# EFFECT OF RATIO OF AERATED AREA OF PARTITION PLATES ON GAS HOLDUP IN BUBBLE COLUMNS WITH PARTITION PLATES

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## Introduction

Bubble columns are increasingly used as gas-liquid reactors and bio-reactors, because of their many advantages. Gas holdup is necessary for reliable design of bubble columns, so there have been many investigations[1-6].

In a previous paper[6], the author studied the effects of partition plates on gas holdup in a 16-cm I.D. bubble column with and without a draught tube and obtained the following correlation:

$$\varepsilon_{g1} / \varepsilon_{g0} = 1 + (0.03\ N / d) \qquad (1)$$

where the range of the parameters are $d = 0.1\text{-}1.0$ cm, $N \leq 2$, $N/d \leq 20$ and $V_g$ = 1-20 cm/s.

But the effects of ratio $\beta$ of the aerated area of the partition plates on the gas holdup in a bubble column and the applicability of Eq. (1) to bubble columns of larger diameters remain obscure.

In this paper, the applicability of Eq. (1) to a 31 cm I.D. bubble column and the effects of the ratio $\beta$ of the aerated area of the partition plates on gas holdup are experimentally determined, and the results are discussed and correlated.

## 1. Experimental

Two bubble columns were used. Both were made of transparent acrylic resin. The 16 cm I.D. bubble column was the column described in the previous paper[6]. **Fig. 1** shows the 31 cm I.D. bubble column with three partition plates (B, C, D in Fig. 1). The height of the 31 cm I.D. column was 350 cm.

The gas distributor of the 16 cm I.D.column was the perforated plate described in the previous paper[6]. The gas distributor of the 31 cm I.D. bubble column (A in Fig. 1) was a single nozzle of 5 cm I.D.. The nozzle was set downward at the center of the column and 10 cm above the bottom of the column.

The partition plates used were perforated plates made of vinyl chloride resin. In the 16 cm I.D. bubble column, the partition plates were set in the same positions as described in the previous paper[6]. In the 31 cm I.D. bubble column, one partition plate was set 100 cm above the bottom of the column at $N$ = 1 (see C in Fig. 1). At $N$ = 2, two partition plates were set at 100 cm and 150 cm above the bottom (see C and D in Fig. 1). At $N$ = 3, three partition plates were set 50 cm, 100 cm and 150 cm above the bottom (see B, C, D in Fig. 1). Holes were set by square pitch on the partition plates. The pitch $p$ was changed to determine the effects of the ratio $\beta$ of the aerated area of the partition plates on gas holdup. Details of the partition plates used are listed in **Table 1**.

The liquid used was tap water at room temperature. During each run, liquid was neither fed nor discharged. The clear liquid height was 134-135.3 cm in the 16 cm I.D. column and 181-182.5 cm in the 31 cm I.D. column. Air was used as a gas.

When gas layers were formed under the partitrion plates, the thickness of the gas layer $L$ was measured.

The average gas holdup was obtained from the difference in height of the bubbling and clear liquid layers. Two kinds of average gas holdup, $\varepsilon_{g0}$ and $\varepsilon_{g1}$, were used. $\varepsilon_{g0}$ is gas holdup in the case of no partition plates, and $\varepsilon_{g1}$ is gas holdup that excludes the effects of gas layers.

## 2. Experimental Results and Discussion

### 2.1 Comparison between Eq. (1) and gas holdup at large $\beta$ in the 31 cm I.D. column

**Fig. 2** shows a comparison between $\varepsilon_{g1,\,cal}$ values calculated by Eq. (1) using experimental values of $\varepsilon_{g0}$ and $\varepsilon_{g1,\,exp}$ experimental values in the 31 cm I.D. bubble column. It is clear from this figure that Eq. (1) shows good agreement with experimental results in the 31 cm I.D. bubble column.

### 2.2 Effects of ratio $\beta$ of aerated area on gas holdup

**Fig. 3** shows the effects of pitch $p$ of the partition plates on $\varepsilon_{g1}$ at $N = 3$, $d$ = 5 mm and $n$ = 177 in the 31 cm I.D. bubble column. It is clear from this figure that the gas holdup increases with $p$. When $p$ becomes smaller at a constant $n$, the ratio $\beta$ of the aerated area becomes

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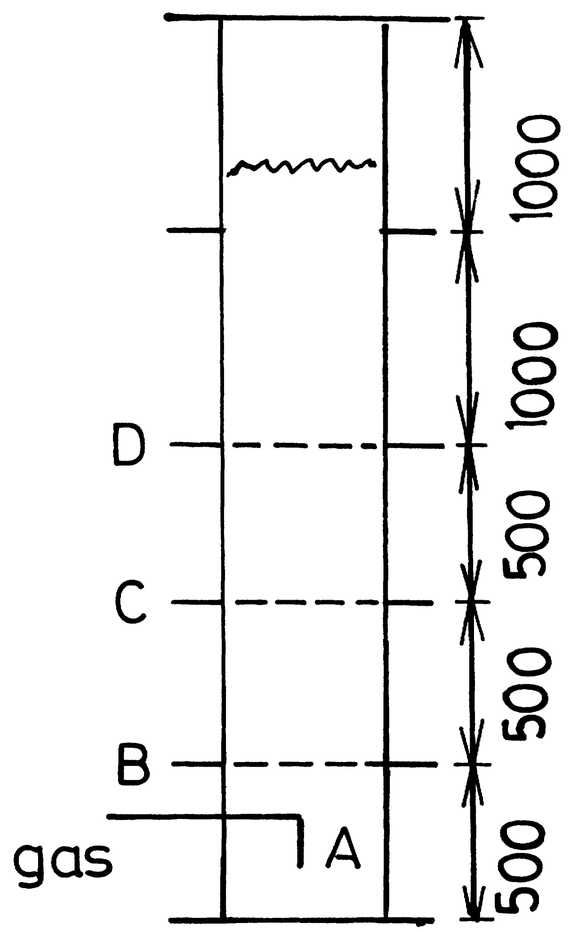


**Fig. 1** Sketch of 31 cm-I.D. bubble column with three partition plates
A = gas distributor, B, C, D = partition plates

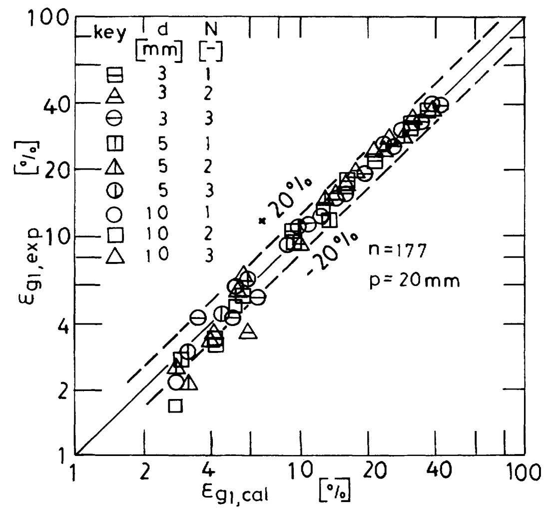


**Fig. 2** Comparison between Eq. (1) and experimental gas holdup at large $\beta$ in 31 cm-I.D. bubble column

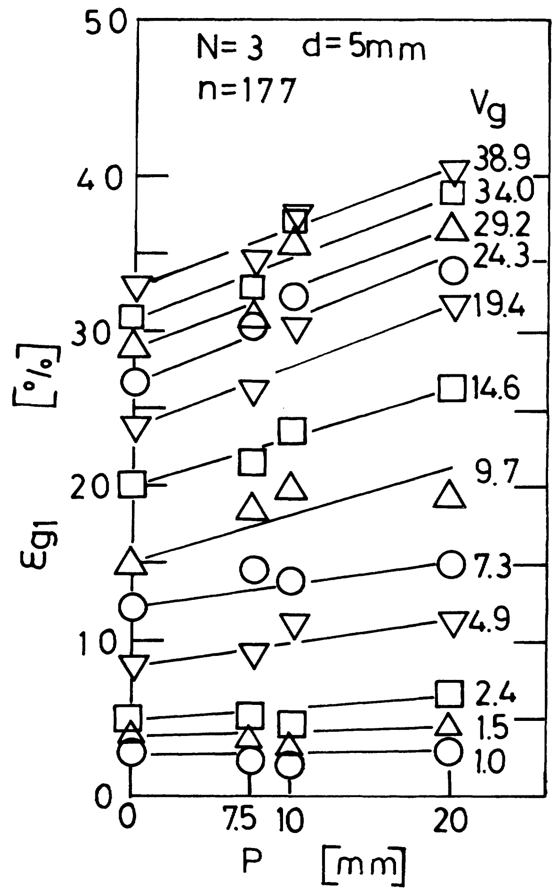


**Fig. 3** Effect of pitch $p$ of holes of partition plates on $\varepsilon_{gl}$ in the 31 cm-I.D. bubble column

**Table 1.** Details of partition plates used and experimental conditions

| No. | $D$ [cm] | $d$ [mm] | $n$ [-] | $p$ [mm] | $\beta$ [%] | $N$ [-] | $V_g$ [cm/s] |
|---|---|---|---|---|---|---|---|
| 1 | 16 | 2 | 45 | 5,10,20 | 5.64-83.3 | 1.2 | 1-20 |
| 2 | 16 | 4 | 45 | 5,10,20 | 6.25-85.6 | 1,2 | 1-20 |
| 3 | 16 | 4 | 185 | 10 | 100 | 1,2 | 1-20 |
| 4 | 31 | 3 | 177 | 7.5,10,20 | 13.3-90.6 | 1-3 | 1-39.3 |
| 5 | 31 | 5 | 177 | 7.5,10,20 | 13.8-91.8 | 1-3 | 1-39.3 |
| 6 | 31 | 10 | 177 | 20 | 94.9 | 1-3 | 1-39.3 |

smaller.

**Fig. 4** shows the dispersion state of bubbles at small $\beta$, at which the holes in the partition plates are concentrated in the central part of the bubble column, as shown in Fig. 4. Thus the dispersion of bubbles becomes worse with decreasing $\beta$. This is the reason why $\varepsilon_{g1}$ increases with $p$.

From the experimental results the following equation was obtained:

$$\varepsilon_{g1} / \varepsilon_{g0} = 1 + (0.03\, N / d)\, \beta^{0.5} \qquad (2)$$

**Fig. 5** shows a comparison between Eq. (2) and experimental results. It is clear from this figure that Eq. (2) shows fairly good agreement with experimental results.

It is concluded that Eq. (1) can apply to the gas holdup in the 31 cm bubble column with three partition plates at $V_g < 40$ cm/s and that Eq. (2) expresses the effects of the ratio of the aerated area of the partition plates on gas holdup in the 16 cm and 31 cm I.D. bubble columns.

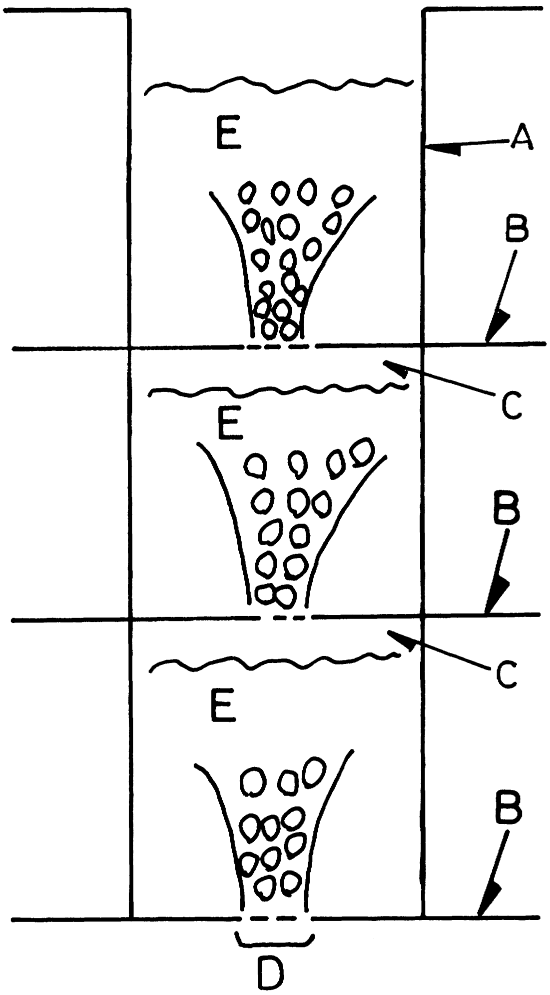


**Fig. 4** Dispersion state of bubbles at small $\beta$
A = bubble column, B = partition plate, C = gas layer, D = aerated area, E = bubbling layer

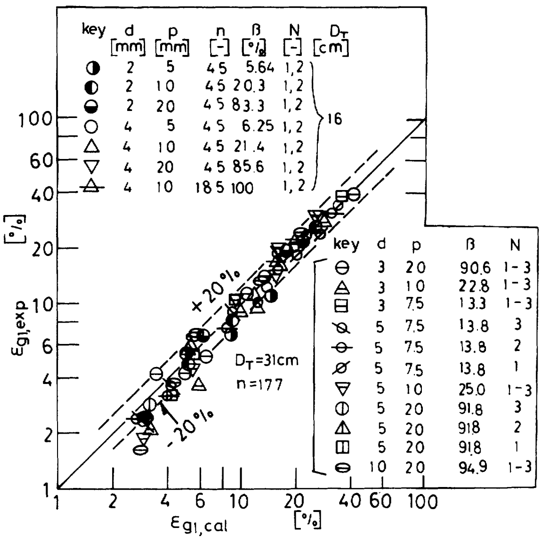


**Fig. 5** Comparison between Eq. (2) and experimental gas holdup


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**Nomenclature**

| | | | |
|---|---|---|---|
| $a$ | = | $V/A$ | [cm] |
| $A$ | = | cross-sectional area of bubble column | [cm$^2$] |
| $d$ | = | diameter of holes | [mm] |
| $d_i$ | = | diameter of innermost shell which contains holes on partition plate | [cm] |
| $D$ | = | diameter of bubble column | [cm] |
| $H_L$ | = | height of clear liquid | [cm] |
| $H$ | = | height of bubbling layer | [cm] |
| $L$ | = | thickness of gas layer | [cm] |
| $n$ | = | number of holes | [-] |
| $N$ | = | number of partition plates | [-] |
| $p$ | = | pitch of holes | [mm] |
| $V$ | = | total volume of partition plates | [cm$^3$] |
| $V_g$ | = | superficial gas velocity | [cm/s] |
| $\beta$ | = | ratio of aerated area $\{= (d_i/D)^2\}$ | [-] |
| $\varepsilon_{g0}$ | = | average gas holdup in absence of partition plates | [-] |
| $\varepsilon_{g1}$ | = | average gas holdup which excludes the effects of gas layer $\{= (H_T\text{-}H_L\text{-}L)/(H_T\text{-}L\text{-}a)\}$ | [-] |
| $\varepsilon_{g1,cal}$ | = | $\varepsilon_{g1}$ value calculated by Eq. (1) or (2) | [-] |
| $\varepsilon_{g1,exp}$ | = | experimental value of $\varepsilon_{g1}$ | [-] |

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