| | | 6.519 | 0.351 | 0.181 | | 4 | 4.135 | 0.281 | |
| | | | | | | | 4.401 | 0.250 | |
| | | | | | | | 4.637 | 0.358 | |
| | | | | | | | 4.903 | 0.304 | |
| 1965 | 2 | 3.022 | 0.315 | 0.161 | 1 | 3 | 4.736 | 0.407 | 0.286 |
| | | 6.526 | 0.226 | 0.137 | | | 5.198 | 0.517 | |
| | | | | | | | 5.608 | 0.302 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 6.263 | 0.495 | | |
| 1441 | 0 | | | | 3 | 2 | 2.981 | 0.183 | 0.598 |
| | | | | | | | 3.051 | 0.263 | |
| | | | | | | 3 | 4.843 | 0.675 | |
| | | | | | | | 4.809 | 0.270 | |
| | | | | | | | 5.214 | 0.541 | |
| | | | | | | 2 | 5.987 | 0.357 | |
| | | | | | | | 6.360 | 0.389 | |
| 1486 | 4 | 3.033 | 0.367 | 0.189 | 1 | 4 | 4.746 | 0.236 | 0.199 |
| | | 5.725 | 0.334 | 0.171 | | | 4.791 | 0.250 | |
| | | 6.006 | 0.272 | 0.198 | | | 5.009 | 0.290 | |
| | | 6.376 | 0.406 | 0.211 | | | 5.290 | 0.310 | |
| 1521 | 2 | 2.997 | 0.308 | 0.254 | 2 | 3 | 4.301 | 0.542 | 0.456 |
| | | 6.057 | 0.311 | 0.259 | | | 4.691 | 0.238 | |
| | | | | | | | 4.709 | 0.275 | |
| | | | | | | 3 | 5.211 | 0.396 | |
| | | | | | | | 5.622 | 0.427 | |
| | | | | | | | 5.881 | 0.233 | |
| 1571 | 3 | 3.064 | 0.267 | 0.191 | 1 | 2 | 5.417 | 0.270 | 0.138 |
| | | 4.841 | 0.393 | 0.204 | | | 5.744 | 0.384 | |
| | | 6.295 | 0.487 | 0.255 | | | | | |
| 1600 | 3 | 3.053 | 0.440 | 0.229 | 0 | | | | |
| | | 6.196 | 0.258 | 0.178 | | | | | |
| | | 6.423 | 0.331 | 0.169 | | | | | |
| 1640 | 2 | 3.068 | 0.402 | 0.209 | 1 | 4 | 4.847 | 0.246 | 0.350 |
| | | 6.292 | 0.571 | 0.300 | | | 4.855 | 0.515 | |
| | | | | | | | 5.198 | 0.372 | |
| | | | | | | | 5.585 | 0.403 | |
| 1690 | 2 | 5.083 | 0.155 | 0.064 | 2 | 2 | 2.985 | 0.227 | 0.252 |
| | | 5.561 | 0.237 | 0.150 | | | 3.186 | 0.250 | |
| | | | | | | 2 | 5.945 | 0.419 | |
| | | | | | | | 6.291 | 0.341 | |
| 1733 | 5 | 2.968 | 0.267 | 0.191 | 0 | | | | |
| | | 4.835 | 0.302 | 0.244 | | | | | |
| | | 5.164 | 0.392 | 0.203 | | | | | |
| | | 5.598 | 0.243 | 0.158 | | | | | |
| 2000 | 2 | 4.597 | 0.097 | 0.025 | 3 | 6 | 3.064 | 0.155 | 0.355 |
| | | 5.583 | 0.094 | 0.024 | | | 3.036 | 0.120 | |
| | | | | | | | 2.952 | 0.168 | |
| | | | | | | | 3.110 | 0.149 | |
| | | | | | | | 3.036 | 0.224 | |
| | | | | | | | 3.232 | 0.169 | |
| | | | | | | 2 | 5.144 | 0.330 | |
| | | | | | | | 5.281 | 0.193 | |
| | | | | | | 2 | 6.023 | 0.303 | |
| | | | | | | | 6.360 | 0.371 | |
| 2029 | 2 | 3.061 | 0.392 | 0.203 | 1 | 2 | 4.575 | 0.497 | 0.225 |
| | | 6.371 | 0.385 | 0.199 | | | 4.887 | 0.424 | |
| 2069 | 3 | 3.155 | 0.292 | 0.228 | 1 | 2 | 4.938 | 0.106 | 0.022 |
| | | 5.579 | 0.309 | 0.255 | | | 4.943 | 0.147 | |
| | | 6.402 | 0.365 | 0.188 | | | | | |
| 2117 | 5 | 3.019 | 0.375 | 0.194 | 0 | | | | |
| | | 4.574 | 0.493 | 0.258 | | | | | |
| | | 4.919 | 0.141 | 0.053 | | | | | |
| | | 5.557 | 0.338 | 0.173 | | | | | |
| | | 6.503 | 0.265 | 0.188 | | | | | |
| 2152 | 3 | 3.032 | 0.291 | 0.226 | 1 | 2 | 4.601 | 0.294 | 0.142 |
| | | 5.564 | 0.195 | 0.102 | | | 4.931 | 0.366 | |
| | | 6.433 | 0.362 | 0.187 | | | | | |
| 2192 | 3 | 2.995 | 0.262 | 0.184 | 0 | | | | |
| | | 5.195 | 0.670 | 0.354 | | | | | |
| | | 6.443 | 0.271 | 0.196 | | | | | |
| 2237 | 6 | 2.969 | 0.275 | 0.202 | 1 | 2 | 5.959 | 0.389 | 0.187 |
| | | 4.873 | 0.205 | 0.112 | | | 6.269 | 0.405 | |
| | | 4.962 | 0.161 | 0.069 | | | | | |
| | | 5.161 | 0.165 | 0.073 | | | | | |
| | | 5.353 | 0.240 | 0.154 | | | | | |
| | | 5.586 | 0.298 | 0.237 | | | | | |
| 2274 | 2 | 2.961 | 0.259 | 0.179 | 1 | 3 | 4.715 | 0.340 | 0.218 |
| | | 6.378 | 0.514 | 0.269 | | | 4.900 | 0.120 | |
| | | | | | | | 5.210 | 0.531 | |

Total number of sample frames, k, 47.
Total number of single bubbles, h, 130.
Total number of merging bubbles, 202.
Average instantaneous bubble population, $n_{av}$, 7.06.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.208.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.3695.
Standard deviation associated with $\varphi_{m,av}$, 0.2142.

[a]3.737 movie analyzer units equal 0.75 inch; left end reading, 2.886; right end reading, 6.623.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(j) Test fluid, methanol; run 63-2-6-4

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 30 | 4 | 4.664 | 0.156 | 0.060 | 1 | 5 | 2.852 | 0.391 | 0.497 |
| | | 4.811 | 0.165 | 0.074 | | | 3.138 | 0.431 | |
| | | 5.320 | 0.269 | 0.197 | | | 3.645 | 0.582 | |
| | | 6.227 | 0.427 | 0.224 | | | 4.020 | 0.268 | |
| | | | | | | | 4.364 | 0.420 | |
| 80 | 1 | 6.243 | 0.321 | 0.166 | 3 | 3 | 2.915 | 0.354 | 0.616 |
| | | | | | | | 3.285 | 0.387 | |
| | | | | | | | 3.630 | 0.303 | |
| | | | | | | 2 | 4.834 | 0.276 | |
| | | | | | | | 4.904 | 0.535 | |
| | | | | | | 2 | 5.440 | 0.451 | |
| | | | | | | | 5.846 | 0.360 | |
| 120 | 1 | 4.848 | 0.471 | 0.249 | 2 | 5 | 2.913 | 0.419 | 0.673 |
| | | | | | | | 3.269 | 0.350 | |
| | | | | | | | 3.576 | 0.273 | |
| | | | | | | | 3.631 | 0.320 | |
| | | | | | | | 4.050 | 0.518 | |
| | | | | | | 2 | 5.821 | 0.502 | |
| | | | | | | | 6.305 | 0.467 | |
| 160 | 3 | 4.149 | 0.270 | 0.199 | 2 | 6 | 2.858 | 0.201 | 0.497 |
| | | 5.865 | 0.299 | 0.244 | | | 2.983 | 0.109 | |
| | | 6.247 | 0.363 | 0.189 | | | 3.098 | 0.131 | |
| | | | | | | | 3.158 | 0.132 | |
| | | | | | | | 3.360 | 0.272 | |
| | | | | | | | 3.702 | 0.412 | |
| | | | | | | 4 | 4.592 | 0.244 | |
| | | | | | | | 4.909 | 0.391 | |
| | | | | | | | 5.102 | 0.194 | |
| | | | | | | | 5.284 | 0.514 | |
| 195 | 3 | 2.875 | 0.315 | 0.162 | 2 | 2 | 4.986 | 0.323 | 0.357 |
| | | 3.686 | 0.353 | 0.183 | | | 5.346 | 0.433 | |
| | | 4.373 | 0.303 | 0.250 | | 2 | 5.905 | 0.376 | |
| | | | | | | | 6.214 | 0.399 | |
| 240 | 2 | 5.377 | 0.317 | 0.163 | 1 | 8 | 2.893 | 0.374 | 0.736 |
| | | 6.283 | 0.341 | 0.177 | | | 3.144 | 0.351 | |
| | | | | | | | 3.448 | 0.333 | |
| | | | | | | | 3.708 | 0.587 | |
| | | | | | | | 4.069 | 0.310 | |
| | | | | | | | 4.363 | 0.446 | |
| | | | | | | | 4.831 | 0.491 | |
| | | | | | | | 4.775 | 0.269 | |
| 270 | 1 | 6.191 | 0.610 | 0.324 | 2 | 12 | 2.874 | 0.171 | 0.567 |
| | | | | | | | 2.977 | 0.179 | |
| | | | | | | | 2.999 | 0.296 | |
| | | | | | | | 3.252 | 0.211 | |
| | | | | | | 4 | 5.391 | 0.341 | |
| | | | | | | | 5.724 | 0.548 | |
| | | | | | | | 5.851 | 0.373 | |
| | | | | | | | 6.229 | 0.462 | |
| 489 | 2 | 4.821 | 0.191 | 0.099 | 1 | 7 | 2.854 | 0.309 | 0.516 |
| | | 6.191 | 0.481 | 0.254 | | | 3.126 | 0.234 | |
| | | | | | | | 3.354 | 0.313 | |
| | | | | | | | 3.595 | 0.169 | |
| | | | | | | | 3.854 | 0.361 | |
| | | | | | | | 4.289 | 0.582 | |
| | | | | | | | 3.929 | 0.399 | |
| 519 | 2 | 4.335 | 0.396 | 0.207 | 2 | 4 | 2.884 | 0.298 | 0.522 |
| | | 4.792 | 0.221 | 0.133 | | | 3.175 | 0.284 | |
| | | | | | | | 3.499 | 0.365 | |
| | | | | | | | 3.797 | 0.466 | |
| | | | | | | 2 | 5.813 | 0.424 | |
| | | | | | | | 6.239 | 0.429 | |
| 564 | 1 | 6.170 | 0.574 | 0.305 | 1 | 6 | 2.889 | 0.305 | 0.633 |
| | | | | | | | 3.097 | 0.361 | |
| | | | | | | | 3.471 | 0.387 | |
| | | | | | | | 3.858 | 0.386 | |
| | | | | | | | 4.435 | 0.768 | |
| | | | | | | | 4.785 | 0.426 | |
| 601 | 0 | | | | 3 | 3 | 2.881 | 0.280 | 0.705 |
| | | | | | | | 3.136 | 0.230 | |
| | | | | | | | 3.371 | 0.240 | |
| | | | | | | 3 | 4.496 | 0.300 | |
| | | | | | | | 4.577 | 0.307 | |
| | | | | | | | 4.893 | 0.510 | |
| | | | | | | 2 | 5.584 | 0.644 | |
| | | | | | | | 6.155 | 0.610 | |
| 653 | 2 | 3.543 | 0.160 | 0.070 | 2 | 3 | 2.901 | 0.367 | 0.747 |
| | | 4.139 | 0.191 | 0.099 | | | 3.165 | 0.310 | |
| | | | | | | | 3.264 | 0.280 | |
| | | | | | | 6 | 4.718 | 0.361 | |
| | | | | | | | 5.135 | 0.659 | |
| | | | | | | | 5.250 | 0.267 | |
| | | | | | | | 5.569 | 0.259 | |
| | | | | | | | 5.745 | 0.216 | |
| | | | | | | | 6.138 | 0.635 | |
| 685 | 1 | 6.391 | 0.278 | 0.211 | 1 | 10 | 2.898 | 0.337 | 0.672 |
| | | | | | | | 3.220 | 0.306 | |
| | | | | | | | 3.786 | 0.926 | |
| | | | | | | | 4.390 | 0.247 | |
| | | | | | | | 4.464 | 0.255 | |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3.273 | 0.323 | | | | | | | | | 4.624 | 0.203 | |
| | | | | | | | 3.569 | 0.268 | | | | | | | | | 4.784 | 0.200 | |
| | | | | | | | 3.674 | 0.294 | | | | | | | | | 4.940 | 0.362 | |
| | | | | | | | 3.887 | 0.204 | | | | | | | | | 5.266 | 0.257 | |
| | | | | | | | 4.014 | 0.214 | | | | | | | | | 5.284 | 0.262 | |
| | | | | | | | 4.145 | 0.154 | | 715 | 2 | 2.866 | 0.317 | 0.163 | 1 | 10 | 3.361 | 0.475 | 0.758 |
| | | | | | | | 4.223 | 0.165 | | | | 6.255 | 0.419 | 0.220 | | | 3.733 | 0.269 | |
| | | | | | | | 4.399 | 0.308 | | | | | | | | | 3.984 | 0.232 | |
| | | | | | | 2 | 4.775 | 0.249 | | | | | | | | | 4.118 | 0.236 | |
| | | | | | | | 4.818 | 0.307 | | | | | | | | | 4.260 | 0.321 | |
| 325 | 0 | | | | 2 | 6 | 2.858 | 0.287 | 0.992 | | | | | | | | 4.304 | 0.280 | |
| | | | | | | | 2.885 | 0.276 | | | | | | | | | 4.655 | 0.524 | |
| | | | | | | | 3.185 | 0.325 | | | | | | | | | 4.982 | 0.429 | |
| | | | | | | | 3.430 | 0.398 | | | | | | | | | 5.369 | 0.344 | |
| | | | | | | | 3.714 | 0.346 | | | | | | | | | 5.693 | 0.349 | |
| | | | | | | | 3.957 | 0.358 | | 754 | 2 | 5.368 | 0.357 | 0.186 | 2 | 4 | 2.828 | 0.324 | 0.473 |
| | | | | | | 5 | 4.822 | 0.402 | | | | 6.184 | 0.476 | 0.251 | | | 3.153 | 0.401 | |
| | | | | | | | 4.800 | 0.413 | | | | | | | | | 3.444 | 0.181 | |
| | | | | | | | 5.256 | 0.499 | | | | | | | | | 3.486 | 0.154 | |
| | | | | | | | 5.761 | 0.510 | | | | | | | | 3 | 4.466 | 0.437 | |
| | | | | | | | 6.238 | 0.444 | | | | | | | | | 4.697 | 0.374 | |
| 365 | 0 | | | | 2 | 7 | 2.882 | 0.312 | 0.843 | | | | | | | | 4.925 | 0.332 | |
| | | | | | | | 3.113 | 0.151 | | 799 | 1 | 5.419 | 0.350 | 0.182 | 3 | 3 | 2.862 | 0.280 | 0.386 |
| | | | | | | | 3.298 | 0.218 | | | | | | | | | 2.948 | 0.313 | |
| | | | | | | | 3.565 | 0.317 | | | | | | | | | 3.157 | 0.278 | |
| | | | | | | | 3.813 | 0.179 | | | | | | | | 2 | 4.479 | 0.234 | |
| | | | | | | | 4.067 | 0.461 | | | | | | | | | 4.580 | 0.210 | |
| | | | | | | | 4.046 | 0.292 | | | | | | | | 2 | 5.911 | 0.167 | |
| | | | | | | 7 | 4.793 | 0.280 | | | | | | | | | 6.247 | 0.505 | |
| | | | | | | | 4.831 | 0.220 | | 833 | 1 | 6.093 | 0.499 | 0.264 | 2 | 2 | 2.868 | 0.296 | 0.357 |
| | | | | | | | 5.113 | 0.344 | | | | | | | | | 3.166 | 0.301 | |
| | | | | | | | 5.459 | 0.349 | | | | | | | | 2 | 4.348 | 0.485 | |
| | | | | | | | 5.800 | 0.333 | | | | | | | | | 4.776 | 0.464 | |
| | | | | | | | 5.867 | 0.240 | | 883 | 0 | | | | 3 | 2 | 2.927 | 0.305 | 0.858 |
| | | | | | | | 6.212 | 0.450 | | | | | | | | | 3.141 | 0.306 | |
| 400 | 3 | 3.594 | 0.197 | 0.106 | 3 | 3 | 2.873 | 0.272 | 0.365 | | | | | | | 2 | 3.678 | 0.748 | |
| | | 4.767 | 0.224 | 0.137 | | | 3.065 | 0.191 | | | | | | | | | 4.208 | 0.313 | |
| | | 6.325 | 0.283 | 0.216 | | | 3.221 | 0.266 | | | | | | | | 3 | 4.795 | 0.289 | |
| | | | | | | 2 | 3.806 | 0.277 | | | | | | | | | 5.302 | 0.883 | |
| | | | | | | | 4.061 | 0.274 | | | | | | | | | 6.089 | 0.691 | |
| | | | | | | 2 | 5.131 | 0.209 | | 927 | 3 | 2.867 | 0.306 | 0.255 | 2 | 3 | 3.482 | 0.249 | 0.303 |
| | | | | | | | 5.457 | 0.443 | | | | 4.383 | 0.337 | 0.175 | | | 3.718 | 0.222 | |
| 443 | 0 | | | | 3 | 5 | 2.894 | 0.350 | 0.818 | | | 6.333 | 0.247 | 0.166 | | | 3.699 | 0.260 | |
| | | | | | | | 3.177 | 0.217 | | | | | | | | 5 | 4.887 | 0.187 | |
| | | | | | | | 3.519 | 0.467 | | | | | | | | | 5.107 | 0.253 | |
| | | | | | | | 3.733 | 0.386 | | | | | | | | | 5.331 | 0.195 | |
| | | | | | | | 4.058 | 0.265 | | | | | | | | | 5.557 | 0.257 | |
| | | | | | | 3 | 4.716 | 0.196 | | | | | | | | | 5.811 | 0.250 | |
| | | | | | | | 4.855 | 0.083 | | 958 | 0 | | | | 3 | 2 | 2.840 | 0.202 | 0.713 |
| | | | | | | | 4.934 | 0.075 | | | | | | | | | 2.989 | 0.197 | |

[a] 3.720 movie analyzer units equal 0.75 inch; left end reading, 2.743, right end reading, 6.463.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(j) Concluded. Test fluid, methanol; run 63-2-6-4

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2 | 3.562 | 0.275 | |
| | | | | | | | 4.078 | 0.757 | |
| | | | | | | 7 | 4.810 | 0.249 | |
| | | | | | | | 4.955 | 0.235 | |
| | | | | | | | 5.036 | 0.309 | |
| | | | | | | | 5.315 | 0.249 | |
| | | | | | | | 5.513 | 0.147 | |
| | | | | | | | 5.776 | 0.378 | |
| | | | | | | | 6.205 | 0.480 | |
| 1001 | 3 | 2.832 | 0.306 | 0.256 | 2 | 3 | 3.383 | 0.521 | 0.545 |
| | | 4.814 | 0.341 | 0.177 | | | 3.723 | 0.453 | |
| | | 5.234 | 0.326 | 0.166 | | | 4.103 | 0.468 | |
| | | | | | | 2 | 5.721 | 0.308 | |
| | | | | | | | 6.117 | 0.484 | |
| 1063 | 2 | 2.842 | 0.229 | 0.143 | 4 | 2 | 3.161 | 0.262 | 0.586 |
| | | 6.268 | 0.340 | 0.176 | | | 3.434 | 0.284 | |
| | | | | | | 2 | 3.767 | 0.320 | |
| | | | | | | | 4.040 | 0.366 | |
| | | | | | | 2 | 4.786 | 0.373 | |
| | | | | | | | 4.791 | 0.270 | |
| | | | | | | 3 | 5.416 | 0.297 | |
| | | | | | | | 5.795 | 0.460 | |
| | | | | | | | 5.959 | 0.173 | |
| 1095 | 3 | 3.811 | 0.266 | 0.193 | 2 | 2 | 2.857 | 0.318 | 0.290 |
| | | 4.164 | 0.365 | 0.190 | | | 3.013 | 0.278 | |
| | | 6.116 | 0.602 | 0.320 | | 2 | 5.308 | 0.332 | |
| | | | | | | | 5.446 | 0.348 | |
| 1140 | 1 | 5.366 | 0.274 | 0.205 | 4 | 2 | 2.850 | 0.245 | 0.667 |
| | | | | | | | 3.010 | 0.238 | |
| | | | | | | 3 | 3.514 | 0.269 | |
| | | | | | | | 3.752 | 0.399 | |
| | | | | | | | 4.226 | 0.548 | |
| | | | | | | 2 | 4.644 | 0.543 | |
| | | | | | | | 5.004 | 0.176 | |
| | | | | | | 2 | 6.112 | 0.419 | |
| | | | | | | | 6.312 | 0.255 | |
| 1160 | 2 | 5.226 | 0.244 | 0.162 | 3 | 2 | 3.540 | 0.473 | 0.385 |
| | | 5.317 | 0.299 | 0.244 | | | 3.876 | 0.199 | |
| | | | | | | 2 | 4.235 | 0.424 | |
| | | | | | | | 4.559 | 0.254 | |
| | | | | | | 2 | 6.055 | 0.271 | |
| | | | | | | | 6.320 | 0.258 | |
| 1223 | 6 | 3.848 | 0.197 | 0.106 | 1 | 3 | 2.903 | 0.316 | 0.174 |
| | | 4.233 | 0.374 | 0.195 | | | 3.194 | 0.263 | |
| | | 4.604 | 0.257 | 0.180 | | | 3.473 | 0.294 | |

| Frame | Single bubbles: Sites | Single bubbles: Bubble center (a) | Single bubbles: Bubble width (a) | Single bubbles: Area fraction, $\varphi_s$ | Merging bubbles: Sites | Merging bubbles: Number of merging bubbles | Merging bubbles: Site center (a) | Merging bubbles: Site width (a) | Merging bubbles: Area fraction, $\varphi_m$ |
|---|---|---|---|---|---|---|---|---|---|
| 1600 | 2 | 5.021 | 0.121 | 0.040 | 1 | 4 | 2.880 | 0.725 | 0.260 |
| | | 6.352 | 0.216 | 0.127 | | | 2.912 | 0.298 | |
| | | | | | | | 3.110 | 0.235 | |
| | | | | | | | 3.482 | 0.508 | |
| 1640 | 1 | 2.912 | 0.365 | 0.190 | 3 | 2 | 3.322 | 0.340 | 0.801 |
| | | | | | | | 3.555 | 0.201 | |
| | | | | | | 3 | 4.276 | 0.596 | |
| | | | | | | | 4.750 | 0.352 | |
| | | | | | | | 4.837 | 0.475 | |
| | | | | | | 3 | 5.452 | 0.417 | |
| | | | | | | | 5.885 | 0.448 | |
| | | | | | | | 6.138 | 0.537 | |
| 1690 | 0 | | | | 3 | 3 | 3.341 | 0.425 | 0.730 |
| | | | | | | | 3.580 | 0.286 | |
| | | | | | | | 3.762 | 0.203 | |
| | | | | | | 5 | 4.253 | 0.354 | |
| | | | | | | | 4.255 | 0.234 | |
| | | | | | | | 4.650 | 0.555 | |
| | | | | | | | 5.051 | 0.332 | |
| | | | | | | | 5.426 | 0.419 | |
| | | | | | | 2 | 6.100 | 0.248 | |
| | | | | | | | 6.303 | 0.314 | |
| 1733 | 4 | 2.876 | 0.315 | 0.162 | 3 | 4 | 3.287 | 0.265 | 0.312 |
| | | 5.185 | 0.287 | 0.224 | | | 3.482 | 0.125 | |
| | | 5.465 | 0.245 | 0.164 | | | 3.653 | 0.716 | |
| | | 6.250 | 0.368 | 0.192 | | | 3.512 | 0.287 | |
| | | | | | | 2 | 4.201 | 0.198 | |
| | | | | | | | 4.276 | 0.207 | |
| | | | | | | 2 | 4.624 | 0.256 | |
| | | | | | | | 4.906 | 0.309 | |
| 1766 | 2 | 5.447 | 0.261 | 0.186 | 4 | 2 | 2.862 | 0.280 | 0.535 |
| | | 5.610 | 0.327 | 0.169 | | | 3.083 | 0.175 | |
| | | | | | | 2 | 4.225 | 0.308 | |
| | | | | | | | 4.249 | 0.220 | |
| | | | | | | 3 | 4.631 | 0.345 | |
| | | | | | | | 4.999 | 0.391 | |
| | | | | | | | 4.748 | 0.093 | |
| | | | | | | 2 | 5.810 | 0.327 | |
| | | | | | | | 6.206 | 0.464 | |
| 1813 | 5 | 2.886 | 0.367 | 0.191 | 1 | 2 | 4.636 | 0.209 | 0.102 |
| | | 3.466 | 0.456 | 0.240 | | | 4.904 | 0.327 | |
| | | 4.184 | 0.504 | 0.267 | | | | | |
| | | 5.436 | 0.426 | 0.224 | | | | | |
| | | 5.836 | 0.374 | 0.195 | | | | | |
| 1858 | 0 | | | | 2 | 8 | 2.872 | 0.311 | 0.934 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5.248 | 0.279 | 0.212 | | | | | |
| | | 5.760 | 0.540 | 0.286 | | | | | |
| | | 6.172 | 0.412 | 0.216 | | | | | |
| 1261 | 4 | 4.162 | 0.330 | 0.171 | 1 | 3 | 2.779 | 0.226 | 0.142 |
| | | 4.783 | 0.136 | 0.050 | | | 3.008 | 0.233 | |
| | | 5.792 | 0.317 | 0.163 | | | 3.287 | 0.324 | |
| | | 6.165 | 0.338 | 0.175 | | | | | |
| 1311 | 2 | 5.208 | 0.734 | 0.392 | 2 | 4 | 2.875 | 0.333 | 0.300 |
| | | 6.233 | 0.419 | 0.220 | | | 3.101 | 0.118 | |
| | | | | | | | 3.290 | 0.261 | |
| | | | | | | | 3.622 | 0.402 | |
| | | | | | | 2 | 4.602 | 0.309 | |
| | | | | | | | 4.773 | 0.116 | |
| 1359 | 4 | 2.874 | 0.310 | 0.159 | 2 | 2 | 4.531 | 0.179 | 0.393 |
| | | 3.693 | 0.294 | 0.235 | | | 4.952 | 0.833 | |
| | | 3.953 | 0.145 | 0.057 | | 2 | 5.934 | 0.272 | |
| | | 5.656 | 0.129 | 0.045 | | | 6.241 | 0.422 | |
| 1411 | 0 | | | | 2 | 4 | 2.920 | 0.320 | 0.663 |
| | | | | | | | 3.166 | 0.173 | |
| | | | | | | | 3.487 | 0.469 | |
| | | | | | | | 3.227 | 0.208 | |
| | | | | | | 5 | 4.820 | 0.304 | |
| | | | | | | | 5.077 | 0.298 | |
| | | | | | | | 5.431 | 0.494 | |
| | | | | | | | 5.802 | 0.309 | |
| | | | | | | | 6.201 | 0.468 | |
| 1441 | 2 | 4.545 | 0.186 | 0.094 | 2 | 6 | 2.847 | 0.255 | 0.368 |
| | | 4.799 | 0.280 | 0.214 | | | 3.052 | 0.154 | |
| | | | | | | | 3.227 | 0.197 | |
| | | | | | | | 3.359 | 0.300 | |
| | | | | | | | 3.659 | 0.300 | |
| | | | | | | | 3.971 | 0.469 | |
| | | | | | | 2 | 5.371 | 0.211 | |
| | | | | | | | 5.544 | 0.135 | |
| 1486 | 1 | 6.366 | 0.187 | 0.095 | 3 | 2 | 2.902 | 0.352 | 0.551 |
| | | | | | | | 3.194 | 0.233 | |
| | | | | | | 2 | 3.990 | 0.658 | |
| | | | | | | | 4.459 | 0.334 | |
| | | | | | | 3 | 4.832 | 0.230 | |
| | | | | | | | 5.087 | 0.281 | |
| | | | | | | | 5.434 | 0.413 | |
| 1521 | 2 | 2.908 | 0.305 | 0.253 | 3 | 2 | 4.075 | 0.506 | 0.406 |
| | | 5.446 | 0.375 | 0.196 | | | 4.492 | 0.329 | |
| | | | | | | 2 | 4.698 | 0.244 | |
| | | | | | | | 4.993 | 0.393 | |
| | | | | | | 2 | 6.010 | 0.149 | |
| | | | | | | | 6.230 | 0.290 | |
| 1571 | 1 | 5.466 | 0.615 | 0.327 | 1 | 3 | 2.856 | 0.266 | 0.170 |
| | | | | | | | 3.074 | 0.171 | |
| | | | | | | | 3.336 | 0.420 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 2.988 | 0.314 | |
| | | | | | | | 3.209 | 0.258 | |
| | | | | | | | 3.539 | 0.403 | |
| | | | | | | | 3.919 | 0.357 | |
| | | | | | | | 4.236 | 0.276 | |
| | | | | | | | 4.609 | 0.470 | |
| | | | | | | | 4.855 | 0.175 | |
| | | | | | | 3 | 5.248 | 0.577 | |
| | | | | | | | 5.757 | 0.541 | |
| | | | | | | | 6.241 | 0.427 | |
| 1890 | 1 | 2.890 | 0.249 | 0.169 | 2 | 2 | 3.709 | 0.453 | 0.742 |
| | | | | | | | 4.085 | 0.444 | |
| | | | | | | 6 | 4.619 | 0.351 | |
| | | | | | | | 4.750 | 0.164 | |
| | | | | | | | 4.981 | 0.368 | |
| | | | | | | | 5.405 | 0.517 | |
| | | | | | | | 5.771 | 0.381 | |
| | | | | | | | 6.200 | 0.477 | |
| 1927 | 1 | 2.857 | 0.249 | 0.169 | 3 | 2 | 3.605 | 0.313 | 0.569 |
| | | | | | | | 3.932 | 0.340 | |
| | | | | | | 5 | 4.617 | 0.573 | |
| | | | | | | | 4.990 | 0.218 | |
| | | | | | | | 5.052 | 0.207 | |
| | | | | | | | 5.184 | 0.156 | |
| | | | | | | | 5.409 | 0.342 | |
| | | | | | | 2 | 5.918 | 0.168 | |
| | | | | | | | 6.218 | 0.433 | |
| 1965 | 1 | 2.869 | 0.291 | 0.231 | 2 | 2 | 3.604 | 0.348 | 0.600 |
| | | | | | | | 4.104 | 0.652 | |
| | | | | | | 8 | 4.576 | 0.213 | |
| | | | | | | | 4.816 | 0.267 | |
| | | | | | | | 4.885 | 0.230 | |
| | | | | | | | 5.159 | 0.318 | |
| | | | | | | | 5.202 | 0.294 | |
| | | | | | | | 5.511 | 0.465 | |
| | | | | | | | 5.918 | 0.433 | |
| | | | | | | | 6.239 | 0.380 | |
| 2000 | 4 | 2.908 | 0.360 | 0.187 | 3 | 3 | 4.151 | 0.233 | 0.309 |
| | | 3.661 | 0.624 | 0.332 | | | 4.331 | 0.126 | |
| | | 4.816 | 0.251 | 0.172 | | | 4.260 | 0.275 | |
| | | 5.515 | 0.318 | 0.164 | | 2 | 5.116 | 0.212 | |
| | | | | | | | 5.140 | 0.200 | |
| | | | | | | 2 | 5.837 | 0.241 | |
| | | | | | | | 6.139 | 0.457 | |
| 2029 | 3 | 2.891 | 0.330 | 0.171 | 3 | 2 | 3.560 | 0.285 | 0.384 |
| | | 4.940 | 0.211 | 0.121 | | | 3.699 | 0.273 | |
| | | 6.212 | 0.468 | 0.247 | | 2 | 4.571 | 0.357 | |
| | | | | | | | 4.769 | 0.141 | |
| | | | | | | 2 | 5.335 | 0.418 | |
| | | | | | | | 5.702 | 0.357 | |

Total number of sample frames, k, 50.
Total number of single bubbles, h, 92.
Total number of merging bubbles, 373.
Average instantaneous bubble population, $n_{av}$, 9.30.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.189.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.5346.
Standard deviation associated with $\varphi_{m,av}$, 0.2164.

[a]3.720 movie analyzer units equal 0.75 inch; left end reading, 2.743, right end reading, 6.463.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(k) Test fluid, methanol; run 63-7-2-2

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 0 | 1 | 3.421 | 0.225 | 0.241 | 4 | 3 | 3.770 | 0.182 | 0.571 |
| | | | | | | | 3.902 | 0.131 | |
| | | | | | | | 4.006 | 0.171 | |
| | | | | | | 2 | 4.326 | 0.250 | |
| | | | | | | | 4.569 | 0.236 | |
| | | | | | | 2 | 4.942 | 0.325 | |
| | | | | | | | 5.235 | 0.260 | |
| | | | | | | 4 | 5.592 | 0.155 | |
| | | | | | | | 5.753 | 0.204 | |
| | | | | | | | 5.857 | 0.150 | |
| | | | | | | | 6.018 | 0.205 | |
| 30 | 1 | 3.873 | 0.216 | 0.222 | 4 | 2 | 3.429 | 0.240 | 0.582 |
| | | | | | | | 3.437 | 0.156 | |
| | | | | | | 3 | 4.262 | 0.200 | |
| | | | | | | | 4.334 | 0.232 | |
| | | | | | | | 4.522 | 0.144 | |
| | | | | | | 4 | 5.010 | 0.155 | |
| | | | | | | | 5.041 | 0.170 | |
| | | | | | | | 5.279 | 0.306 | |
| | | | | | | | 5.267 | 0.195 | |
| | | | | | | 3 | 5.723 | 0.239 | |
| | | | | | | | 5.944 | 0.203 | |
| | | | | | | | 6.046 | 0.148 | |
| 80 | 1 | 3.443 | 0.239 | 0.163 | 3 | 3 | 4.007 | 0.398 | 0.628 |
| | | | | | | | 4.338 | 0.264 | |
| | | | | | | | 4.557 | 0.174 | |
| | | | | | | 4 | 4.948 | 0.204 | |
| | | | | | | | 5.162 | 0.225 | |
| | | | | | | | 5.218 | 0.249 | |
| | | | | | | | 5.391 | 0.184 | |
| | | | | | | 4 | 5.608 | 0.133 | |
| | | | | | | | 5.740 | 0.175 | |
| | | | | | | | 5.863 | 0.230 | |
| | | | | | | | 6.029 | 0.175 | |
| 120 | 2 | 3.507 | 0.387 | 0.271 | 2 | 5 | 4.306 | 0.288 | 0.435 |
| | | 5.650 | 0.153 | 0.112 | | | 4.546 | 0.193 | |
| | | | | | | | 4.716 | 0.169 | |
| | | | | | | | 4.977 | 0.353 | |
| | | | | | | | 5.304 | 0.301 | |
| | | | | | | 2 | 5.922 | 0.159 | |
| | | | | | | | 6.058 | 0.148 | |
| 160 | 1 | 3.458 | 0.289 | 0.200 | 1 | 16 | 3.849 | 0.169 | 0.845 |
| | | | | | | | 4.021 | 0.215 | |
| | | | | | | | 4.245 | 0.299 | |
| | | | | | | | 4.234 | 0.154 | |
| | | | | | | | 4.485 | 0.180 | |
| | | | | | | | 4.481 | 0.234 | |
| | | | | | | | 4.665 | 0.238 | |
| | | | | | | | 4.749 | 0.256 | |
| | | | | | | | 5.000 | 0.246 | |
| | | | | | | | 5.219 | 0.193 | |
| | | | | | | | 5.448 | 0.265 | |
| | | | | | | | 5.624 | 0.153 | |
| | | | | | | | 5.763 | 0.124 | |
| | | | | | | | 5.753 | 0.246 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 4.411 | 0.221 | |
| | | | | | | | 4.679 | 0.315 | |
| | | | | | | 3 | 5.287 | 0.227 | |
| | | | | | | | 5.487 | 0.172 | |
| | | | | | | | 5.662 | 0.179 | |
| | | | | | | 2 | 5.990 | 0.273 | |
| | | | | | | | 6.046 | 0.162 | |
| 489 | 1 | 3.426 | 0.254 | 0.174 | 3 | 3 | 3.741 | 0.179 | 0.579 |
| | | | | | | | 3.902 | 0.143 | |
| | | | | | | | 4.100 | 0.252 | |
| | | | | | | 4 | 4.496 | 0.203 | |
| | | | | | | | 4.686 | 0.177 | |
| | | | | | | | 4.885 | 0.221 | |
| | | | | | | | 5.155 | 0.318 | |
| | | | | | | 2 | 5.711 | 0.315 | |
| | | | | | | | 5.970 | 0.303 | |
| 519 | 1 | 6.005 | 0.229 | 0.250 | 1 | 11 | 3.456 | 0.292 | 0.798 |
| | | | | | | | 3.725 | 0.246 | |
| | | | | | | | 3.918 | 0.140 | |
| | | | | | | | 4.161 | 0.347 | |
| | | | | | | | 4.459 | 0.248 | |
| | | | | | | | 4.578 | 0.236 | |
| | | | | | | | 4.753 | 0.228 | |
| | | | | | | | 5.004 | 0.275 | |
| | | | | | | | 5.163 | 0.242 | |
| | | | | | | | 5.411 | 0.255 | |
| | | | | | | | 5.661 | 0.244 | |
| 564 | 3 | 3.465 | 0.319 | 0.222 | 2 | 2 | 3.765 | 0.158 | 0.286 |
| | | 4.405 | 0.320 | 0.222 | | | 3.986 | 0.285 | |
| | | 4.968 | 0.148 | 0.104 | | 2 | 5.759 | 0.290 | |
| | | | | | | | 5.992 | 0.261 | |
| 601 | 2 | 4.013 | 0.224 | 0.239 | 3 | 2 | 3.388 | 0.154 | 0.303 |
| | | 4.436 | 0.232 | 0.256 | | | 3.459 | 0.296 | |
| | | | | | | 2 | 4.936 | 0.178 | |
| | | | | | | | 4.958 | 0.133 | |
| | | | | | | 3 | 5.840 | 0.204 | |
| | | | | | | | 5.971 | 0.196 | |
| | | | | | | | 6.049 | 0.152 | |
| 653 | 4 | 3.421 | 0.226 | 0.243 | 2 | 2 | 4.209 | 0.133 | 0.191 |
| | | 3.770 | 0.220 | 0.231 | | | 4.356 | 0.161 | |
| | | 4.932 | 0.173 | 0.143 | | 3 | 5.664 | 0.169 | |
| | | 5.225 | 0.217 | 0.224 | | | 5.803 | 0.157 | |
| | | | | | | | 6.009 | 0.255 | |
| 685 | 0 | | | | 3 | 2 | 3.436 | 0.248 | 0.701 |
| | | | | | | | 3.657 | 0.195 | |
| | | | | | | 4 | 3.919 | 0.226 | |
| | | | | | | | 4.080 | 0.203 | |
| | | | | | | | 4.203 | 0.135 | |
| | | | | | | | 4.395 | 0.248 | |
| | | | | | | 5 | 4.897 | 0.185 | |
| | | | | | | | 5.205 | 0.430 | |
| | | | | | | | 5.566 | 0.292 | |
| | | | | | | | 5.823 | 0.223 | |
| | | | | | | | 6.030 | 0.191 | |
| 715 | 2 | 3.452 | 0.284 | 0.196 | 3 | 4 | 3.838 | 0.172 | 0.471 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 5.857 | 0.177 | |
| | | | | | | | 6.034 | 0.176 | |
| 195 | 2 | 3.450 | 0.275 | 0.189 | 3 | 4 | 4.323 | 0.209 | 0.540 |
| | | 3.877 | 0.168 | 0.134 | | | 4.461 | 0.162 | |
| | | | | | | | 4.523 | 0.255 | |
| | | | | | | | 4.754 | 0.206 | |
| | | | | | | 2 | 5.031 | 0.170 | |
| | | | | | | | 5.063 | 0.234 | |
| | | | | | | 6 | 5.291 | 0.135 | |
| | | | | | | | 5.354 | 0.127 | |
| | | | | | | | 5.492 | 0.148 | |
| | | | | | | | 5.574 | 0.195 | |
| | | | | | | | 5.798 | 0.253 | |
| | | | | | | | 6.021 | 0.193 | |
| 240 | 3 | 3.443 | 0.276 | 0.190 | 2 | 2 | 3.731 | 0.240 | 0.666 |
| | | 5.659 | 0.173 | 0.143 | | | 3.947 | 0.240 | |
| | | 6.018 | 0.205 | 0.200 | | 8 | 4.291 | 0.328 | |
| | | | | | | | 4.460 | 0.239 | |
| | | | | | | | 4.649 | 0.214 | |
| | | | | | | | 4.835 | 0.158 | |
| | | | | | | | 4.861 | 0.250 | |
| | | | | | | | 5.057 | 0.227 | |
| | | | | | | | 5.298 | 0.254 | |
| | | | | | | | 5.269 | 0.228 | |
| 270 | 3 | 3.470 | 0.251 | 0.172 | 3 | 2 | 4.301 | 0.237 | 0.359 |
| | | 3.799 | 0.353 | 0.246 | | | 4.494 | 0.183 | |
| | | 5.280 | 0.153 | 0.112 | | 2 | 4.839 | 0.152 | |
| | | | | | | | 4.995 | 0.161 | |
| | | | | | | 3 | 5.712 | 0.260 | |
| | | | | | | | 5.878 | 0.200 | |
| | | | | | | | 6.007 | 0.240 | |
| 325 | 2 | 3.447 | 0.272 | 0.187 | 2 | 4 | 3.804 | 0.292 | 0.583 |
| | | 4.947 | 0.261 | 0.179 | | | 4.062 | 0.343 | |
| | | | | | | | 4.333 | 0.199 | |
| | | | | | | | 4.484 | 0.226 | |
| | | | | | | 7 | 5.223 | 0.198 | |
| | | | | | | | 5.428 | 0.213 | |
| | | | | | | | 5.542 | 0.221 | |
| | | | | | | | 5.661 | 0.169 | |
| | | | | | | | 5.797 | 0.159 | |
| | | | | | | | 5.900 | 0.137 | |
| | | | | | | | 6.044 | 0.151 | |
| 365 | 3 | 3.433 | 0.245 | 0.167 | 2 | 5 | 3.742 | 0.265 | 0.385 |
| | | 4.932 | 0.256 | 0.175 | | | 3.839 | 0.200 | |
| | | 5.606 | 0.170 | 0.136 | | | 4.067 | 0.319 | |
| | | | | | | | 4.354 | 0.255 | |
| | | | | | | | 4.516 | 0.106 | |
| | | | | | | 2 | 5.924 | 0.161 | |
| | | | | | | | 6.035 | 0.174 | |
| 400 | 3 | 3.462 | 0.250 | 0.171 | 3 | 3 | 3.799 | 0.217 | 0.420 |
| | | 4.958 | 0.191 | 0.174 | | | 3.889 | 0.339 | |
| | | 5.546 | 0.411 | 0.288 | | | 4.047 | 0.186 | |
| | | | | | | 3 | 4.323 | 0.220 | |
| | | | | | | | 4.505 | 0.145 | |
| | | | | | | | 4.681 | 0.207 | |
| | | | | | | 2 | 5.982 | 0.230 | |
| | | | | | | | 6.072 | 0.116 | |
| 443 | 1 | 4.994 | 0.222 | 0.235 | 3 | 6 | 3.512 | 0.311 | 0.672 |
| | | | | | | | 3.838 | 0.341 | |
| | | | | | | | 4.062 | 0.106 | |
| | | | | | | | 4.208 | 0.186 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5.502 | 0.211 | 0.212 | | | 4.028 | 0.209 | |
| | | | | | | | 4.202 | 0.139 | |
| | | | | | | | 4.379 | 0.290 | |
| | | | | | | 2 | 4.950 | 0.226 | |
| | | | | | | | 5.182 | 0.237 | |
| | | | | | | 3 | 5.757 | 0.195 | |
| | | | | | | | 5.877 | 0.208 | |
| | | | | | | | 5.975 | 0.194 | |
| 754 | 5 | 3.465 | 0.310 | 0.215 | 1 | 4 | 5.430 | 0.227 | 0.185 |
| | | 3.905 | 0.350 | 0.244 | | | 5.670 | 0.252 | |
| | | 4.233 | 0.163 | 0.127 | | | 5.676 | 0.161 | |
| | | 4.935 | 0.157 | 0.117 | | | 6.010 | 0.106 | |
| | | 5.172 | 0.193 | 0.177 | | | | | |
| 799 | 2 | 3.501 | 0.326 | 0.227 | 2 | 2 | 4.464 | 0.333 | 0.698 |
| | | 3.873 | 0.296 | 0.197 | | | 4.467 | 0.147 | |
| | | | | | | 8 | 4.924 | 0.271 | |
| | | | | | | | 5.121 | 0.201 | |
| | | | | | | | 5.215 | 0.315 | |
| | | | | | | | 5.486 | 0.226 | |
| | | | | | | | 5.661 | 0.255 | |
| | | | | | | | 5.706 | 0.236 | |
| | | | | | | | 5.776 | 0.304 | |
| | | | | | | | 6.031 | 0.194 | |
| 833 | 5 | 3.475 | 0.307 | 0.213 | 1 | 3 | 5.563 | 0.174 | 0.171 |
| | | 3.907 | 0.235 | 0.162 | | | 5.790 | 0.280 | |
| | | 4.542 | 0.392 | 0.274 | | | 6.031 | 0.203 | |
| | | 4.951 | 0.117 | 0.065 | | | | | |
| | | 5.215 | 0.184 | 0.161 | | | | | |
| 883 | 1 | 3.462 | 0.317 | 0.220 | 3 | 2 | 3.894 | 0.259 | 0.562 |
| | | | | | | | 3.915 | 0.178 | |
| | | | | | | 3 | 4.639 | 0.371 | |
| | | | | | | | 4.951 | 0.252 | |
| | | | | | | | 5.211 | 0.268 | |
| | | | | | | 2 | 5.720 | 0.336 | |
| | | | | | | | 6.000 | 0.225 | |
| 927 | 1 | 5.234 | 0.293 | 0.203 | 5 | 2 | 3.414 | 0.215 | 0.703 |
| | | | | | | | 3.466 | 0.357 | |
| | | | | | | 2 | 3.965 | 0.366 | |
| | | | | | | | 4.023 | 0.177 | |
| | | | | | | 2 | 4.352 | 0.276 | |
| | | | | | | | 4.502 | 0.255 | |
| | | | | | | 2 | 4.758 | 0.162 | |
| | | | | | | | 4.936 | 0.195 | |
| | | | | | | 4 | 5.363 | 0.160 | |
| | | | | | | | 5.703 | 0.132 | |
| | | | | | | | 5.881 | 0.205 | |
| | | | | | | | 6.056 | 0.144 | |
| 958 | 4 | 3.439 | 0.272 | 0.187 | 2 | 3 | 3.812 | 0.242 | 0.375 |
| | | 4.623 | 0.241 | 0.164 | | | 4.041 | 0.251 | |
| | | 4.951 | 0.172 | 0.141 | | | 4.511 | 0.289 | |
| | | 5.222 | 0.201 | 0.192 | | 3 | 5.670 | 0.194 | |
| | | | | | | | 5.834 | 0.179 | |
| | | | | | | | 6.012 | 0.223 | |
| 1001 | 5 | 3.446 | 0.310 | 0.215 | 1 | 5 | 5.430 | 0.166 | 0.205 |
| | | 3.846 | 0.257 | 0.176 | | | 5.608 | 0.191 | |
| | | 4.252 | 0.229 | 0.250 | | | 5.762 | 0.231 | |
| | | 4.673 | 0.256 | 0.175 | | | 5.959 | 0.163 | |
| | | 4.975 | 0.192 | 0.176 | | | 6.047 | 0.155 | |
| 1033 | 3 | 3.413 | 0.219 | 0.228 | 2 | 4 | 3.742 | 0.213 | 0.370 |
| | | 4.887 | 0.262 | 0.180 | | | 3.921 | 0.145 | |

[a]2.813 movie analyzer units equal 0.75 inch; left end reading 3.310; right end reading, 6.123.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(k) Concluded. Test fluid, methanol; run 63-7-2-2

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | 5.159 | 0.228 | 0.248 | | | 4.086 | 0.184 | |
| | | | | | | | 4.302 | 0.249 | |
| | | | | | | 4 | 5.453 | 0.209 | |
| | | | | | | | 5.662 | 0.208 | |
| | | | | | | | 5.849 | 0.167 | |
| | | | | | | | 6.026 | 0.187 | |
| 1063 | 3 | 3.456 | 0.308 | 0.214 | 2 | 4 | 3.764 | 0.222 | 0.370 |
| | | 4.964 | 0.127 | 0.077 | | | 4.002 | 0.254 | |
| | | 5.455 | 0.209 | 0.208 | | | 4.235 | 0.213 | |
| | | | | | | | 4.372 | 0.280 | |
| | | | | | | 2 | 5.789 | 0.219 | |
| | | | | | | | 5.989 | 0.181 | |
| 1095 | 6 | 3.453 | 0.277 | 0.191 | 1 | 2 | 3.777 | 0.181 | 0.125 |
| | | 4.383 | 0.264 | 0.181 | | | 4.009 | 0.292 | |
| | | 4.944 | 0.173 | 0.143 | | | | | |
| | | 5.406 | 0.183 | 0.160 | | | | | |
| | | 5.641 | 0.162 | 0.125 | | | | | |
| | | 5.995 | 0.235 | 0.175 | | | | | |
| 1140 | 4 | 4.393 | 0.253 | 0.175 | 1 | 3 | 3.460 | 0.297 | 0.255 |
| | | 4.985 | 0.215 | 0.229 | | | 3.760 | 0.302 | |
| | | 5.656 | 0.147 | 0.105 | | | 4.029 | 0.236 | |
| | | 6.026 | 0.210 | 0.210 | | | | | |
| 1180 | 4 | 3.435 | 0.246 | 0.176 | 2 | 2 | 3.780 | 0.174 | 0.195 |
| | | 4.392 | 0.242 | 0.165 | | | 4.002 | 0.253 | |
| | | 4.921 | 0.273 | 0.185 | | 2 | 5.001 | 0.250 | |
| | | 5.661 | 0.189 | 0.170 | | | 6.074 | 0.103 | |
| 1223 | 3 | 3.447 | 0.265 | 0.182 | 2 | 2 | 3.733 | 0.220 | 0.473 |
| | | 4.423 | 0.251 | 0.172 | | | 4.037 | 0.388 | |
| | | 4.973 | 0.143 | 0.097 | | 3 | 5.362 | 0.234 | |
| | | | | | | | 5.660 | 0.313 | |
| | | | | | | | 5.969 | 0.304 | |
| 1261 | 3 | 3.455 | 0.246 | 0.205 | 2 | 2 | 3.796 | 0.313 | 0.453 |
| | | 4.40[illegible] | 0.351 | 0.245 | | | 4.367 | 0.352 | |
| | | 4.747 | 0.172 | 0.170 | | 4 | 5.330 | 0.236 | |
| | | | | | | | 5.564 | 0.232 | |
| | | | | | | | 5.785 | 0.210 | |
| | | | | | | | 6.002 | 0.225 | |
| 1311 | 2 | 4.901 | 0.217 | 0.224 | 2 | 8 | 3.427 | 0.253 | 0.557 |
| | | 5.987 | 0.274 | 0.189 | | | 3.657 | 0.205 | |
| | | | | | | | 3.778 | 0.117 | |
| | | | | | | | 3.893 | 0.170 | |
| | | | | | | | 4.121 | 0.286 | |
| | | | | | | | 4.312 | 0.188 | |
| | | | | | | | 4.377 | 0.287 | |
| | | | | | | | 4.562 | 0.267 | |
| | | | | | | 2 | 5.194 | 0.227 | |
| | | | | | | | 5.362 | 0.191 | |
| 1359 | 1 | 5.301 | 0.334 | 0.235 | 2 | 8 | 3.539 | 0.265 | 0.593 |
| | | | | | | | 4.078 | 0.273 | |
| | | | | | | | 4.316 | 0.317 | |
| | | | | | | | 4.579 | 0.263 | |
| | | | | | | | 4.777 | 0.133 | |
| | | | | | | | 4.923 | 0.158 | |
| | | | | | | | 5.099 | 0.195 | |
| | | | | | | | 5.252 | 0.165 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 4.773 | 0.377 | |
| | | | | | | | 5.081 | 0.238 | |
| | | | | | | 3 | 5.629 | 0.209 | |
| | | | | | | | 5.719 | 0.161 | |
| | | | | | | | 5.923 | 0.246 | |
| 1690 | 2 | 3.460 | 0.329 | 0.227 | 4 | 2 | 3.875 | 0.273 | 0.392 |
| | | 5.674 | 0.135 | 0.083 | | | 4.077 | 0.151 | |
| | | | | | | 2 | 4.315 | 0.212 | |
| | | | | | | | 4.460 | 0.271 | |
| | | | | | | 2 | 4.872 | 0.174 | |
| | | | | | | | 5.100 | 0.283 | |
| | | | | | | 2 | 5.976 | 0.113 | |
| | | | | | | | 6.067 | 0.107 | |
| 1733 | 2 | 3.428 | 0.233 | 0.257 | 2 | 2 | 3.865 | 0.317 | 0.613 |
| | | 4.432 | 0.210 | 0.210 | | | 4.136 | 0.224 | |
| | | | | | | 8 | 4.748 | 0.243 | |
| | | | | | | | 4.924 | 0.141 | |
| | | | | | | | 5.003 | 0.159 | |
| | | | | | | | 5.171 | 0.177 | |
| | | | | | | | 5.450 | 0.380 | |
| | | | | | | | 5.687 | 0.215 | |
| | | | | | | | 5.820 | 0.180 | |
| | | | | | | | 6.004 | 0.243 | |
| 1766 | 1 | 5.993 | 0.254 | 0.174 | 4 | 2 | 3.373 | 0.121 | 0.614 |
| | | | | | | | 3.422 | 0.218 | |
| | | | | | | 4 | 3.788 | 0.302 | |
| | | | | | | | 3.951 | 0.350 | |
| | | | | | | | 4.110 | 0.263 | |
| | | | | | | | 4.353 | 0.223 | |
| | | | | | | 2 | 4.912 | 0.130 | |
| | | | | | | | 5.089 | 0.225 | |
| | | | | | | 2 | 5.414 | 0.214 | |
| | | | | | | | 5.630 | 0.219 | |
| 1813 | 1 | 5.436 | 0.187 | 0.167 | 3 | 4 | 3.474 | 0.326 | 0.691 |
| | | | | | | | 3.741 | 0.209 | |
| | | | | | | | 3.956 | 0.221 | |
| | | | | | | | 4.177 | 0.221 | |
| | | | | | | 4 | 4.445 | 0.203 | |
| | | | | | | | 4.677 | 0.260 | |
| | | | | | | | 4.918 | 0.223 | |
| | | | | | | | 5.144 | 0.228 | |
| | | | | | | 3 | 5.693 | 0.242 | |
| | | | | | | | 5.940 | 0.253 | |
| | | | | | | | 6.060 | 0.143 | |
| 1858 | 1 | 6.054 | 0.157 | 0.120 | 3 | 5 | 3.445 | 0.248 | 0.567 |
| | | | | | | | 3.702 | 0.266 | |
| | | | | | | | 3.834 | 0.212 | |
| | | | | | | | 3.878 | 0.177 | |
| | | | | | | | 4.072 | 0.305 | |
| | | | | | | 3 | 4.882 | 0.114 | |
| | | | | | | | 4.960 | 0.086 | |
| | | | | | | | 5.117 | 0.228 | |
| | | | | | | 4 | 5.367 | 0.161 | |
| | | | | | | | 5.467 | 0.195 | |
| | | | | | | | 5.612 | 0.195 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2 | 5.755 | 0.278 | |
| | | | | | | | 6.017 | 0.247 | |
| 1411 | 3 | 3.466 | 0.327 | 0.227 | 2 | 2 | 4.327 | 0.204 | 0.238 |
| | | 3.893 | 0.278 | 0.192 | | | 4.543 | 0.229 | |
| | | 4.956 | 0.137 | 0.089 | | 3 | 5.717 | 0.179 | |
| | | | | | | | 5.864 | 0.154 | |
| | | | | | | | 6.026 | 0.224 | |
| 1441 | 2 | 3.472 | 0.303 | 0.210 | 4 | 3 | 3.889 | 0.301 | 0.581 |
| | | 5.671 | 0.158 | 0.119 | | | 4.162 | 0.245 | |
| | | | | | | | 4.320 | 0.158 | |
| | | | | | | 2 | 4.870 | 0.250 | |
| | | | | | | | 4.937 | 0.094 | |
| | | | | | | 2 | 5.187 | 0.180 | |
| | | | | | | | 5.325 | 0.388 | |
| | | | | | | 2 | 5.986 | 0.289 | |
| | | | | | | | 6.034 | 0.194 | |
| 1486 | 1 | 3.433 | 0.256 | 0.175 | 2 | 8 | 3.862 | 0.209 | 0.464 |
| | | | | | | | 4.004 | 0.075 | |
| | | | | | | | 4.103 | 0.122 | |
| | | | | | | | 4.239 | 0.151 | |
| | | | | | | | 4.425 | 0.220 | |
| | | | | | | | 4.702 | 0.334 | |
| | | | | | | | 4.935 | 0.133 | |
| | | | | | | | 5.106 | 0.209 | |
| | | | | | | 2 | 5.829 | 0.286 | |
| | | | | | | | 6.054 | 0.165 | |
| 1521 | 3 | 3.472 | 0.326 | 0.227 | 1 | 6 | 3.872 | 0.365 | 0.489 |
| | | 5.321 | 0.208 | 0.206 | | | 3.884 | 0.269 | |
| | | 5.966 | 0.319 | 0.222 | | | 4.117 | 0.125 | |
| | | | | | | | 4.308 | 0.256 | |
| | | | | | | | 4.600 | 0.328 | |
| | | | | | | | 4.905 | 0.282 | |
| 1571 | 0 | | | | 2 | 2 | 3.426 | 0.237 | 0.870 |
| | | | | | | | 3.489 | 0.363 | |
| | | | | | | 10 | 3.925 | 0.253 | |
| | | | | | | | 4.134 | 0.265 | |
| | | | | | | | 4.372 | 0.211 | |
| | | | | | | | 4.563 | 0.170 | |
| | | | | | | | 4.728 | 0.160 | |
| | | | | | | | 4.935 | 0.254 | |
| | | | | | | | 5.235 | 0.346 | |
| | | | | | | | 5.608 | 0.400 | |
| | | | | | | | 5.856 | 0.225 | |
| | | | | | | | 6.049 | 0.160 | |
| 1600 | 1 | 3.485 | 0.347 | 0.242 | 3 | 6 | 3.860 | 0.193 | 0.539 |
| | | | | | | | 4.007 | 0.101 | |
| | | | | | | | 4.136 | 0.156 | |
| | | | | | | | 4.312 | 0.197 | |
| | | | | | | | 4.495 | 0.168 | |
| | | | | | | | 4.700 | 0.242 | |
| | | | | | | 3 | 5.015 | 0.180 | |
| | | | | | | | 5.057 | 0.169 | |
| | | | | | | | 5.237 | 0.190 | |
| | | | | | | 4 | 5.478 | 0.115 | |
| | | | | | | | 5.672 | 0.273 | |
| | | | | | | | 5.897 | 0.257 | |
| | | | | | | | 6.065 | 0.166 | |
| 1640 | 1 | 3.442 | 0.289 | 0.206 | 3 | 2 | 3.573 | 0.173 | 0.535 |
| | | | | | | | 4.061 | 0.202 | |
| | | | | | | 4 | 4.303 | 0.164 | |
| | | | | | | | 4.460 | 0.249 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 5.816 | 0.213 | |
| 1890 | 3 | 3.446 | 0.278 | 0.192 | 2 | 4 | 3.804 | 0.346 | 0.564 |
| | | 4.938 | 0.239 | 0.163 | | | 4.144 | 0.334 | |
| | | 5.291 | 0.195 | 0.181 | | | 4.409 | 0.196 | |
| | | | | | | | 4.645 | 0.277 | |
| | | | | | | 3 | 5.578 | 0.261 | |
| | | | | | | | 5.736 | 0.197 | |
| | | | | | | | 5.977 | 0.284 | |
| 1927 | 2 | 3.458 | 0.287 | 0.198 | 3 | 3 | 4.135 | 0.271 | 0.407 |
| | | 3.876 | 0.175 | 0.146 | | | 4.360 | 0.179 | |
| | | | | | | | 4.536 | 0.173 | |
| | | | | | | 2 | 4.894 | 0.202 | |
| | | | | | | | 5.102 | 0.214 | |
| | | | | | | 4 | 5.544 | 0.101 | |
| | | | | | | | 5.600 | 0.091 | |
| | | | | | | | 5.758 | 0.232 | |
| | | | | | | | 5.989 | 0.231 | |
| 1965 | 1 | 3.449 | 0.275 | 0.189 | 4 | 3 | 3.964 | 0.324 | 0.427 |
| | | | | | | | 4.201 | 0.150 | |
| | | | | | | | 4.370 | 0.188 | |
| | | | | | | 2 | 4.935 | 0.115 | |
| | | | | | | | 5.094 | 0.202 | |
| | | | | | | 2 | 5.518 | 0.257 | |
| | | | | | | | 5.674 | 0.185 | |
| | | | | | | 2 | 5.948 | 0.172 | |
| | | | | | | | 6.034 | 0.177 | |
| 2000 | 5 | 3.443 | 0.268 | 0.184 | 1 | 4 | 5.341 | 0.352 | 0.254 |
| | | 3.892 | 0.151 | 0.104 | | | 5.621 | 0.208 | |
| | | 4.091 | 0.090 | 0.039 | | | 5.812 | 0.174 | |
| | | 4.450 | 0.238 | 0.162 | | | 6.003 | 0.208 | |
| | | 4.797 | 0.153 | 0.112 | | | | | |
| 2029 | 2 | 3.410 | 0.217 | 0.224 | 2 | 6 | 3.725 | 0.210 | 0.462 |
| | | 5.929 | 0.350 | 0.244 | | | 3.885 | 0.110 | |
| | | | | | | | 3.939 | 0.158 | |
| | | | | | | | 4.052 | 0.224 | |
| | | | | | | | 4.247 | 0.166 | |
| | | | | | | | 4.499 | 0.338 | |
| | | | | | | 3 | 4.894 | 0.214 | |
| | | | | | | | 5.101 | 0.201 | |
| | | | | | | | 5.314 | 0.225 | |
| 2069 | 3 | 3.407 | 0.191 | 0.174 | 1 | 8 | 3.728 | 0.186 | 0.451 |
| | | 5.582 | 0.155 | 0.114 | | | 3.912 | 0.183 | |
| | | 5.970 | 0.302 | 0.209 | | | 4.069 | 0.178 | |
| | | | | | | | 4.268 | 0.221 | |
| | | | | | | | 4.518 | 0.279 | |
| | | | | | | | 4.808 | 0.300 | |
| | | | | | | | 5.075 | 0.235 | |
| | | | | | | | 5.229 | 0.154 | |
| 2117 | 6 | 3.890 | 0.128 | 0.078 | 2 | 2 | 3.518 | 0.369 | 0.342 |
| | | 4.117 | 0.203 | 0.196 | | | 3.492 | 0.317 | |
| | | 4.937 | 0.154 | 0.113 | | 2 | 4.387 | 0.095 | |
| | | 5.270 | 0.133 | 0.084 | | | 4.534 | 0.334 | |
| | | 5.600 | 0.273 | 0.185 | | | | | |
| | | 5.994 | 0.247 | 0.169 | | | | | |
| 2152 | 7 | 3.487 | 0.247 | 0.169 | 1 | 2 | 5.944 | 0.204 | 0.075 |
| | | 3.795 | 0.176 | 0.148 | | | 6.058 | 0.147 | |
| | | 4.107 | 0.191 | 0.174 | | | | | |
| | | 4.387 | 0.210 | 0.210 | | | | | |
| | | 4.959 | 0.182 | 0.158 | | | | | |
| | | 5.270 | 0.158 | 0.117 | | | | | |
| | | 5.638 | 0.205 | 0.206 | | | | | |

Total number of sample frames, k, 55.
Total number of single bubbles, h, 135.
Total number of merging bubbles, 447.
Average instantaneous bubble population, $n_{av}$, 10.58.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.182.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.4704.
Standard deviations associated with $\varphi_{m,av}$, 0.1833.

[a]2.813 movie analyzer units equal 0.75 inch; left end reading, 3.310; right end reading, 6.123.

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(l) Test fluid, methanol; run 63-7-8-1

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 0 | 2 | 3.249 | 0.133 | 0.081 | 2 | 3 | 5.004 | 0.263 | 0.280 |
| | | 3.732 | 0.262 | 0.289 | | | 5.326 | 0.380 | |
| | | | | | | | 5.567 | 0.103 | |
| | | | | | | 2 | 5.770 | 0.216 | |
| | | | | | | | 5.868 | 0.148 | |
| 30 | 2 | 4.808 | 0.268 | 0.183 | 1 | 2 | 5.249 | 0.166 | 0.113 |
| | | 5.776 | 0.129 | 0.070 | | | 5.475 | 0.286 | |
| 80 | 5 | 3.252 | 0.071 | 0.021 | 0 | | | | |
| | | 4.097 | 0.124 | 0.065 | | | | | |
| | | 4.815 | 0.079 | 0.026 | | | | | |
| | | 4.984 | 0.095 | 0.038 | | | | | |
| | | 5.457 | 0.220 | 0.204 | | | | | |
| 120 | 2 | 3.264 | 0.095 | 0.038 | 2 | 2 | 3.462 | 0.253 | 0.316 |
| | | 4.976 | 0.162 | 0.110 | | | 3.705 | 0.232 | |
| | | | | | | 6 | 5.268 | 0.288 | |
| | | | | | | | 5.450 | 0.128 | |
| | | | | | | | 5.553 | 0.177 | |
| | | | | | | | 5.669 | 0.132 | |
| | | | | | | | 5.769 | 0.124 | |
| | | | | | | | 5.904 | 0.146 | |
| 160 | 6 | 3.257 | 0.081 | 0.028 | 1 | 2 | 5.883 | 0.114 | 0.035 |
| | | 4.113 | 0.230 | 0.223 | | | 5.905 | 0.143 | |
| | | 4.828 | 0.095 | 0.036 | | | | | |
| | | 5.000 | 0.180 | 0.136 | | | | | |
| | | 5.245 | 0.176 | 0.130 | | | | | |
| | | 5.590 | 0.289 | 0.199 | | | | | |
| 195 | 7 | 3.253 | 0.143 | 0.086 | 0 | | | | |
| | | 3.618 | 0.207 | 0.180 | | | | | |
| | | 4.245 | 0.225 | 0.213 | | | | | |
| | | 4.578 | 0.347 | 0.241 | | | | | |
| | | 4.992 | 0.106 | 0.047 | | | | | |
| | | 5.540 | 0.186 | 0.146 | | | | | |
| | | 5.897 | 0.123 | 0.064 | | | | | |
| 240 | 3 | 3.311 | 0.093 | 0.036 | 0 | | | | |
| | | 4.994 | 0.134 | 0.076 | | | | | |
| | | 5.868 | 0.223 | 0.209 | | | | | |
| 270 | 4 | 3.586 | 0.391 | 0.273 | 2 | 2 | 3.244 | 0.087 | 0.073 |
| | | 4.982 | 0.218 | 0.200 | | | 3.303 | 0.113 | |
| | | 5.341 | 0.070 | 0.021 | | 2 | 5.561 | 0.111 | |
| | | 5.443 | 0.066 | 0.018 | | | 5.602 | 0.192 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 715 | 5 | 3.253 | 0.077 | 0.025 | 1 | 2 | 4.820 | 0.155 | 0.080 |
| | | 3.358 | 0.083 | 0.029 | | | 5.012 | 0.229 | |
| | | 4.543 | 0.117 | 0.058 | | | | | |
| | | 5.458 | 0.221 | 0.206 | | | | | |
| | | 5.946 | 0.114 | 0.055 | | | | | |
| 754 | 7 | 3.253 | 0.067 | 0.019 | 0 | | | | |
| | | 3.667 | 0.234 | 0.230 | | | | | |
| | | 4.533 | 0.207 | 0.180 | | | | | |
| | | 4.839 | 0.152 | 0.097 | | | | | |
| | | 5.006 | 0.078 | 0.026 | | | | | |
| | | 5.453 | 0.172 | 0.125 | | | | | |
| | | 5.883 | 0.163 | 0.112 | | | | | |
| 799 | 4 | 3.276 | 0.082 | 0.028 | 0 | | | | |
| | | 4.241 | 0.257 | 0.278 | | | | | |
| | | 4.975 | 0.205 | 0.177 | | | | | |
| | | 5.426 | 0.271 | 0.185 | | | | | |
| 833 | 5 | 3.238 | 0.058 | 0.014 | 0 | | | | |
| | | 3.607 | 0.319 | 0.221 | | | | | |
| | | 4.093 | 0.093 | 0.036 | | | | | |
| | | 4.996 | 0.187 | 0.147 | | | | | |
| | | 5.957 | 0.046 | 0.009 | | | | | |
| 927 | 3 | 3.265 | 0.113 | 0.054 | 3 | 2 | 3.712 | 0.255 | 0.215 |
| | | 3.890 | 0.066 | 0.016 | | | 3.708 | 0.167 | |
| | | 4.452 | 0.236 | 0.234 | | 2 | 4.039 | 0.213 | |
| | | | | | | | 4.036 | 0.090 | |
| | | | | | | 2 | 5.816 | 0.203 | |
| | | | | | | | 5.929 | 0.127 | |
| 958 | 4 | 3.262 | 0.105 | 0.046 | 0 | | | | |
| | | 3.702 | 0.064 | 0.017 | | | | | |
| | | 5.475 | 0.139 | 0.081 | | | | | |
| | | 5.907 | 0.136 | 0.078 | | | | | |
| 1001 | 2 | 4.831 | 0.127 | 0.068 | 1 | 2 | 3.325 | 0.208 | 0.137 |
| | | 5.446 | 0.176 | 0.130 | | | 3.547 | 0.291 | |
| 1033 | 4 | 3.276 | 0.098 | 0.040 | 0 | | | | |
| | | 4.994 | 0.168 | 0.119 | | | | | |
| | | 5.455 | 0.100 | 0.042 | | | | | |
| | | 5.903 | 0.170 | 0.122 | | | | | |
| 1063 | 2 | 3.272 | 0.090 | 0.034 | 2 | 2 | 3.809 | 0.239 | 0.343 |
| | | 5.946 | 0.076 | 0.024 | | | 4.047 | 0.291 | |
| | | | | | | 2 | 5.373 | 0.266 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 325 | 5 | 3.261 | 0.150 | 0.095 | 0 | | | | |
| | | 4.116 | 0.075 | 0.024 | | | | | |
| | | 5.001 | 0.142 | 0.085 | | | | | |
| | | 5.455 | 0.149 | 0.093 | | | | | |
| | | 5.896 | 0.173 | 0.126 | | | | | |
| 365 | 3 | 3.305 | 0.093 | 0.036 | 2 | 2 | 4.810 | 0.154 | 0.230 |
| | | 5.208 | 0.128 | 0.069 | | | 5.018 | 0.252 | |
| | | 5.866 | 0.162 | 0.110 | | 3 | 5.310 | 0.259 | |
| | | | | | | | 5.554 | 0.193 | |
| | | | | | | | 5.697 | 0.068 | |
| 400 | 3 | 3.248 | 0.070 | 0.021 | 0 | | | | |
| | | 5.216 | 0.163 | 0.112 | | | | | |
| | | 5.791 | 0.342 | 0.238 | | | | | |
| 443 | 4 | 3.269 | 0.116 | 0.057 | 1 | 3 | 5.699 | 0.101 | 0.046 |
| | | 3.637 | 0.384 | 0.268 | | | 5.783 | 0.102 | |
| | | 4.116 | 0.239 | 0.240 | | | 5.761 | 0.157 | |
| | | 4.995 | 0.097 | 0.040 | | | | | |
| 489 | 2 | 4.850 | 0.139 | 0.081 | 1 | 2 | 3.610 | 0.186 | 0.092 |
| | | 5.934 | 0.117 | 0.058 | | | 3.799 | 0.230 | |
| 519 | 2 | 3.269 | 0.107 | 0.046 | 1 | 3 | 3.782 | 0.111 | 0.077 |
| | | 4.837 | 0.143 | 0.086 | | | 3.900 | 0.180 | |
| | | | | | | | 3.999 | 0.174 | |
| 564 | 6 | 3.263 | 0.092 | 0.036 | 1 | 2 | 4.304 | 0.352 | 0.152 |
| | | 4.842 | 0.194 | 0.156 | | | 4.527 | 0.195 | |
| | | 4.988 | 0.073 | 0.022 | | | | | |
| | | 5.297 | 0.414 | 0.290 | | | | | |
| | | 5.579 | 0.096 | 0.037 | | | | | |
| | | 5.857 | 0.117 | 0.058 | | | | | |
| 601 | 4 | 3.268 | 0.102 | 0.044 | 1 | 2 | 5.869 | 0.107 | 0.020 |
| | | 3.965 | 0.140 | 0.083 | | | 5.966 | 0.087 | |
| | | 5.448 | 0.075 | 0.024 | | | | | |
| | | 5.593 | 0.153 | 0.099 | | | | | |
| 653 | 6 | 3.295 | 0.152 | 0.097 | 0 | | | | |
| | | 3.607 | 0.174 | 0.127 | | | | | |
| | | 4.311 | 0.097 | 0.040 | | | | | |
| | | 5.007 | 0.076 | 0.024 | | | | | |
| | | 5.484 | 0.085 | 0.030 | | | | | |
| | | 5.938 | 0.103 | 0.045 | | | | | |
| 685 | 6 | 3.275 | 0.177 | 0.132 | 1 | 2 | 5.327 | 0.195 | 0.063 |
| | | 4.405 | 0.093 | 0.036 | | | 5.448 | 0.147 | |
| | | 4.548 | 0.094 | 0.037 | | | | | |
| | | 4.858 | 0.139 | 0.081 | | | | | |
| | | 5.023 | 0.154 | 0.100 | | | | | |
| | | 5.742 | 0.075 | 0.024 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 5.667 | 0.375 | |
| 1075 | 3 | 3.307 | 0.151 | 0.096 | 2 | 2 | 4.827 | 0.163 | 0.075 |
| | | 3.687 | 0.179 | 0.135 | | | 4.980 | 0.166 | |
| | | 4.102 | 0.136 | 0.080 | | 2 | 5.791 | 0.090 | |
| | | | | | | | 5.887 | 0.102 | |
| 1140 | 3 | 3.746 | 0.113 | 0.054 | 2 | 2 | 3.243 | 0.083 | 0.262 |
| | | 4.105 | 0.229 | 0.221 | | | 3.329 | 0.088 | |
| | | 5.920 | 0.113 | 0.054 | | 3 | 4.830 | 0.120 | |
| | | | | | | | 4.959 | 0.282 | |
| | | | | | | | 5.323 | 0.446 | |
| 1150 | 1 | 4.841 | 0.239 | 0.240 | 2 | 2 | 3.266 | 0.121 | 0.197 |
| | | | | | | | 3.362 | 0.127 | |
| | | | | | | 4 | 3.719 | 0.147 | |
| | | | | | | | 3.804 | 0.204 | |
| | | | | | | | 3.939 | 0.187 | |
| | | | | | | | 4.003 | 0.246 | |
| 1223 | 7 | 3.245 | 0.086 | 0.031 | 0 | | | | |
| | | 3.676 | 0.166 | 0.119 | | | | | |
| | | 4.255 | 0.247 | 0.257 | | | | | |
| | | 4.575 | 0.324 | 0.224 | | | | | |
| | | 4.677 | 0.183 | 0.141 | | | | | |
| | | 5.265 | 0.124 | 0.065 | | | | | |
| | | 5.645 | 0.263 | 0.271 | | | | | |
| 1261 | 3 | 3.265 | 0.161 | 0.107 | 1 | 3 | 4.586 | 0.307 | 0.161 |
| | | 3.623 | 0.175 | 0.129 | | | 4.849 | 0.218 | |
| | | 5.911 | 0.140 | 0.085 | | | 4.987 | 0.128 | |
| 1311 | 3 | 3.235 | 0.067 | 0.017 | 2 | 2 | 3.523 | 0.202 | 0.167 |
| | | 4.46 | 0.243 | 0.249 | | | 3.717 | 0.271 | |
| | | 4.992 | 0.069 | 0.020 | | 2 | 3.829 | 0.174 | |
| | | | | | | | 3.923 | 0.116 | |
| 1357 | 2 | 5.635 | 0.076 | 0.024 | 1 | 5 | 3.305 | 0.069 | 0.264 |
| | | 5.557 | 0.248 | 0.259 | | | 3.473 | 0.266 | |
| | | | | | | | 3.515 | 0.303 | |
| | | | | | | | 3.711 | 0.202 | |
| | | | | | | | 3.832 | 0.224 | |
| 1411 | 2 | 4.491 | 0.168 | 0.111 | 2 | 3 | 3.245 | 0.367 | 0.19[illegible] |
| | | 5.774 | 0.172 | 0.125 | | | 3.349 | 0.121 | |
| | | | | | | | 3.430 | 0.122 | |
| | | | | | | 2 | 4.976 | 0.240 | |
| | | | | | | | 5.257 | 0.319 | |
| 1441 | 3 | 3.267 | 0.120 | 0.061 | 0 | | | | |
| | | 4.395 | 0.033 | 0.027 | | | | | |
| | | 5.731 | 0.134 | 0.076 | | | | | |

[a]3.194 movie analyzer units equal 0.75 inch; left end reading, 3.180; right end reading, 6.374 (average right limit, 5.984; reduced area of strip evaluated because of obscuration of film).

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

($l$) Concluded. Test fluid, methanol; run 63-7-8-1

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 1486 | 2 | 4.270 | 0.246 | 0.255 | 1 | 3 | 3.207 | 0.037 | 0.016 |
| | | 5.945 | 0.091 | 0.035 | | | 3.265 | 0.078 | |
| | | | | | | | 3.349 | 0.090 | |
| 1521 | 5 | 3.259 | 0.108 | 0.049 | 0 | | | | |
| | | 4.088 | 0.188 | 0.149 | | | | | |
| | | 4.488 | 0.211 | 0.187 | | | | | |
| | | 4.990 | 0.125 | 0.066 | | | | | |
| | | 5.302 | 0.213 | 0.191 | | | | | |
| 1571 | 4 | 3.554 | 0.318 | 0.220 | 2 | 2 | 3.253 | 0.074 | 0.087 |
| | | 4.12- | 0.225 | 0.213 | | | 3.304 | 0.097 | |
| | | 4.825 | 0.168 | 0.119 | | 2 | 5.751 | 0.175 | |
| | | 4.99- | 0.117 | 0.058 | | | 5.895 | 0.192 | |
| 1600 | 4 | 3.505 | 0.106 | 0.047 | 3 | 2 | 3.245 | 0.082 | 0.333 |
| | | 4.511 | 0.229 | 0.221 | | | 3.328 | 0.085 | |
| | | 4.990 | 0.136 | 0.078 | | 2 | 3.896 | 0.318 | |
| | | 5.275 | 0.240 | 0.242 | | | 4.157 | 0.309 | |
| | | | | | | 3 | 5.647 | 0.270 | |
| | | | | | | | 5.792 | 0.152 | |
| | | | | | | | 5.902 | 0.155 | |
| 1640 | 5 | 3.252 | 0.076 | 0.024 | 2 | 2 | 4.798 | 0.214 | 0.132 |
| | | 3.367 | 0.084 | 0.030 | | | 4.963 | 0.235 | |
| | | 3.879 | 0.142 | 0.085 | | 2 | 5.857 | 0.138 | |
| | | 4.460 | 0.183 | 0.141 | | | 5.952 | 0.075 | |
| | | 5.590 | 0.189 | 0.150 | | | | | |
| 1690 | 3 | 3.641 | 0.330 | 0.227 | 2 | 2 | 3.248 | 0.086 | 0.391 |
| | | 5.844 | 0.100 | 0.042 | | | 3.304 | 0.087 | |
| | | 5.963 | 0.043 | 0.008 | | 5 | 4.838 | 0.197 | |
| | | | | | | | 4.986 | 0.237 | |
| | | | | | | | 5.220 | 0.364 | |
| | | | | | | | 5.291 | 0.138 | |
| | | | | | | | 5.568 | 0.417 | |
| 1733 | 5 | 3.704 | 0.131 | 0.072 | 3 | 2 | 3.265 | 0.114 | 0.157 |
| | | 4.480 | 0.145 | 0.087 | | | 3.308 | 0.127 | |
| | | 4.993 | 0.086 | 0.031 | | 2 | 3.850 | 0.153 | |
| | | 5.548 | 0.110 | 0.051 | | | 3.882 | 0.157 | |
| | | 5.967 | 0.060 | 0.015 | | 2 | 5.393 | 0.141 | |
| | | | | | | | 5.530 | 0.229 | |
| 1766 | 4 | 3.672 | 0.151 | 0.096 | 1 | 2 | 3.215 | 0.074 | 0.020 |
| | | 4.311 | 0.107 | 0.048 | | | 3.309 | 0.115 | |
| | | 4.993 | 0.164 | 0.113 | | | | | |
| | | | | | | 2 | 3.576 | 0.205 | |
| | | | | | | | 3.589 | 0.231 | |
| | | | | | | 4 | 3.875 | 0.198 | |
| | | | | | | | 3.868 | 0.204 | |
| | | | | | | | 4.060 | 0.180 | |
| | | | | | | | 4.044 | 0.140 | |
| 2192 | 3 | 4.502 | 0.150 | 0.095 | 3 | 2 | 3.203 | 0.076 | 0.267 |
| | | 5.299 | 0.431 | 0.302 | | | 3.257 | 0.083 | |
| | | 5.910 | 0.110 | 0.051 | | 2 | 3.755 | 0.264 | |
| | | | | | | | 3.749 | 0.275 | |
| | | | | | | 2 | 4.724 | 0.222 | |
| | | | | | | | 4.877 | 0.216 | |
| 2237 | 3 | 3.225 | 0.100 | 0.042 | 1 | 3 | 5.213 | 0.144 | 0.074 |
| | | 3.743 | 0.097 | 0.040 | | | 5.299 | 0.183 | |
| | | 4.819 | 0.077 | 0.025 | | | 5.328 | 0.125 | |
| 2274 | 3 | 3.237 | 0.109 | 0.050 | 2 | 2 | 3.621 | 0.186 | 0.226 |
| | | 4.817 | 0.091 | 0.035 | | | 3.763 | 0.190 | |
| | | 5.954 | 0.058 | 0.014 | | 2 | 4.066 | 0.217 | |
| | | | | | | | 4.319 | 0.326 | |
| 2317 | 4 | 3.217 | 0.068 | 0.019 | 0 | | | | |
| | | 3.700 | 0.116 | 0.057 | | | | | |
| | | 4.813 | 0.107 | 0.048 | | | | | |
| | | 5.883 | 0.153 | 0.099 | | | | | |
| 2347 | 3 | 3.646 | 0.234 | 0.230 | 2 | 2 | 3.200 | 0.135 | 0.484 |
| | | 4.504 | 0.190 | 0.152 | | | 3.349 | 0.254 | |
| | | 5.893 | 0.175 | 0.129 | | 5 | 4.974 | 0.312 | |
| | | | | | | | 5.324 | 0.388 | |
| | | | | | | | 5.420 | 0.313 | |
| | | | | | | | 5.626 | 0.217 | |
| | | | | | | | 5.690 | 0.166 | |
| 2397 | 6 | 3.236 | 0.119 | 0.060 | 0 | | | | |
| | | 3.603 | 0.120 | 0.061 | | | | | |
| | | 4.530 | 0.169 | 0.120 | | | | | |
| | | 4.980 | 0.173 | 0.126 | | | | | |
| | | 5.694 | 0.155 | 0.101 | | | | | |
| | | 5.938 | 0.101 | 0.043 | | | | | |
| 2437 | 5 | 3.237 | 0.107 | 0.048 | 1 | 2 | 5.494 | 0.141 | 0.034 |
| | | 4.068 | 0.168 | 0.119 | | | 5.601 | 0.112 | |
| | | 4.521 | 0.217 | 0.198 | | | | | |
| | | 4.971 | 0.151 | 0.096 | | | | | |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5.435 | 0.106 | 0.042 | | | | | | | | 5.305 | 0.204 | 0.175 | | | | | |
| 1813 | 4 | 3.264 | 0.131 | 0.072 | 1 | 3 | 4.582 | 0.374 | 0.195 | 2473 | 4 | 3.950 | 0.342 | 0.236 | 1 | 2 | 3.260 | 0.100 | 0.023 |
| | | 3.660 | 0.243 | 0.261 | | | 4.843 | 0.148 | | | | 4.830 | 0.102 | 0.044 | | | 3.318 | 0.108 | |
| | | 5.563 | 0.202 | 0.172 | | | 5.026 | 0.219 | | | | 5.467 | 0.263 | 0.291 | | | | | |
| | | 5.925 | 0.133 | 0.074 | | | | | | | | 5.920 | 0.121 | 0.062 | | | | | |
| 1858 | 3 | 4.121 | 0.245 | 0.255 | 3 | 2 | 3.234 | 0.145 | 0.132 | 2516 | 3 | 4.311 | 0.242 | 0.247 | 3 | 2 | 3.216 | 0.067 | 0.209 |
| | | 4.530 | 0.241 | 0.244 | | | 3.339 | 0.137 | | | | 4.982 | 0.135 | 0.077 | | | 3.293 | 0.087 | |
| | | 5.247 | 0.177 | 0.132 | | 2 | 3.635 | 0.113 | | | | 5.942 | 0.084 | 0.030 | | 2 | 3.876 | 0.167 | |
| | | | | | | | 3.756 | 0.258 | | | | | | | | | 4.033 | 0.146 | |
| | | | | | | 2 | 5.726 | 0.041 | | | | | | | | 3 | 5.305 | 0.252 | |
| | | | | | | | 5.780 | 0.067 | | | | | | | | | 5.436 | 0.135 | |
| 1890 | 8 | 3.367 | 0.300 | 0.207 | 0 | | | | | | | | | | | | 5.504 | 0.236 | |
| | | 3.624 | 0.128 | 0.069 | | | | | | 2551 | 2 | 4.311 | 0.140 | 0.083 | 3 | 2 | 3.245 | 0.086 | 0.162 |
| | | 4.023 | 0.215 | 0.196 | | | | | | | | 4.624 | 0.135 | 0.077 | | | 3.338 | 0.189 | |
| | | 4.602 | 0.125 | 0.065 | | | | | | | | | | | | 3 | 3.998 | 0.084 | |
| | | 4.981 | 0.131 | 0.072 | | | | | | | | | | | | | 4.026 | 0.074 | |
| | | 5.239 | 0.135 | 0.144 | | | | | | | | | | | | | 4.084 | 0.210 | |
| | | 5.550 | 0.234 | 0.230 | | | | | | | | | | | | 2 | 5.854 | 0.206 | |
| | | 5.964 | 0.067 | 0.019 | | | | | | | | | | | | | 5.928 | 0.108 | |
| 1927 | 4 | 4.981 | 0.122 | 0.063 | 1 | 2 | 3.246 | 0.120 | 0.045 | 2584 | 4 | 3.312 | 0.244 | 0.251 | 1 | 2 | 3.991 | 0.126 | 0.041 |
| | | 5.231 | 0.230 | 0.223 | | | 3.395 | 0.173 | | | | 4.985 | 0.153 | 0.099 | | | 4.130 | 0.153 | |
| | | 5.585 | 0.195 | 0.160 | | | | | | | | 5.457 | 0.224 | 0.211 | | | | | |
| | | 5.937 | 0.116 | 0.059 | | | | | | | | 5.857 | 0.186 | 0.149 | | | | | |
| 1965 | 2 | 4.277 | 0.318 | 0.220 | 2 | 2 | 3.227 | 0.115 | 0.224 | 2624 | 5 | 3.277 | 0.203 | 0.173 | 0 | | | | |
| | | 5.005 | 0.108 | 0.049 | | | 3.360 | 0.185 | | | | 3.607 | 0.278 | 0.190 | | | | | |
| | | | | | | 3 | 5.612 | 0.262 | | | | 4.821 | 0.134 | 0.076 | | | | | |
| | | | | | | | 5.737 | 0.232 | | | | 5.564 | 0.184 | 0.143 | | | | | |
| | | | | | | | 5.880 | 0.208 | | | | 5.852 | 0.221 | 0.206 | | | | | |
| 2000 | 3 | 3.242 | 0.103 | 0.045 | 1 | 2 | 3.558 | 0.278 | 0.165 | 2673 | 5 | 3.238 | 0.121 | 0.062 | 0 | | | | |
| | | 4.987 | 0.152 | 0.097 | | | 3.802 | 0.289 | | | | 3.745 | 0.316 | 0.220 | | | | | |
| | | 5.675 | 0.213 | 0.191 | | | | | | | | 4.631 | 0.137 | 0.073 | | | | | |
| 2029 | 5 | 3.211 | 0.102 | 0.044 | 0 | | | | | | | 5.605 | 0.140 | 0.083 | | | | | |
| | | 3.601 | 0.329 | 0.229 | | | | | | | | 5.923 | 0.139 | 0.081 | | | | | |
| | | 4.982 | 0.185 | 0.144 | | | | | | 2705 | 4 | 4.815 | 0.128 | 0.069 | 2 | 2 | 3.681 | 0.189 | 0.191 |
| | | 5.584 | 0.235 | 0.232 | | | | | | | | 5.005 | 0.138 | 0.080 | | | 3.789 | 0.240 | |
| | | 5.808 | 0.138 | 0.080 | | | | | | | | 5.253 | 0.237 | 0.236 | | 2 | 4.080 | 0.121 | |
| 2063 | 2 | 3.212 | 0.095 | 0.038 | 0 | | | | | | | 5.610 | 0.144 | 0.087 | | | 4.255 | 0.272 | |
| | | 5.828 | 0.108 | 0.049 | | | | | | 2745 | 4 | 3.230 | 0.112 | 0.053 | 2 | 2 | 4.430 | 0.173 | 0.078 |
| 2117 | 4 | 3.226 | 0.122 | 0.065 | 0 | | | | | | | 3.745 | 0.088 | 0.033 | | | 4.504 | 0.138 | |
| | | 3.636 | 0.321 | 0.222 | | | | | | | | 5.215 | 0.193 | 0.157 | | 2 | 5.855 | 0.141 | |
| | | 4.285 | 0.307 | 0.212 | | | | | | | | 5.696 | 0.088 | 0.033 | | | 5.952 | 0.071 | |
| | | 4.990 | 0.141 | 0.084 | | | | | | 2790 | 2 | 3.221 | 0.096 | 0.039 | 1 | 3 | 3.596 | 0.153 | 0.062 |
| 2152 | 1 | 4.835 | 0.199 | 0.167 | 3 | 2 | 3.230 | 0.195 | 0.345 | | | 5.940 | 0.105 | 0.046 | | | 3.733 | 0.121 | |
| | | | | | | | 3.312 | 0.248 | | | | | | | | | 3.866 | 0.144 | |

Total number of sample frames, k, 70.
Total number of single bubbles, h, 263.
Total number of merging bubbles, 196.
Average instantaneous bubble population, $n_{av}$, 6.56.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.109.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.1099.
Standard deviation associated with $\varphi_{m,av}$, 0.1173.

[a]3.194 movie analyzer units equal 0.75 inch; left end reading, 3.180; right end reading, 6.374 (average right limit, 5.984; reduced area of strip evaluated because of obscuration of film).

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(m) Test fluid, methanol; run 63-7-8-4

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 0 | 4 | 3.231 | 0.207 | 0.178 | 2 | 2 | 3.710 | 0.120 | 0.212 |
| | | 3.455 | 0.144 | 0.086 | | | 3.833 | 0.207 | |
| | | 4.091 | 0.163 | 0.110 | | 3 | 5.380 | 0.199 | |
| | | 4.771 | 0.054 | 0.012 | | | 5.559 | 0.186 | |
| | | | | | | | 5.786 | 0.269 | |
| 30 | 1 | 4.720 | 0.353 | 0.243 | 3 | 2 | 3.245 | 0.128 | 0.416 |
| | | | | | | | 3.450 | 0.283 | |
| | | | | | | 2 | 4.057 | 0.209 | |
| | | | | | | | 4.253 | 0.309 | |
| | | | | | | 5 | 5.387 | 0.170 | |
| | | | | | | | 5.507 | 0.161 | |
| | | | | | | | 5.662 | 0.148 | |
| | | | | | | | 5.785 | 0.191 | |
| | | | | | | | 5.818 | 0.241 | |
| 90 | 1 | 3.221 | 0.142 | 0.084 | 4 | 3 | 3.538 | 0.230 | 0.605 |
| | | | | | | | 3.671 | 0.242 | |
| | | | | | | | 3.855 | 0.263 | |
| | | | | | | 3 | 4.422 | 0.007 | |
| | | | | | | | 4.606 | 0.360 | |
| | | | | | | | 4.872 | 0.255 | |
| | | | | | | 2 | 5.412 | 0.369 | |
| | | | | | | | 5.582 | 0.271 | |
| | | | | | | 2 | 5.836 | 0.173 | |
| | | | | | | | 5.872 | 0.101 | |
| 120 | 2 | 3.904 | 0.184 | 0.141 | 3 | 2 | 3.219 | 0.134 | 0.304 |
| | | 4.604 | 0.171 | 0.122 | | | 3.404 | 0.237 | |
| | | | | | | 3 | 4.775 | 0.068 | |
| | | | | | | | 4.925 | 0.278 | |
| | | | | | | | 5.185 | 0.243 | |
| | | | | | | 3 | 5.653 | 0.147 | |
| | | | | | | | 5.771 | 0.186 | |
| | | | | | | | 5.863 | 0.149 | |
| 160 | 3 | 4.074 | 0.194 | 0.156 | 2 | 2 | 3.248 | 0.191 | 0.329 |
| | | 4.344 | 0.154 | 0.099 | | | 3.387 | 0.199 | |
| | | 5.064 | 0.131 | 0.071 | | 5 | 5.312 | 0.313 | |
| | | | | | | | 5.257 | 0.152 | |
| | | | | | | | 5.492 | 0.205 | |
| | | | | | | | 5.634 | 0.203 | |
| | | | | | | | 5.839 | 0.206 | |
| 195 | 2 | 3.746 | 0.154 | 0.099 | 4 | 2 | 3.168 | 0.119 | 0.411 |
| | | 4.067 | 0.230 | 0.220 | | | 3.271 | 0.130 | |
| | | | | | | 2 | 4.425 | 0.315 | |
| | | | | | | | 4.639 | 0.113 | |
| | | | | | | 2 | 4.931 | 0.292 | |
| | | | | | | | 5.185 | 0.216 | |
| | | | | | | 3 | 5.472 | 0.215 | |
| | | | | | | | 5.652 | 0.219 | |
| | | | | | | | 5.857 | 0.190 | |
| 240 | 4 | 3.964 | 0.165 | 0.115 | 2 | 4 | 3.213 | 0.162 | 0.254 |
| | | 4.426 | 0.192 | 0.153 | | | 3.303 | 0.153 | |
| | | 4.946 | 0.221 | 0.205 | | | 3.478 | 0.196 | |
| | | 5.223 | 0.168 | 0.117 | | | 3.674 | 0.197 | |
| | | | | | | 5 | 5.522 | 0.215 | |
| | | | | | | | 5.560 | 0.113 | |
| | | | | | | | 5.672 | 0.111 | |
| | | | | | | | 5.779 | 0.149 | |
| | | | | | | | 5.879 | 0.155 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 5.766 | 0.377 | |
| 601 | 1 | 5.416 | 0.174 | 0.126 | 4 | 2 | 3.150 | 0.082 | 0.249 |
| | | | | | | | 3.263 | 0.144 | |
| | | | | | | 2 | 3.611 | 0.126 | |
| | | | | | | | 3.743 | 0.138 | |
| | | | | | | 2 | 4.809 | 0.167 | |
| | | | | | | | 4.951 | 0.158 | |
| | | | | | | 2 | 5.668 | 0.165 | |
| | | | | | | | 5.761 | 0.326 | |
| 653 | 0 | | | | 4 | 2 | 3.225 | 0.145 | 0.403 |
| | | | | | | | 3.391 | 0.186 | |
| | | | | | | 2 | 3.929 | 0.261 | |
| | | | | | | | 4.142 | 0.329 | |
| | | | | | | 2 | 4.595 | 0.229 | |
| | | | | | | | 4.770 | 0.184 | |
| | | | | | | 2 | 5.611 | 0.139 | |
| | | | | | | | 5.804 | 0.246 | |
| 685 | 0 | | | | 3 | 3 | 3.210 | 0.129 | 0.637 |
| | | | | | | | 3.278 | 0.177 | |
| | | | | | | | 3.453 | 0.172 | |
| | | | | | | 2 | 3.694 | 0.170 | |
| | | | | | | | 3.814 | 0.237 | |
| | | | | | | 6 | 4.594 | 0.302 | |
| | | | | | | | 4.781 | 0.205 | |
| | | | | | | | 4.982 | 0.380 | |
| | | | | | | | 5.324 | 0.305 | |
| | | | | | | | 5.603 | 0.253 | |
| | | | | | | | 5.843 | 0.226 | |
| 715 | 3 | 3.208 | 0.207 | 0.178 | 3 | 4 | 3.418 | 0.118 | 0.446 |
| | | 4.297 | 0.066 | 0.018 | | | 3.577 | 0.261 | |
| | | 4.788 | 0.092 | 0.035 | | | 3.819 | 0.223 | |
| | | | | | | | 4.078 | 0.294 | |
| | | | | | | 2 | 4.982 | 0.217 | |
| | | | | | | | 5.140 | 0.180 | |
| | | | | | | 2 | 5.560 | 0.282 | |
| | | | | | | | 5.819 | 0.236 | |
| 754 | 0 | | | | 3 | 4 | 3.213 | 0.120 | 0.379 |
| | | | | | | | 3.257 | 0.133 | |
| | | | | | | | 3.376 | 0.105 | |
| | | | | | | | 3.497 | 0.137 | |
| | | | | | | 3 | 4.814 | 0.257 | |
| | | | | | | | 4.974 | 0.188 | |
| | | | | | | | 5.099 | 0.312 | |
| | | | | | | 2 | 5.610 | 0.247 | |
| | | | | | | | 5.845 | 0.222 | |
| 799 | 1 | 3.711 | 0.133 | 0.074 | 4 | 3 | 3.149 | 0.090 | 0.428 |
| | | | | | | | 3.257 | 0.168 | |
| | | | | | | | 3.434 | 0.212 | |
| | | | | | | 3 | 4.008 | 0.224 | |
| | | | | | | | 4.214 | 0.225 | |
| | | | | | | | 4.446 | 0.233 | |
| | | | | | | 2 | 4.854 | 0.130 | |
| | | | | | | | 4.996 | 0.155 | |
| | | | | | | 3 | 5.556 | 0.170 | |
| | | | | | | | 5.629 | 0.257 | |
| | | | | | | | 5.855 | 0.174 | |
| 833 | 2 | 3.260 | 0.230 | 0.220 | 4 | 2 | 3.714 | 0.117 | 0.353 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 270 | 2 | 3.749 | 0.184 | 0.141 | 3 | 2 | 3.241 | 0.105 | 0.350 |
| | | 5.548 | 0.250 | 0.260 | | | 3.385 | 0.184 | |
| | | | | | | 3 | 4.216 | 0.393 | |
| | | | | | | | 4.495 | 0.164 | |
| | | | | | | | 4.721 | 0.288 | |
| | | | | | | 2 | 5.834 | 0.215 | |
| | | | | | | | 5.890 | 0.122 | |
| 325 | 1 | 4.023 | 0.232 | 0.224 | 3 | 5 | 3.179 | 0.173 | 0.526 |
| | | | | | | | 3.289 | 0.225 | |
| | | | | | | | 3.494 | 0.184 | |
| | | | | | | | 3.658 | 0.145 | |
| | | | | | | | 3.693 | 0.117 | |
| | | | | | | 3 | 4.408 | 0.396 | |
| | | | | | | | 4.719 | 0.227 | |
| | | | | | | | 4.928 | 0.131 | |
| | | | | | | 2 | 5.535 | 0.191 | |
| | | | | | | | 5.761 | 0.358 | |
| 365 | 4 | 3.696 | 0.180 | 0.135 | 2 | 3 | 3.174 | 0.126 | 0.133 |
| | | 4.001 | 0.207 | 0.176 | | | 3.265 | 0.160 | |
| | | 4.442 | 0.303 | 0.207 | | | 3.417 | 0.144 | |
| | | 4.908 | 0.293 | 0.200 | | 2 | 5.651 | 0.125 | |
| | | | | | | | 5.826 | 0.224 | |
| 400 | 1 | 4.829 | 0.137 | 0.078 | 4 | 3 | 3.181 | 0.129 | 0.665 |
| | | | | | | | 3.247 | 0.152 | |
| | | | | | | | 3.385 | 0.232 | |
| | | | | | | 5 | 3.881 | 0.229 | |
| | | | | | | | 4.046 | 0.184 | |
| | | | | | | | 4.176 | 0.152 | |
| | | | | | | | 4.313 | 0.122 | |
| | | | | | | | 4.465 | 0.357 | |
| | | | | | | 2 | 5.024 | 0.166 | |
| | | | | | | | 5.048 | 0.261 | |
| | | | | | | 3. | 5.442 | 0.425 | |
| | | | | | | | 5.638 | 0.212 | |
| | | | | | | | 5.842 | 0.196 | |
| 443 | 4 | 3.202 | 0.186 | 0.144 | 2 | 2 | 4.055 | 0.244 | 0.177 |
| | | 3.441 | 0.157 | 0.102 | | | 4.257 | 0.161 | |
| | | 4.784 | 0.108 | 0.048 | | 3 | 5.413 | 0.140 | |
| | | 5.833 | 0.202 | 0.170 | | | 5.551 | 0.136 | |
| | | | | | | | 5.591 | 0.216 | |
| 489 | 4 | 3.194 | 0.174 | 0.126 | 1 | 3 | 5.444 | 0.232 | 0.136 |
| | | 3.594 | 0.147 | 0.090 | | | 5.664 | 0.208 | |
| | | 4.290 | 0.261 | 0.283 | | | 5.860 | 0.185 | |
| | | 4.776 | 0.095 | 0.038 | | | | | |
| 519 | 0 | | | | 3 | 2 | 3.145 | 0.103 | 0.578 |
| | | | | | | | 3.255 | 0.116 | |
| | | | | | | 6 | 3.656 | 0.152 | |
| | | | | | | | 3.816 | 0.221 | |
| | | | | | | | 4.027 | 0.272 | |
| | | | | | | | 4.284 | 0.242 | |
| | | | | | | | 4.615 | 0.420 | |
| | | | | | | | 4.748 | 0.148 | |
| | | | | | | 3 | 5.357 | 0.275 | |
| | | | | | | | 5.628 | 0.267 | |
| | | | | | | | 5.844 | 0.165 | |
| 564 | 1 | 4.008 | 0.179 | 0.133 | 3 | 4 | 3.210 | 0.181 | 0.498 |
| | | | | | | | 3.350 | 0.167 | |
| | | | | | | | 3.457 | 0.147 | |
| | | | | | | | 3.603 | 0.145 | |
| | | | | | | 2 | 4.641 | 0.236 | |
| | | | | | | | 4.930 | 0.342 | |
| | | | | | | 2 | 5.409 | 0.337 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 3.466 | 0.097 | 0.039 | | | 3.756 | 0.133 | |
| | | | | | | 2 | 4.275 | 0.215 | |
| | | | | | | | 4.485 | 0.255 | |
| | | | | | | 2 | 4.822 | 0.125 | |
| | | | | | | | 5.007 | 0.244 | |
| | | | | | | 3 | 5.515 | 0.190 | |
| | | | | | | | 5.684 | 0.148 | |
| | | | | | | | 5.829 | 0.252 | |
| 883 | 2 | 3.225 | 0.165 | 0.113 | 2 | 3 | 3.427 | 0.137 | 0.270 |
| | | 4.800 | 0.080 | 0.027 | | | 3.620 | 0.248 | |
| | | | | | | | 3.893 | 0.298 | |
| | | | | | | 3 | 5.515 | 0.181 | |
| | | | | | | | 5.682 | 0.153 | |
| | | | | | | | 5.857 | 0.196 | |
| 927 | 4 | 3.194 | 0.199 | 0.165 | 2 | 2 | 3.733 | 0.154 | 0.147 |
| | | 3.469 | 0.079 | 0.026 | | | 3.907 | 0.194 | |
| | | 4.809 | 0.074 | 0.023 | | 2 | 5.673 | 0.174 | |
| | | 5.378 | 0.318 | 0.218 | | | 5.840 | 0.228 | |
| 958 | 0 | | | | 2 | 7 | 3.218 | 0.187 | 0.832 |
| | | | | | | | 3.379 | 0.135 | |
| | | | | | | | 3.552 | 0.210 | |
| | | | | | | | 3.712 | 0.110 | |
| | | | | | | | 3.851 | 0.169 | |
| | | | | | | | 4.055 | 0.312 | |
| | | | | | | | 4.237 | 0.295 | |
| | | | | | | 5 | 4.689 | 0.276 | |
| | | | | | | | 4.750 | 0.237 | |
| | | | | | | | 5.097 | 0.456 | |
| | | | | | | | 5.444 | 0.363 | |
| | | | | | | | 5.791 | 0.331 | |
| 1001 | 3 | 3.224 | 0.199 | 0.165 | 3 | 4 | 3.444 | 0.155 | 0.323 |
| | | 4.067 | 0.206 | 0.176 | | | 3.565 | 0.087 | |
| | | 4.753 | 0.096 | 0.038 | | | 3.567 | 0.187 | |
| | | | | | | | 3.715 | 0.212 | |
| | | | | | | 2 | 5.015 | 0.252 | |
| | | | | | | | 5.181 | 0.164 | |
| | | | | | | 2 | 5.598 | 0.231 | |
| | | | | | | | 5.831 | 0.235 | |
| 1033 | 2 | 3.217 | 0.198 | 0.163 | 4 | 2 | 3.680 | 0.122 | 0.227 |
| | | 4.358 | 0.353 | 0.243 | | | 3.819 | 0.157 | |
| | | | | | | 2 | 4.774 | 0.071 | |
| | | | | | | | 4.806 | 0.078 | |
| | | | | | | 2 | 5.058 | 0.190 | |
| | | | | | | | 5.235 | 0.154 | |
| | | | | | | 2 | 5.625 | 0.150 | |
| | | | | | | | 5.771 | 0.291 | |
| 1063 | 4 | 3.469 | 0.120 | 0.060 | 3 | 2 | 3.197 | 0.187 | 0.278 |
| | | 4.262 | 0.157 | 0.102 | | | 3.230 | 0.253 | |
| | | 4.781 | 0.076 | 0.024 | | 2 | 3.721 | 0.191 | |
| | | 5.241 | 0.164 | 0.112 | | | 3.749 | 0.160 | |
| | | | | | | 2 | 5.615 | 0.260 | |
| | | | | | | | 5.843 | 0.196 | |
| 1095 | 0 | | | | 3 | 7 | 3.222 | 0.231 | 0.555 |
| | | | | | | | 3.427 | 0.179 | |
| | | | | | | | 3.523 | 0.136 | |
| | | | | | | | 3.622 | 0.128 | |
| | | | | | | | 3.741 | 0.157 | |
| | | | | | | | 3.874 | 0.183 | |
| | | | | | | | 4.128 | 0.324 | |
| | | | | | | 2 | 4.725 | 0.126 | |
| | | | | | | | 4.942 | 0.309 | |
| | | | | | | 4 | 5.260 | 0.117 | |

[a]3.204 movie analyzer units equal 0.75 inch; left end reading, 3.114; right end reading, 6.317 (average right limit, 5.945; reduced area of strip evaluated because of obscuration of film).

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(m) Concluded. Test fluid, methanol; run 63-7-8-4

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 5.455 | 0.273 | |
| | | | | | | | 5.657 | 0.130 | |
| | | | | | | | 5.833 | 0.222 | |
| 1140 | 2 | 3.848 | 0.135 | 0.076 | 4 | 2 | 3.220 | 0.180 | 0.510 |
| | | 5.428 | 0.083 | 0.029 | | | 3.244 | 0.098 | |
| | | | | | | 3 | 3.474 | 0.202 | |
| | | | | | | | 3.604 | 0.141 | |
| | | | | | | | 3.627 | 0.213 | |
| | | | | | | 4 | 4.703 | 0.300 | |
| | | | | | | | 4.937 | 0.168 | |
| | | | | | | | 5.040 | 0.237 | |
| | | | | | | | 5.139 | 0.135 | |
| | | | | | | 3 | 5.740 | 0.169 | |
| | | | | | | | 5.874 | 0.188 | |
| | | | | | | | 5.813 | 0.310 | |
| 1180 | 1 | 4.052 | 0.206 | 0.176 | 3 | 6 | 3.174 | 0.081 | 0.355 |
| | | | | | | | 3.285 | 0.140 | |
| | | | | | | | 3.413 | 0.116 | |
| | | | | | | | 3.450 | 0.186 | |
| | | | | | | | 3.556 | 0.171 | |
| | | | | | | | 3.672 | 0.259 | |
| | | | | | | 3 | 4.655 | 0.254 | |
| | | | | | | | 4.656 | 0.182 | |
| | | | | | | | 4.818 | 0.079 | |
| | | | | | | 2 | 5.666 | 0.168 | |
| | | | | | | | 5.849 | 0.198 | |
| 1223 | 1 | 4.797 | 0.091 | 0.034 | 3 | 2 | 3.188 | 0.122 | 0.522 |
| | | | | | | | 3.245 | 0.140 | |
| | | | | | | 6 | 3.496 | 0.216 | |
| | | | | | | | 3.681 | 0.154 | |
| | | | | | | | 3.694 | 0.127 | |
| | | | | | | | 3.848 | 0.180 | |
| | | | | | | | 3.988 | 0.100 | |
| | | | | | | | 4.196 | 0.418 | |
| | | | | | | 3 | 5.479 | 0.391 | |
| | | | | | | | 5.754 | 0.245 | |
| | | | | | | | 5.878 | 0.159 | |
| 1261 | 0 | | | | 4 | 2 | 3.184 | 0.122 | 0.564 |
| | | | | | | | 3.248 | 0.151 | |
| | | | | | | 2 | 3.447 | 0.136 | |
| | | | | | | | 3.587 | 0.144 | |
| | | | | | | 5 | 4.012 | 0.132 | |
| | | | | | | | 4.207 | 0.377 | |
| | | | | | | | 4.286 | 0.159 | |
| | | | | | | | 4.481 | 0.230 | |
| | | | | | | | 4.720 | 0.249 | |
| | | | | | | 3 | 5.488 | 0.328 | |
| | | | | | | | 5.703 | 0.274 | |
| | | | | | | | 5.892 | 0.138 | |
| 1311 | 4 | 3.261 | 0.159 | 0.105 | 2 | 2 | 3.740 | 0.105 | 0.172 |
| | | 3.482 | 0.090 | 0.034 | | | 3.852 | 0.119 | |
| | | 4.332 | 0.227 | 0.214 | | 4 | 5.423 | 0.179 | |
| | | 4.794 | 0.081 | 0.027 | | | 5.601 | 0.234 | |
| | | | | | | | 5.755 | 0.174 | |
| | | | | | | | 5.900 | 0.116 | |
| 1359 | 1 | 3.624 | 0.078 | 0.025 | 3 | 2 | 3.242 | 0.153 | 0.361 |
| | | | | | | | 3.429 | 0.220 | |
| | | | | | | | 3.653 | 0.163 | |
| | | | | | | | 3.788 | 0.167 | |
| | | | | | | | 3.829 | 0.188 | |
| | | | | | | | 4.028 | 0.210 | |
| | | | | | | | 4.136 | 0.210 | |
| | | | | | | | 4.336 | 0.190 | |
| | | | | | | 7 | 4.580 | 0.142 | |
| | | | | | | | 4.608 | 0.115 | |
| | | | | | | | 4.741 | 0.151 | |
| | | | | | | | 4.907 | 0.414 | |
| | | | | | | | 5.402 | 0.577 | |
| | | | | | | | 5.815 | 0.248 | |
| | | | | | | | 5.865 | 0.148 | |
| 1766 | 2 | 3.869 | 0.335 | 0.230 | 2 | 4 | 3.160 | 0.090 | 0.352 |
| | | 4.416 | 0.282 | 0.192 | | | 3.289 | 0.168 | |
| | | | | | | | 3.440 | 0.134 | |
| | | | | | | | 3.503 | 0.103 | |
| | | | | | | 5 | 5.056 | 0.269 | |
| | | | | | | | 5.251 | 0.290 | |
| | | | | | | | 5.534 | 0.276 | |
| | | | | | | | 5.736 | 0.128 | |
| | | | | | | | 5.882 | 0.165 | |
| 1813 | 1 | 3.238 | 0.163 | 0.110 | 5 | 2 | 3.448 | 0.150 | 0.507 |
| | | | | | | | 3.637 | 0.228 | |
| | | | | | | 3 | 3.920 | 0.237 | |
| | | | | | | | 4.198 | 0.319 | |
| | | | | | | | 4.385 | 0.297 | |
| | | | | | | 2 | 4.810 | 0.123 | |
| | | | | | | | 4.951 | 0.226 | |
| | | | | | | 2 | 5.165 | 0.071 | |
| | | | | | | | 5.278 | 0.155 | |
| | | | | | | 3 | 5.587 | 0.198 | |
| | | | | | | | 5.739 | 0.176 | |
| | | | | | | | 5.888 | 0.122 | |
| 1858 | 5 | 4.805 | 0.057 | 0.014 | 2 | 3 | 3.202 | 0.117 | 0.107 |
| | | 4.946 | 0.068 | 0.019 | | | 3.292 | 0.183 | |
| | | 5.071 | 0.073 | 0.022 | | | 3.463 | 0.159 | |
| | | 5.545 | 0.195 | 0.158 | | 2 | 3.715 | 0.125 | |
| | | 5.875 | 0.165 | 0.113 | | | 3.843 | 0.130 | |
| 1890 | 5 | 3.245 | 0.090 | 0.034 | 2 | 3 | 4.713 | 0.078 | 0.172 |
| | | 3.551 | 0.295 | 0.201 | | | 4.828 | 0.153 | |
| | | 3.812 | 0.149 | 0.092 | | | 5.000 | 0.191 | |
| | | 4.193 | 0.395 | 0.274 | | 3 | 5.555 | 0.187 | |
| | | 5.249 | 0.212 | 0.187 | | | 5.768 | 0.238 | |
| | | | | | | | 5.932 | 0.090 | |
| 1927 | 4 | 3.176 | 0.158 | 0.104 | 2 | 2 | 4.818 | 0.091 | 0.242 |
| | | 3.556 | 0.137 | 0.080 | | | 4.958 | 0.270 | |
| | | 3.754 | 0.110 | 0.056 | | 5 | 5.271 | 0.190 | |
| | | 4.067 | 0.235 | 0.230 | | | 5.469 | 0.205 | |
| | | | | | | | 5.657 | 0.171 | |
| | | | | | | | 5.841 | 0.197 | |
| | | | | | | | 5.921 | 0.074 | |
| 1965 | 1 | 4.451 | 0.143 | 0.085 | 4 | 3 | 3.135 | 0.087 | 0.456 |
| | | | | | | | 3.233 | 0.146 | |
| | | | | | | | 3.427 | 0.242 | |
| | | | | | | 5 | 3.689 | 0.133 | |
| | | | | | | | 3.806 | 0.101 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2 | 4.814 | 0.163 | |
| | | | | | | | 4.965 | 0.352 | |
| | | | | | | 3 | 5.446 | 0.220 | |
| | | | | | | | 5.683 | 0.255 | |
| | | | | | | | 5.873 | 0.170 | |
| 1411 | 4 | 3.245 | 0.143 | 0.085 | 2 | 5 | 3.471 | 0.147 | 0.160 |
| | | 4.536 | 0.349 | 0.240 | | | 3.594 | 0.098 | |
| | | 5.385 | 0.307 | 0.210 | | | 3.719 | 0.153 | |
| | | 5.867 | 0.186 | 0.144 | | | 3.869 | 0.147 | |
| | | | | | | | 3.967 | 0.141 | |
| | | | | | | 3 | 4.786 | 0.108 | |
| | | | | | | | 4.825 | 0.122 | |
| | | | | | | | 4.929 | 0.178 | |
| 1441 | 4 | 3.241 | 0.117 | 0.057 | 2 | 3 | 3.757 | 0.158 | 0.151 |
| | | 3.477 | 0.145 | 0.087 | | | 3.881 | 0.090 | |
| | | 4.572 | 0.070 | 0.020 | | | 4.040 | 0.229 | |
| | | 4.796 | 0.078 | 0.025 | | 2 | 5.855 | 0.200 | |
| | | | | | | | 5.885 | 0.139 | |
| 1486 | 2 | 4.304 | 0.144 | 0.086 | 2 | 3 | 3.271 | 0.185 | 0.442 |
| | | 4.728 | 0.359 | 0.248 | | | 3.473 | 0.338 | |
| | | | | | | | 3.466 | 0.174 | |
| | | | | | | 4 | 5.513 | 0.395 | |
| | | | | | | | 5.620 | 0.242 | |
| | | | | | | | 5.738 | 0.168 | |
| | | | | | | | 5.852 | 0.223 | |
| 1521 | 5 | 3.252 | 0.148 | 0.091 | 3 | 2 | 3.730 | 0.203 | 0.261 |
| | | 3.520 | 0.149 | 0.092 | | | 3.834 | 0.410 | |
| | | 5.845 | 0.238 | 0.235 | | 2 | 4.651 | 0.178 | |
| | | | | | | | 4.798 | 0.117 | |
| | | | | | | 2 | 5.490 | 0.116 | |
| | | | | | | | 5.561 | 0.148 | |
| 1571 | 5 | 3.244 | 0.147 | 0.090 | 1 | 3 | 5.574 | 0.160 | 0.121 |
| | | 3.723 | 0.144 | 0.086 | | | 5.662 | 0.237 | |
| | | 4.650 | 0.133 | 0.080 | | | 5.839 | 0.187 | |
| | | 4.792 | 0.073 | 0.022 | | | | | |
| | | 5.399 | 0.162 | 0.109 | | | | | |
| 1603 | 2 | 3.256 | 0.149 | 0.092 | 2 | 2 | 4.655 | 0.230 | 0.186 |
| | | 3.825 | 0.068 | 0.019 | | | 4.822 | 0.105 | |
| | | | | | | 3 | 5.511 | 0.164 | |
| | | | | | | | 5.676 | 0.258 | |
| | | | | | | | 5.881 | 0.153 | |
| 1640 | 0 | | | | 3 | 3 | 3.220 | 0.146 | 0.377 |
| | | | | | | | 3.402 | 0.273 | |
| | | | | | | | 3.547 | 0.234 | |
| | | | | | | 2 | 4.621 | 0.240 | |
| | | | | | | | 4.805 | 0.175 | |
| | | | | | | 3 | 5.549 | 0.274 | |
| | | | | | | | 5.725 | 0.169 | |
| | | | | | | | 5.882 | 0.144 | |
| 1690 | 2 | 3.810 | 0.083 | 0.029 | 3 | 2 | 3.201 | 0.216 | 0.425 |
| | | 4.016 | 0.260 | 0.281 | | | 3.410 | 0.202 | |
| | | | | | | 5 | 4.251 | 0.126 | |
| | | | | | | | 4.378 | 0.128 | |
| | | | | | | | 4.422 | 0.216 | |
| | | | | | | | 4.664 | 0.263 | |
| | | | | | | | 4.798 | 0.214 | |
| | | | | | | 3 | 5.503 | 0.226 | |
| | | | | | | | 5.732 | 0.232 | |
| | | | | | | | 5.867 | 0.139 | |
| 1733 | | | | | 3 | 2 | 3.248 | 0.135 | 0.774 |
| | | | | | | | 3.408 | 0.185 | |
| | | | | | | 7 | 3.635 | 0.149 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3.901 | 0.033 | |
| | | | | | | | 4.004 | 0.117 | |
| | | | | | | | 4.160 | 0.262 | |
| | | | | | | 2 | 4.812 | 0.178 | |
| | | | | | | | 5.032 | 0.263 | |
| | | | | | | 4 | 5.522 | 0.290 | |
| | | | | | | | 5.676 | 0.123 | |
| | | | | | | | 5.744 | 0.111 | |
| | | | | | | | 5.873 | 0.146 | |
| 2000 | 2 | 4.191 | 0.289 | 0.197 | 3 | 6 | 3.210 | 0.167 | 0.367 |
| | | 4.515 | 0.082 | 0.025 | | | 3.273 | 0.172 | |
| | | | | | | | 3.434 | 0.130 | |
| | | | | | | | 3.581 | 0.164 | |
| | | | | | | | 3.741 | 0.185 | |
| | | | | | | | 3.907 | 0.146 | |
| | | | | | | 2 | 4.811 | 0.389 | |
| | | | | | | | 5.053 | 0.394 | |
| | | | | | | 3 | 5.655 | 0.153 | |
| | | | | | | | 5.810 | 0.156 | |
| | | | | | | | 5.909 | 0.112 | |
| 2029 | 5 | 3.244 | 0.148 | 0.091 | 3 | 2 | 3.586 | 0.105 | 0.195 |
| | | 4.150 | 0.153 | 0.097 | | | 3.716 | 0.154 | |
| | | 4.430 | 0.231 | 0.222 | | 2 | 4.716 | 0.133 | |
| | | 5.013 | 0.104 | 0.045 | | | 4.806 | 0.127 | |
| | | 5.398 | 0.222 | 0.205 | | 2 | 5.653 | 0.135 | |
| | | | | | | | 5.809 | 0.287 | |
| 2069 | 2 | 3.692 | 0.213 | 0.189 | 2 | 2 | 3.182 | 0.155 | 0.271 |
| | | 4.445 | 0.391 | 0.271 | | | 3.273 | 0.148 | |
| | | | | | | 7 | 4.888 | 0.228 | |
| | | | | | | | 5.082 | 0.160 | |
| | | | | | | | 5.241 | 0.159 | |
| | | | | | | | 5.411 | 0.181 | |
| | | | | | | | 5.591 | 0.179 | |
| | | | | | | | 5.779 | 0.197 | |
| | | | | | | | 5.924 | 0.393 | |
| 2117 | 2 | 3.234 | 0.134 | 0.075 | 2 | 2 | 4.686 | 0.234 | 0.285 |
| | | 3.713 | 0.248 | 0.256 | | | 4.783 | 0.153 | |
| | | | | | | 5 | 5.255 | 0.232 | |
| | | | | | | | 5.465 | 0.168 | |
| | | | | | | | 5.483 | 0.159 | |
| | | | | | | | 5.672 | 0.213 | |
| | | | | | | | 5.867 | 0.172 | |
| 2152 | 1 | 5.213 | 0.192 | 0.153 | 4 | 2 | 3.182 | 0.122 | 0.380 |
| | | | | | | | 3.249 | 0.175 | |
| | | | | | | 4 | 3.724 | 0.195 | |
| | | | | | | | 3.846 | 0.183 | |
| | | | | | | | 4.007 | 0.139 | |
| | | | | | | | 4.226 | 0.299 | |
| | | | | | | 2 | 4.673 | 0.136 | |
| | | | | | | | 4.759 | 0.162 | |
| | | | | | | 3 | 5.500 | 0.166 | |
| | | | | | | | 5.675 | 0.184 | |
| | | | | | | | 5.865 | 0.173 | |
| 2192 | 2 | 4.248 | 0.151 | 0.095 | 3 | 2 | 3.179 | 0.120 | 0.214 |
| | | 4.782 | 0.079 | 0.025 | | | 3.264 | 0.138 | |
| | | | | | | 2 | 3.865 | 0.243 | |
| | | | | | | | 3.976 | 0.268 | |
| | | | | | | 4 | 5.638 | 0.129 | |
| | | | | | | | 5.751 | 0.096 | |
| | | | | | | | 5.851 | 0.104 | |
| | | | | | | | 5.937 | 0.068 | |

Total number of sample frames, k, 56.
Total number of single bubbles, h, 119.
Total number of merging bubbles, 472.
Average instantaneous bubble population, $n_{av}$, 10.55.
Average area fraction of influence of bubble, $\varphi_{s,av}$, 0.121.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.3582.
Standard deviation associated with $\varphi_{m,av}$, 0.1671.

[a]3.204 movie analyzer units equal 0.75 inch; left end reading, 3.114; right end reading, 6.317 (average right limit, 5.945; reduced area of strip evaluated because of obscuration of film).

TABLE II. - Continued. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(n) Test fluid, methanol; run 63-7-8-5

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 30 | 2 | 3.486 | 0.188 | 0.144 | 2 | 2 | 3.151 | 0.084 | 0.120 |
| | | 4.630 | 0.265 | 0.287 | | | 3.225 | 0.140 | |
| | | | | | | 4 | 5.445 | 0.135 | |
| | | | | | | | 5.581 | 0.137 | |
| | | | | | | | 5.705 | 0.176 | |
| | | | | | | | 5.868 | 0.151 | |
| 80 | 4 | 3.229 | 0.139 | 0.079 | 2 | 3 | 4.139 | 0.111 | 0.192 |
| | | 3.464 | 0.191 | 0.149 | | | 4.256 | 0.123 | |
| | | 3.714 | 0.200 | 0.163 | | | 4.467 | 0.299 | |
| | | 5.165 | 0.170 | 0.118 | | 4 | 5.526 | 0.177 | |
| | | | | | | | 5.650 | 0.128 | |
| | | | | | | | 5.773 | 0.118 | |
| | | | | | | | 5.888 | 0.113 | |
| 120 | 0 | | | | 3 | 5 | 3.138 | 0.070 | 0.417 |
| | | | | | | | 3.252 | 0.158 | |
| | | | | | | | 3.457 | 0.252 | |
| | | | | | | | 3.690 | 0.215 | |
| | | | | | | | 3.954 | 0.312 | |
| | | | | | | 3 | 4.288 | 0.084 | |
| | | | | | | | 4.422 | 0.185 | |
| | | | | | | | 4.573 | 0.116 | |
| | | | | | | 3 | 5.522 | 0.267 | |
| | | | | | | | 5.739 | 0.167 | |
| | | | | | | | 5.899 | 0.152 | |
| 160 | 1 | 3.221 | 0.126 | 0.065 | 3 | 2 | 3.470 | 0.152 | 0.291 |
| | | | | | | | 3.519 | 0.163 | |
| | | | | | | 2 | 4.760 | 0.148 | |
| | | | | | | | 4.935 | 0.203 | |
| | | | | | | 3 | 5.440 | 0.333 | |
| | | | | | | | 5.724 | 0.235 | |
| | | | | | | | 5.908 | 0.132 | |
| 195 | 2 | 3.465 | 0.195 | 0.155 | 2 | 2 | 3.156 | 0.092 | 0.201 |
| | | 4.058 | 0.348 | 0.237 | | | 3.233 | 0.148 | |
| | | | | | | 6 | 5.216 | 0.218 | |
| | | | | | | | 5.431 | 0.213 | |
| | | | | | | | 5.567 | 0.141 | |
| | | | | | | | 5.704 | 0.132 | |
| | | | | | | | 5.812 | 0.130 | |
| | | | | | | | 5.901 | 0.141 | |
| 240 | 2 | 4.057 | 0.186 | 0.141 | 3 | 2 | 3.163 | 0.086 | 0.636 |
| | | 4.638 | 0.215 | 0.189 | | | 3.237 | 0.162 | |
| | | | | | | 3 | 3.497 | 0.245 | |
| | | | | | | | 3.687 | 0.220 | |
| | | | | | | | 3.781 | 0.261 | |
| | | | | | | 6 | 4.947 | 0.273 | |
| | | | | | | | 5.221 | 0.275 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 3.361 | 0.282 | |
| | | | | | | | 3.629 | 0.254 | |
| | | | | | | | 3.843 | 0.174 | |
| | | | | | | | 4.039 | 0.218 | |
| | | | | | | 6 | 4.665 | 0.279 | |
| | | | | | | | 4.917 | 0.225 | |
| | | | | | | | 4.997 | 0.259 | |
| | | | | | | | 5.193 | 0.239 | |
| | | | | | | | 5.245 | 0.236 | |
| | | | | | | | 5.492 | 0.259 | |
| | | | | | | 2 | 5.826 | 0.271 | |
| | | | | | | | 5.830 | 0.163 | |
| 564 | 2 | 3.470 | 0.136 | 0.076 | 4 | 2 | 3.156 | 0.097 | 0.268 |
| | | 3.710 | 0.190 | 0.147 | | | 3.208 | 0.119 | |
| | | | | | | 2 | 3.944 | 0.176 | |
| | | | | | | | 4.154 | 0.245 | |
| | | | | | | 2 | 4.504 | 0.231 | |
| | | | | | | | 4.703 | 0.208 | |
| | | | | | | 3 | 5.708 | 0.159 | |
| | | | | | | | 5.819 | 0.123 | |
| | | | | | | | 5.909 | 0.104 | |
| 601 | 3 | 3.219 | 0.134 | 0.073 | 2 | 2 | 3.840 | 0.254 | 0.338 |
| | | 3.463 | 0.205 | 0.172 | | | 4.056 | 0.179 | |
| | | 4.576 | 0.090 | 0.035 | | 6 | 4.948 | 0.211 | |
| | | | | | | | 5.156 | 0.205 | |
| | | | | | | | 5.320 | 0.172 | |
| | | | | | | | 5.479 | 0.147 | |
| | | | | | | | 5.638 | 0.171 | |
| | | | | | | | 5.828 | 0.260 | |
| 653 | 3 | 4.486 | 0.161 | 0.106 | 2 | 6 | 3.150 | 0.093 | 0.465 |
| | | 4.706 | 0.157 | 0.101 | | | 3.224 | 0.173 | |
| | | 4.926 | 0.223 | 0.203 | | | 3.435 | 0.249 | |
| | | | | | | | 3.746 | 0.373 | |
| | | | | | | | 3.947 | 0.197 | |
| | | | | | | | 4.109 | 0.234 | |
| | | | | | | 4 | 5.380 | 0.194 | |
| | | | | | | | 5.506 | 0.168 | |
| | | | | | | | 5.657 | 0.135 | |
| | | | | | | | 5.849 | 0.248 | |
| 685 | 3 | 3.714 | 0.177 | 0.126 | 2 | 3 | 3.190 | 0.139 | 0.226 |
| | | 4.996 | 0.151 | 0.093 | | | 3.285 | 0.226 | |
| | | 5.238 | 0.077 | 0.024 | | | 3.445 | 0.198 | |
| | | | | | | 4 | 5.433 | 0.148 | |
| | | | | | | | 5.600 | 0.228 | |
| | | | | | | | 5.779 | 0.130 | |
| | | | | | | | 5.704 | 0.146 | |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 5.221 | 0.275 | | 715 | 5 | 3.187 | 0.158 | 0.102 | 2 | 2 | 4.418 | 0.376 | 0.290 |
| | | | | | | | 5.506 | 0.294 | | | | 3.435 | 0.217 | 0.192 | | | 4.650 | 0.339 | |
| | | | | | | | 5.592 | 0.125 | | | | 4.080 | 0.200 | 0.163 | | 4 | 5.507 | 0.134 | |
| | | | | | | | 5.806 | 0.303 | | | | 4.962 | 0.074 | 0.022 | | | 5.638 | 0.129 | |
| 270 | 1 | 4.959 | 0.075 | 0.023 | 3 | 4 | 3.190 | 0.108 | 0.510 | | | 5.214 | 0.179 | 0.131 | | | 5.767 | 0.128 | |
| | | | | | | | 3.282 | 0.146 | | | | | | | | | 5.879 | 0.142 | |
| | | | | | | | 3.472 | 0.234 | | 754 | 4 | 3.841 | 0.191 | 0.149 | 2 | 3 | 3.147 | 0.089 | 0.222 |
| | | | | | | | 3.702 | 0.227 | | | | 4.015 | 0.075 | 0.023 | | | 3.232 | 0.164 | |
| | | | | | | 3 | 4.071 | 0.162 | | | | 4.394 | 0.287 | 0.193 | | | 3.452 | 0.276 | |
| | | | | | | | 4.229 | 0.398 | | | | 4.985 | 0.174 | 0.124 | | 4 | 5.511 | 0.246 | |
| | | | | | | | 4.521 | 0.186 | | | | | | | | | 5.677 | 0.139 | |
| | | | | | | 4 | 5.375 | 0.196 | | | | | | | | | 5.814 | 0.134 | |
| | | | | | | | 5.532 | 0.247 | | | | | | | | | 5.928 | 0.094 | |
| | | | | | | | 5.754 | 0.247 | | 799 | 5 | 3.173 | 0.144 | 0.085 | 2 | 4 | 3.714 | 0.289 | 0.320 |
| | | | | | | | 5.917 | 0.120 | | | | 3.426 | 0.194 | 0.154 | | | 3.958 | 0.198 | |
| 325 | 5 | 3.183 | 0.110 | 0.047 | 1 | 4 | 5.410 | 0.175 | 0.115 | | | 4.338 | 0.104 | 0.044 | | | 4.124 | 0.261 | |
| | | 3.450 | 0.204 | 0.170 | | | 5.590 | 0.185 | | | | 4.649 | 0.058 | 0.014 | | | 4.135 | 0.157 | |
| | | 3.698 | 0.220 | 0.198 | | | 5.774 | 0.182 | | | | 4.960 | 0.183 | 0.137 | | 3 | 5.544 | 0.197 | |
| | | 4.510 | 0.265 | 0.287 | | | 5.926 | 0.122 | | | | | | | | | 5.707 | 0.201 | |
| | | 4.975 | 0.288 | 0.194 | | | | | | | | | | | | | 5.880 | 0.145 | |
| 365 | 4 | 3.189 | 0.102 | 0.042 | 2 | 4 | 3.497 | 0.175 | 0.278 | 833 | 1 | 3.670 | 0.231 | 0.218 | 3 | 2 | 3.220 | 0.157 | 0.523 |
| | | 4.533 | 0.286 | 0.193 | | | 3.700 | 0.230 | | | | | | | | | 3.378 | 0.158 | |
| | | 4.952 | 0.153 | 0.096 | | | 3.930 | 0.230 | | | | | | | | 4 | 4.410 | 0.318 | |
| | | 5.211 | 0.226 | 0.209 | | | 3.991 | 0.268 | | | | | | | | | 4.657 | 0.240 | |
| | | | | | | 3 | 5.646 | 0.144 | | | | | | | | | 4.889 | 0.273 | |
| | | | | | | | 5.802 | 0.169 | | | | | | | | | 5.234 | 0.417 | |
| | | | | | | | 5.906 | 0.121 | | | | | | | | 3 | 5.632 | 0.203 | |
| 400 | 3 | 3.508 | 0.284 | 0.191 | 2 | 2 | 3.152 | 0.079 | 0.178 | | | | | | | | 5.843 | 0.218 | |
| | | 4.117 | 0.245 | 0.245 | | | 3.240 | 0.145 | | | | | | | | | 5.890 | 0.124 | |
| | | 4.996 | 0.176 | 0.126 | | 5 | 5.212 | 0.191 | | 883 | 6 | 3.478 | 0.110 | 0.049 | 2 | 2 | 3.167 | 0.121 | 0.274 |
| | | | | | | | 5.381 | 0.146 | | | | 3.748 | 0.137 | 0.077 | | | 3.242 | 0.184 | |
| | | | | | | | 5.547 | 0.187 | | | | 4.022 | 0.161 | 0.106 | | 5 | 5.254 | 0.210 | |
| | | | | | | | 5.719 | 0.156 | | | | 4.292 | 0.234 | 0.224 | | | 5.475 | 0.233 | |
| | | | | | | | 5.883 | 0.173 | | | | 4.650 | 0.161 | 0.106 | | | 5.610 | 0.258 | |
| 443 | 3 | 4.311 | 0.299 | 0.202 | 4 | 3 | 3.137 | 0.065 | 0.442 | | | 4.942 | 0.099 | 0.040 | | | 5.751 | 0.202 | |
| | | 4.641 | 0.165 | 0.111 | | | 3.261 | 0.216 | | | | | | | | | 5.911 | 0.119 | |
| | | 5.385 | 0.161 | 0.106 | | | 3.480 | 0.223 | | 927 | 1 | 4.694 | 0.118 | 0.057 | 3 | 2 | 3.156 | 0.086 | 0.340 |
| | | | | | | 2 | 3.913 | 0.244 | | | | | | | | | 3.221 | 0.126 | |
| | | | | | | | 3.974 | 0.313 | | | | | | | | 3 | 3.468 | 0.259 | |
| | | | | | | 2 | 4.828 | 0.130 | | | | | | | | | 3.763 | 0.331 | |
| | | | | | | | 4.994 | 0.290 | | | | | | | | | 4.031 | 0.205 | |
| | | | | | | 5 | 5.628 | 0.119 | | | | | | | | 4 | 5.470 | 0.144 | |
| | | | | | | | 5.757 | 0.139 | | | | | | | | | 5.607 | 0.130 | |
| | | | | | | | 5.832 | 0.135 | | | | | | | | | 5.747 | 0.150 | |
| | | | | | | | 5.903 | 0.153 | | | | | | | | | 5.860 | 0.203 | |
| | | | | | | | 5.940 | 0.080 | | 958 | 2 | 3.391 | 0.105 | 0.045 | 2 | 2 | 3.113 | 0.065 | 0.259 |
| 489 | 3 | 3.191 | 0.145 | 0.086 | 2 | 2 | 4.974 | 0.240 | 0.173 | | | 3.803 | 0.336 | 0.229 | | | 3.188 | 0.114 | |
| | | 3.461 | 0.249 | 0.253 | | | 5.230 | 0.273 | | | | | | | | 4 | 5.130 | 0.229 | |
| | | 5.567 | 0.161 | 0.106 | | 2 | 5.757 | 0.127 | | | | | | | | | 5.396 | 0.303 | |
| | | | | | | | 5.894 | 0.146 | | | | | | | | | 5.648 | 0.232 | |
| 519 | 0 | | | | 3 | 5 | 3.182 | 0.156 | 0.735 | | | | | | | | 5.867 | 0.207 | |

[a]3.232 movie analyzer units equal 0.75 inch; left end reading, 3.098; right end reading, 6.330 (average right limit, 5.955; reduced area of strip evaluated because of obscuration of film).

TABLE II. - Concluded. BUBBLE MEASUREMENT FROM MOVIE ANALYZER

[1/16- by 3/4-in. heating strip.]

(n) Concluded. Test fluid, methanol; run 63-7-8-5

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| 1001 | 2 | 3.455 | 0.161 | 0.106 | 3 | 2 | 3.127 | 0.046 | 0.277 |
| | | 5.377 | 0.180 | 0.132 | | | 3.190 | 0.126 | |
| | | | | | | 3 | 4.674 | 0.333 | |
| | | | | | | | 4.833 | 0.189 | |
| | | | | | | | 4.954 | 0.227 | |
| | | | | | | 2 | 5.703 | 0.155 | |
| | | | | | | | 5.847 | 0.206 | |
| 1033 | 3 | 3.448 | 0.220 | 0.198 | 2 | 2 | 3.157 | 0.115 | 0.208 |
| | | 3.932 | 0.209 | 0.178 | | | 3.226 | 0.148 | |
| | | 4.981 | 0.157 | 0.101 | | 3 | 5.359 | 0.212 | |
| | | | | | | | 5.635 | 0.341 | |
| | | | | | | | 5.877 | 0.143 | |
| 1063 | 2 | 3.236 | 0.170 | 0.118 | 2 | 2 | 3.522 | 0.195 | 0.261 |
| | | 4.984 | 0.081 | 0.027 | | | 3.729 | 0.331 | |
| | | | | | | 4 | 5.436 | 0.159 | |
| | | | | | | | 5.631 | 0.231 | |
| | | | | | | | 5.826 | 0.159 | |
| | | | | | | | 5.950 | 0.120 | |
| 1095 | 2 | 4.427 | 0.365 | 0.250 | 3 | 2 | 3.140 | 0.093 | 0.459 |
| | | 4.967 | 0.170 | 0.118 | | | 3.200 | 0.149 | |
| | | | | | | 3 | 3.486 | 0.161 | |
| | | | | | | | 3.734 | 0.335 | |
| | | | | | | | 4.047 | 0.291 | |
| | | | | | | 5 | 5.369 | 0.237 | |
| | | | | | | | 5.600 | 0.225 | |
| | | | | | | | 5.735 | 0.164 | |
| | | | | | | | 5.833 | 0.240 | |
| | | | | | | | 5.885 | 0.136 | |
| 1140 | 1 | 3.485 | 0.162 | 0.107 | 3 | 2 | 3.148 | 0.106 | 0.328 |
| | | | | | | | 3.230 | 0.132 | |
| | | | | | | 4 | 4.203 | 0.545 | |
| | | | | | | | 4.402 | 0.172 | |
| | | | | | | | 4.546 | 0.116 | |
| | | | | | | | 4.638 | 0.178 | |
| | | | | | | 2 | 5.777 | 0.160 | |
| | | | | | | | 5.888 | 0.117 | |
| 1180 | 3 | 3.188 | 0.114 | 0.053 | 1 | 6 | 3.446 | 0.205 | 0.283 |
| | | 5.454 | 0.301 | 0.203 | | | 3.702 | 0.306 | |
| | | 5.771 | 0.210 | 0.180 | | | 3.712 | 0.116 | |
| | | | | | | | 3.880 | 0.117 | |
| | | | | | | | 4.040 | 0.203 | |
| | | | | | | | 4.262 | 0.274 | |
| 1223 | 1 | 5.851 | 0.209 | 0.178 | 2 | 7 | 3.150 | 0.095 | 0.570 |
| | | | | | | | 3.265 | 0.213 | |
| | | | | | | | 3.475 | 0.206 | |
| | | | | | | | 3.693 | 0.230 | |
| | | | | | | | 3.890 | 0.164 | |

| Frame | Single bubbles | | | | Merging bubbles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sites | Bubble center (a) | Bubble width (a) | Area fraction, $\varphi_s$ | Sites | Number of merging bubbles | Site center (a) | Site width (a) | Area fraction, $\varphi_m$ |
| | | | | | | | 4.556 | 0.233 | |
| | | | | | | 2 | 5.781 | 0.146 | |
| | | | | | | | 5.902 | 0.097 | |
| 1486 | 2 | 3.467 | 0.122 | 0.061 | 4 | 2 | 3.176 | 0.096 | 0.535 |
| | | 4.216 | 0.260 | 0.276 | | | 3.227 | 0.185 | |
| | | | | | | 2 | 3.738 | 0.214 | |
| | | | | | | | 3.877 | 0.203 | |
| | | | | | | 6 | 4.607 | 0.234 | |
| | | | | | | | 4.715 | 0.177 | |
| | | | | | | | 4.898 | 0.327 | |
| | | | | | | | 5.016 | 0.149 | |
| | | | | | | | 5.162 | 0.256 | |
| | | | | | | | 5.411 | 0.243 | |
| | | | | | | 3 | 5.674 | 0.180 | |
| | | | | | | | 5.791 | 0.130 | |
| | | | | | | | 5.892 | 0.119 | |
| 1521 | 2 | 3.188 | 0.100 | 0.041 | 3 | 2 | 3.415 | 0.140 | 0.444 |
| | | 4.284 | 0.157 | 0.101 | | | 3.659 | 0.348 | |
| | | | | | | 2 | 5.011 | 0.207 | |
| | | | | | | | 5.045 | 0.363 | |
| | | | | | | 3 | 5.395 | 0.267 | |
| | | | | | | | 5.642 | 0.227 | |
| | | | | | | | 5.845 | 0.179 | |
| 1571 | 3 | 3.229 | 0.127 | 0.066 | 2 | 2 | 4.917 | 0.214 | 0.207 |
| | | 3.449 | 0.188 | 0.144 | | | 5.122 | 0.196 | |
| | | 3.714 | 0.165 | 0.111 | | 3 | 5.482 | 0.233 | |
| | | | | | | | 5.703 | 0.209 | |
| | | | | | | | 5.879 | 0.144 | |
| 1600 | 4 | 3.243 | 0.196 | 0.157 | 1 | 2 | 5.518 | 0.194 | 0.136 |
| | | 3.470 | 0.163 | 0.108 | | | 5.778 | 0.327 | |
| | | 3.975 | 0.245 | 0.245 | | | | | |
| | | 4.949 | 0.248 | 0.251 | | | | | |
| 1640 | 1 | 3.212 | 0.168 | 0.115 | 3 | 2 | 3.474 | 0.154 | 0.614 |
| | | | | | | | 3.684 | 0.266 | |
| | | | | | | 2 | 4.029 | 0.242 | |
| | | | | | | | 4.187 | 0.306 | |
| | | | | | | 7 | 4.611 | 0.276 | |
| | | | | | | | 4.900 | 0.356 | |
| | | | | | | | 5.187 | 0.218 | |
| | | | | | | | 5.404 | 0.216 | |
| | | | | | | | 5.616 | 0.209 | |
| | | | | | | | 5.745 | 0.095 | |
| | | | | | | | 5.875 | 0.165 | |
| 1690 | 5 | 4.287 | 0.248 | 0.251 | 3 | 2 | 3.172 | 0.089 | 0.161 |
| | | 4.604 | 0.236 | 0.227 | | | 3.224 | 0.111 | |
| | | 4.906 | 0.186 | 0.141 | | 2 | 3.452 | 0.227 | |
| | | 5.203 | 0.145 | 0.086 | | | 3.674 | 0.216 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 4.078 | 0.212 | |
| | | | | | | | 4.300 | 0.233 | |
| | | | | | | 4 | 4.943 | 0.376 | |
| | | | | | | | 5.214 | 0.147 | |
| | | | | | | | 5.364 | 0.191 | |
| | | | | | | | 5.436 | 0.334 | |
| 1261 | 4 | 3.481 | 0.166 | 0.113 | 3 | 2 | 3.204 | 0.034 | 0.222 |
| | | 3.707 | 0.157 | 0.101 | | | 3.250 | 0.132 | |
| | | 3.869 | 0.100 | 0.041 | | 3 | 4.870 | 0.246 | |
| | | 4.442 | 0.320 | 0.217 | | | 5.033 | 0.127 | |
| | | | | | | | 5.148 | 0.203 | |
| | | | | | | 4 | 5.523 | 0.141 | |
| | | | | | | | 5.671 | 0.154 | |
| | | | | | | | 5.801 | 0.107 | |
| | | | | | | | 5.887 | 0.136 | |
| 1311 | 2 | 3.220 | 0.167 | 0.114 | 3 | 3 | 3.667 | 0.461 | 0.618 |
| | | 4.047 | 0.215 | 0.189 | | | 3.557 | 0.182 | |
| | | | | | | | 3.728 | 0.160 | |
| | | | | | | 3 | 4.583 | 0.342 | |
| | | | | | | | 4.682 | 0.194 | |
| | | | | | | | 4.910 | 0.312 | |
| | | | | | | 6 | 5.536 | 0.274 | |
| | | | | | | | 5.613 | 0.203 | |
| | | | | | | | 5.708 | 0.108 | |
| | | | | | | | 5.825 | 0.127 | |
| | | | | | | | 5.887 | 0.133 | |
| | | | | | | | 5.921 | 0.065 | |
| 1359 | 5 | 3.193 | 0.111 | 0.050 | 1 | 4 | 5.339 | 0.365 | 0.180 |
| | | 3.481 | 0.223 | 0.203 | | | 5.583 | 0.134 | |
| | | 3.731 | 0.185 | 0.140 | | | 5.737 | 0.175 | |
| | | 4.603 | 0.186 | 0.141 | | | 5.887 | 0.124 | |
| | | 4.904 | 0.234 | 0.224 | | | | | |
| 1411 | 1 | 3.971 | 0.108 | 0.048 | 4 | 2 | 3.155 | 0.077 | 0.446 |
| | | | | | | | 3.236 | 0.181 | |
| | | | | | | 2 | 3.623 | 0.237 | |
| | | | | | | | 3.749 | 0.214 | |
| | | | | | | 4 | 4.460 | 0.235 | |
| | | | | | | | 4.593 | 0.138 | |
| | | | | | | | 4.693 | 0.301 | |
| | | | | | | | 4.831 | 0.193 | |
| | | | | | | 4 | 5.562 | 0.150 | |
| | | | | | | | 5.647 | 0.149 | |
| | | | | | | | 5.744 | 0.191 | |
| | | | | | | | 5.877 | 0.130 | |
| 1441 | 0 | | | | 3 | 2 | 3.176 | 0.092 | 0.359 |
| | | | | | | | 3.262 | 0.118 | |
| | | | | | | 6 | 3.486 | 0.158 | |
| | | | | | | | 3.615 | 0.134 | |
| | | | | | | | 3.801 | 0.238 | |
| | | | | | | | 3.967 | 0.094 | |
| | | | | | | | 4.227 | 0.426 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5.462 | 0.278 | 0.187 | | 2 | 5.742 | 0.127 | |
| | | | | | | | 5.881 | 0.151 | |
| 1733 | 3 | 3.195 | 0.129 | 0.068 | 2 | 3 | 3.463 | 0.223 | 0.261 |
| | | 4.291 | 0.129 | 0.068 | | | 3.679 | 0.208 | |
| | | 4.908 | 0.233 | 0.222 | | | 3.911 | 0.256 | |
| | | | | | | 3 | 5.511 | 0.200 | |
| | | | | | | | 5.696 | 0.171 | |
| | | | | | | | 5.866 | 0.168 | |
| 1766 | 3 | 3.675 | 0.068 | 0.019 | 2 | 3 | 3.186 | 0.115 | 0.201 |
| | | 3.869 | 0.172 | 0.121 | | | 3.309 | 0.131 | |
| | | 4.286 | 0.304 | 0.206 | | | 3.448 | 0.147 | |
| | | | | | | 4 | 4.688 | 0.149 | |
| | | | | | | | 4.831 | 0.201 | |
| | | | | | | | 4.983 | 0.134 | |
| | | | | | | | 5.120 | 0.253 | |
| 1813 | 3 | 3.211 | 0.177 | 0.128 | 3 | 2 | 3.797 | 0.278 | 0.312 |
| | | 3.439 | 0.198 | 0.160 | | | 4.047 | 0.223 | |
| | | 4.690 | 0.313 | 0.212 | | 2 | 4.972 | 0.164 | |
| | | | | | | | 5.176 | 0.245 | |
| | | | | | | 3 | 5.644 | 0.202 | |
| | | | | | | | 5.761 | 0.195 | |
| | | | | | | | 5.892 | 0.116 | |
| 1858 | 2 | 3.209 | 0.111 | 0.050 | 3 | 3 | 3.507 | 0.294 | 0.438 |
| | | 4.037 | 0.229 | 0.214 | | | 3.708 | 0.109 | |
| | | | | | | | 3.738 | 0.216 | |
| | | | | | | 2 | 5.026 | 0.182 | |
| | | | | | | | 5.143 | 0.361 | |
| | | | | | | 3 | 5.574 | 0.329 | |
| | | | | | | | 5.766 | 0.163 | |
| | | | | | | | 5.887 | 0.130 | |
| 1890 | 2 | 3.195 | 0.135 | 0.074 | 3 | 3 | 3.727 | 0.135 | 0.372 |
| | | 3.459 | 0.273 | 0.183 | | | 3.854 | 0.198 | |
| | | | | | | | 4.030 | 0.154 | |
| | | | | | | 2 | 4.786 | 0.175 | |
| | | | | | | | 4.982 | 0.216 | |
| | | | | | | 3 | 5.300 | 0.292 | |
| | | | | | | | 5.573 | 0.254 | |
| | | | | | | | 5.820 | 0.241 | |
| 1927 | 1 | 4.042 | 0.304 | 0.206 | 3 | 2 | 3.202 | 0.125 | 0.240 |
| | | | | | | | 3.353 | 0.296 | |
| | | | | | | 2 | 3.574 | 0.095 | |
| | | | | | | | 3.672 | 0.100 | |
| | | | | | | 4 | 5.403 | 0.192 | |
| | | | | | | | 5.586 | 0.174 | |
| | | | | | | | 5.762 | 0.178 | |
| | | | | | | | 5.898 | 0.128 | |
| 1965 | 2 | 3.463 | 0.155 | 0.098 | 2 | 2 | 3.123 | 0.073 | 0.069 |
| | | 5.748 | 0.409 | 0.281 | | | 3.213 | 0.107 | |
| | | | | | | 2 | 4.054 | 0.126 | |
| | | | | | | | 4.085 | 0.188 | |

Total number of sample frames, k, 49.
Total number of single bubbles, h, 124.
Total number of merging bubbles, 385.
Average instantaneous bubble population, $n_{av}$, 10.39.
Average area fraction of influence of single bubble, $\varphi_{s,av}$, 0.136.
Average area fraction of merging bubbles, $\varphi_{m,av}$, 0.3269.
Standard deviation associated with $\varphi_{m,av}$, 0.1523.

[a]3.232 movie analyzer units equal 0.75 inch; left end reading, 3.098; right end reading, 6.330 (average right limit, 5.955; reduced area of strip evaluated because of obscuration of film).

TABLE III. - COMPARISON OF THEORETICAL AND EMPIRICAL VARIATION

| Run | Average area fraction of merging bubbles, $\varphi_{m,av}$ | $1 - \varphi_{m,av}$ | Average area fraction of influence of bubbles, $\varphi_{s,av}$ | Theoretical variation, $\sigma, \sqrt{\varphi_{m,av}(1 - \varphi_{m,av})\varphi_{s,av}}$ | Standard deviation associated with $\varphi_{m,av}$, S |
|---|---|---|---|---|---|
| 62-12-4-1 | 0.0451 | 0.955 | 0.121 | 0.0722 | 0.0929 |
| 62-12-4-2 | .0182 | .982 | .102 | .0426 | .0451 |
| 62-12-4-3 | .0240 | .976 | .109 | .0505 | .0649 |
| 62-12-4-5 | .0402 | .960 | .138 | .073 | .0936 |
| 62-12-4-6 | .0171 | .983 | .128 | .0463 | .0533 |
| 63-1-14-6 | .0291 | .971 | .143 | .0635 | .0702 |
| 63-2-6-1 | .115 | .885 | .186 | .138 | .135 |
| 63-2-6-2 | .255 | .745 | .185 | .188 | .225 |
| 63-2-6-3 | .3695 | .630 | .208 | .220 | .214 |
| 63-2-6-4 | .535 | .465 | .189 | .217 | .216 |
| 63-7-2-2 | .470 | .530 | .182 | .213 | .183 |
| 63-7-8-1 | .110 | .890 | .109 | .103 | .117 |
| 63-7-8-4 | .358 | .642 | .121 | .167 | .167 |
| 63-7-8-5 | .327 | .673 | .136 | .173 | .152 |

NASA-Langley, 1964 E-2535

*"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."*

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