*Int. J. Heat Mass Transfer.* Vol. 30, No. 6, pp. 1095–1101, 1987
Printed in Great Britain

0017-9310/87 $3.00+0.00

# Effect of an immersed tube-bank in a gas fluidized bed

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(*Received* 5 *June* 1986 *and in final form* 12 *September* 1986)

**Abstract**—Bubble properties in a three-dimensional, freely-bubbling, gas fluidized bed are reported in the presence and the absence of a horizontal tube-bundle. The tube-bundle is a staggered-array of tubes 1.9 cm in diameter, with a pitch:diameter ratio of 3.5. Two different gas distributor plates, one made from sintered metal and one a simple perforated plate, were used and results compared under identical fluidizing conditions. Bubble rise velocities, bubble size and frequency distributions are measured and reported. Greater bubble rise velocities are recorded in a bed free of solid obstacles with both distributor plates. Bubble size distributions do not seem to be greatly affected by the presence of a horizontal tube-bank in the bed.

## INTRODUCTION

HEAT removal from a gas fluidized bed may be carried out by the use of tubes, containing a circulating coolant. Since the mobile particles surrounding the tubes are solid and have a high heat capacity, a heat transfer coefficient of about five times greater than for gas–solid contacting can be obtained. Glass [1] observed the effect of thirteen 1 cm diameter cylinders mounted in three horizontal rows (4–5–4) on a 2 cm square pitch on the behaviour of a two-dimensional air-fluidized bed. When rising air bubbles met this tube array, they generally passed right through it unchanged, commonly on a diagonal path. Bubble splitting was not often observed, except when bubbles larger than the tube size made direct collisions with the tubes.

However, when this occurred bubble coalescence usually made good the damage in a short distance above the tube array, and thus, with regard to size and number, the bubbles above the array were not noticeably different from those below it. This observation suggests that unless the array of tubes fills the bed the influence it has on the average bubble size is small.

However, several authors have reported that the presence of a tube-array in a fluidized bed has the effect of reducing the bubble size. Whitehead *et al.* [2] reported that incorporating a bundle of horizontal tubes in a fluidized bed has the effect of markedly reducing the bubble size compared with the bubble size at corresponding conditions in an open bed. They calculated that the presence of a tube bundle produced a much more uniform bubble distribution, indicating a reduction in the axial mixing of gas and solids.

Grace and Harrison [3], Chandran [4], Rooney [5] and Newby and Keairns [6] among others, have studied particle movement around an immersed horizontal tube as well as bed-to-tube heat transfer rates. There are contradictory reports on the behaviour of bubbles in such a bed. To answer some of the questions arising from immersion of a horizontal tube-array in a three-dimensional, freely-bubbling, gas fluidized bed, an experimental investigation of this phenomenon was undertaken and some of the results are reported in this paper.

## TUBE-BANK

A tube-bank, shown in Fig. 1, was assembled and was immersed in the bed to study the effect on the bubble formation, coalescence and various bubble statistics.

The bed, the measuring technique and the experimental procedure have been described elsewhere [7]. Briefly, a three-dimensional bed of rectangular cross-section was used. The fluidized material in all the experiments was a round sand of density 2.50 g cm$^{-3}$ and a minimum fluidizing velocity of 0.95 cm s$^{-1}$ (with both distributor plates). A staggered-array of wooden tubes 1.9 cm in diameter, in 7 × 7 cm pitch was constructed which could be lowered down to rest at either 11 or 21 cm above the distributor plate (Fig. 1). The tubes were fixed into chip-board which was 2 cm thick, thus narrowing the bed slightly. A horizontal tube arrangement was chosen since this is often used in coal combustion fluidized bed furnaces. Skinner [8] reported that a pitch:diameter ratio of 2–8 is used over a wide range of industrial applications. A pitch:diameter ratio of 3.5 was used in these experiments, as representing common industrial practice with heat transfer tubes in fluidized beds.

## RESULTS AND DISCUSSION OF RESULTS

Figure 2 shows the size distribution variation of bubbles encountered by the probe in the bed, with and without the tube-bank present, at a point 50 cm

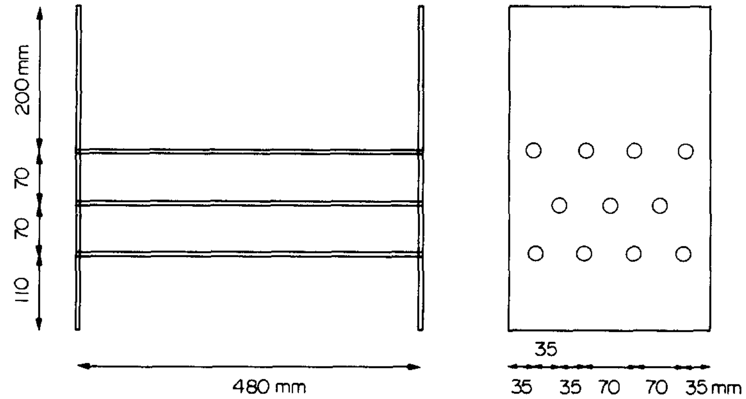

FIG. 1. Tube-bank.

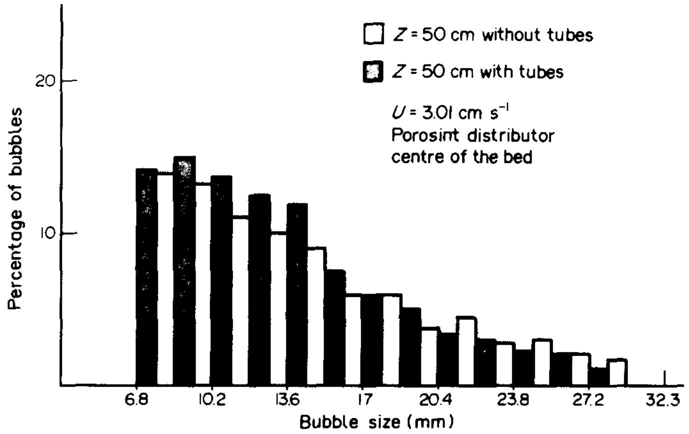

FIG. 2. Bubble size distributions with and without a tube-bank.

above the porosint distributor plate on the bed vertical centreline. The histogram corresponding to the latter case (without the tube-bank), shows a peak in the 8–10 mm size range. Otherwise the two histograms follow a very similar and very close pattern of bubble frequency decreasing steadily with an increase in bubble size. It seems as though the bubbles are sliding off the tubes or splitting when they hit the tubes but reforming immediately above the top array, so that no significant difference in the size distribution is revealed.

This conclusion is reinforced when the comparison is extended to another plane, 20 cm higher (i.e. 70 cm above the distributor plate), Fig. 3. Again the two histograms reveal a similar pattern of frequency increasing to a maximum (peak value of 12–13%) and then decreasing steadily with increasing size.

In Fig. 4 two bubble size distribution histograms are compared.

(1) When the sampling point is 30 cm above the distributor plate but without the tube-bank.

(2) With the case where the tube-bank is present, but the point of measurement is 70 cm above the distributor on the bed vertical axis, about 35 cm above the top array.

The two histograms show very different patterns of frequency-size distribution variation. The one corresponding to the point with $Z = 70$ cm shows a gradual increase, a peak and a steady decline. The histogram corresponding to the point with $Z = 30$ cm has already peaked, the most frequent size being less than 6.8 mm.

The purpose of making this comparison was to test the hypothesis that a tube-bundle acts as a redistributor for the fluidizing gas. Were this the case, similar size distributions would be expected at almost equal heights above the distributor and the tube-bundle. As can be seen from Fig. 4, no such similarity exists. It must, therefore, be concluded that the tube-bundle acts as a redistributor only to the extent of improving the uniformity of bubbling activity in the bed.

It is of interest to compare the bubble rise velocities in the bed, with and without the presence of a solid obstacle (e.g. a tube-bank). In Tables 1 and 2, rise velocities measured at elevations of 50, 60 and 70 cm above the distributors, are tabulated. The two distributors used, were a porosint plate and a multiorifice distributor of 5 mm thick mild steel with 66 perforations, each 3.2 mm in diameter, symmetrically dis-

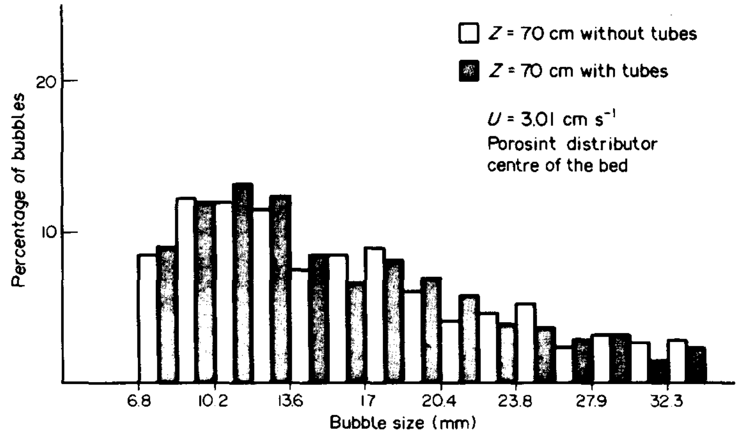

FIG. 3. Bubble size distributions with and without a tube-bank.

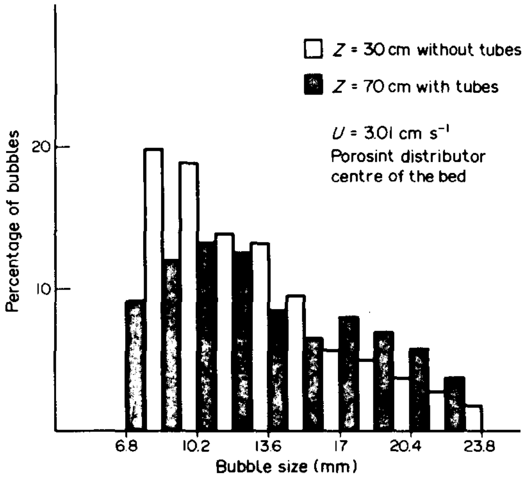

FIG. 4. Bubble size distributions with and without a tube-bank.

Table 1. Bubble rise velocities with and without a tube-bank with a porosint distributor ($U = 3.01\,\mathrm{cm\,s^{-1}}$)

| | $Z = 50\,\mathrm{cm}$ | | $Z = 60\,\mathrm{cm}$ | | $Z = 70\,\mathrm{cm}$ | |
|---|---|---|---|---|---|---|
| Bubble size (cm) | $U_B$ with ($\mathrm{cm\,s^{-1}}$) | $U_B$ without ($\mathrm{cm\,s^{-1}}$) | $U_B$ with ($\mathrm{cm\,s^{-1}}$) | $U_B$ without ($\mathrm{cm\,s^{-1}}$) | $U_B$ with ($\mathrm{cm\,s^{-1}}$) | $U_B$ without ($\mathrm{cm\,s^{-1}}$) |
| 0.765 | 21.753 | 26.395 | 21.273 | 27.125 | 21.480 | 29.290 |
| 0.935 | 23.238 | 27.642 | 23.218 | 28.897 | 26.390 | 33.077 |
| 1.105 | 23.787 | 34.134 | 24.544 | 29.940 | 27.449 | 31.941 |
| 1.275 | 25.071 | 34.417 | 27.676 | 33.760 | 29.481 | 31.973 |
| 1.445 | 29.256 | 35.228 | 28.992 | 31.905 | 30.914 | 32.896 |
| 1.615 | 28.267 | 41.387 | 33.526 | 38.843 | 31.202 | 37.217 |
| 1.785 | 32.930 | 42.066 | 31.585 | 45.132 | 37.354 | 39.878 |
| 1.955 | 33.172 | 44.752 | 39.537 | 41.778 | 38.072 | 42.027 |
| 2.125 | 37.894 | 54.961 | 39.361 | 48.111 | 42.037 | 46.265 |
| 2.295 | 39.322 | 56.094 | 39.000 | 45.694 | 45.337 | 49.219 |
| 2.465 | 35.298 | 47.974 | 42.960 | 59.312 | 54.507 | 60.235 |
| 2.635 | 41.939 | 59.800 | 46.700 | 47.745 | 52.608 | 63.453 |
| 2.805 | 46.143 | 53.448 | 48.399 | 61.939 | 52.999 | 52.120 |
| 2.975 | 44.195 | 63.624 | 47.242 | 61.749 | 53.677 | 54.463 |
| 3.145 | 48.528 | 66.797 | 51.797 | 69.034 | 46.192 | 68.995 |
| 3.315 | | | | | 51.905 | 64.087 |
| 3.485 | | | | | 52.960 | 67.745 |

Table 2. Bubble rise velocities with and without a tube-bank with a multiorifice distributor ($U = 3.01\,\mathrm{cm\,s^{-1}}$)

| | $Z = 50\,\mathrm{cm}$ | | $Z = 60\,\mathrm{cm}$ | | $Z = 70\,\mathrm{cm}$ | |
|---|---|---|---|---|---|---|
| Bubble size (cm) | $U_B$ with ($\mathrm{cm\,s^{-1}}$) | $U_B$ without ($\mathrm{cm\,s^{-1}}$) | $U_B$ with ($\mathrm{cm\,s^{-1}}$) | $U_B$ without ($\mathrm{cm\,s^{-1}}$) | $U_B$ with ($\mathrm{cm\,s^{-1}}$) | $U_B$ without ($\mathrm{cm\,s^{-1}}$) |
| 0.765 | 14.275 | 20.665 | 14.120 | 20.840 | 15.010 | 21.907 |
| 0.935 | 16.179 | 22.947 | 17.558 | 22.769 | 17.300 | 20.518 |
| 1.105 | 22.764 | 24.488 | 20.613 | 25.335 | 18.628 | 22.459 |
| 1.275 | 21.568 | 25.276 | 22.476 | 25.667 | 24.195 | 25.330 |
| 1.445 | 26.273 | 25.645 | 24.061 | 29.022 | 27.615 | 27.923 |
| 1.615 | 31.849 | 31.456 | 24.625 | 31.497 | 26.270 | 30.872 |
| 1.785 | 27.549 | 31.124 | 25.377 | 29.900 | 26.673 | 34.568 |
| 1.955 | 34.156 | 30.118 | 29.336 | 40.274 | 34.073 | 37.442 |
| 2.125 | 32.620 | 33.968 | 32.989 | 37.857 | 31.653 | 36.470 |
| 2.295 | 33.003 | 38.057 | 30.955 | 33.594 | 36.019 | 36.973 |
| 2.465 | 38.511 | 60.079 | 44.087 | 37.125 | 35.596 | 44.561 |
| 2.635 | 34.979 | 52.813 | 32.720 | 39.019 | 31.641 | 41.148 |
| 2.805 | 43.541 | 52.706 | 38.419 | 43.511 | 36.951 | 43.819 |
| 2.975 | 36.246 | 49.483 | 50.157 | 46.524 | 44.170 | 54.424 |
| 3.145 | 41.651 | 57.330 | 43.624 | 43.624 | 35.413 | 58.018 |
| 3.315 | | | 47.159 | 50.684 | 47.178 | 50.674 |

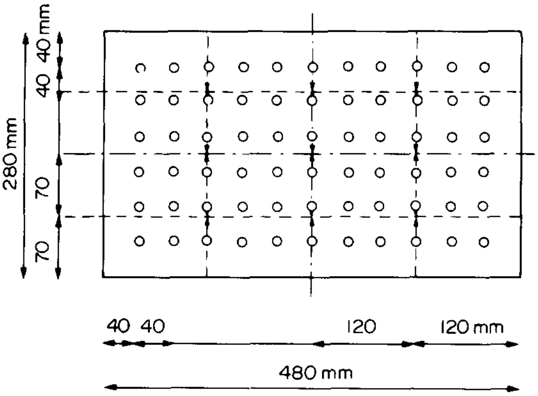

FIG. 5. Sampling points (×) with reference to the perforations of a multiorifice distributor (○).

tributed on a 11 × 6 grid. Figure 5 shows the nine sampling points with reference to the perforations of the multiorifice distributor. The two distributors are described in more detail in ref. [9]. Table 1 shows that the rise velocities, for each interval of bubble size, measured at these elevations, are significantly greater when the bed is free of any solid obstacles. It must be remembered that the point of measurement when $Z = 50\,\mathrm{cm}$ and the tube-bank is present, is about 20 cm above the top array. Table 2, referring to the multiorifice distributor, shows a similar trend for the three elevations compared. (All the operating conditions are identical in these two sets of experiments.) In Table 2, the three sets of data corresponding to the bed free of the solid obstacles show greater rise velocities for each interval of bubble height. This, presumably reflects the effect of the particulate phase circulation patterns in these two cases. Burgess and Calderbank [10] and more recently Lin *et al.* [11] have investigated the motion of solids in a gas fluidized bed with the view to predict the behaviour of the particle phase circulation patterns in the bed.

Finally, the spatial frequency distributions across the bed, at the nine symmetrically distributed points across the bed cross-section, are tabulated in Tables 3–6. These are the point values of bubble frequencies (bubbles per minute) recorded in 'B' mode [9]. Tables 3 and 4 show the frequencies in the bed, with and without the tube-bank, when the porosint distributor is employed, Tables 5 and 6 with the multiorifice distributor. The fluidizing conditions are identical in all four tables.

A comparison of Tables 3 and 5 with 4 and 6 shows that the presence of the tube-bank in the bed has the effect of increasing the uniformity of frequency distribution across the bed cross-sectional area. This could be due to the fact that the tube-bank helps redistribute the bubbles across the bed cross-section (i.e. shifting the bubbles sideways, randomly, without affecting their size distribution).

A summary of the procedure for recording bubbles in 'B' mode is given in refs. [7, 9]. The bubble selection (and collection) in this mode are subject to two constraints. The first is to ensure that bubbles greater than a fixed size are collected and the second is to ensure that only bubbles co-axial with the probe axis are collected. Although the imposition of these two constraints is necessary for accurate bubble size and rise velocity measurements, however, it causes the rejection of a large proportion of small bubbles and therefore, an accurate picture of bubble frequency distribution across the bed cross-sectional area cannot be obtained. Tables 3–6 can only be used as a frame of reference.

To measure the bubble frequency, free of any constraints, there is another mode of timing provided by the microprocessor, namely 'C' mode [9]. Only one probe is used to detect the passage of bubbles in 'C' mode. For the sake of comparison, the sum of

Table 3. Bubble frequencies (in 'B' mode) = min$^{-1}$, bed depth = 82 cm

*Porosint plate distributor with tube-bank*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1.18 | 0.56 | 1.34 | 10.44 | 4.40 | 5.63 | 14.22 | 4.46 | 11.14 |
| 11.76 | 17.02 | 15.18 | 20.00 | 17.12 | 18.88 | 15.25 | 20.97 | 17.60 |
| 1.49 | 10.83 | 7.00 | 9.27 | 22.90 | 15.91 | 12.57 | 9.06 | 11.04 |
| $Z = 70$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| 0.37 | 0.32 | 0.29 | 10.45 | 5.43 | 2.38 | 13.77 | 25.67 | 9.03 |
| 11.99 | 9.25 | 15.18 | 17.02 | 5.22 | 22.88 | 19.40 | 9.20 | 18.14 |
| 1.78 | 11.00 | 10.36 | 7.03 | 24.43 | 13.23 | 7.00 | 16.02 | 13.73 |
| $Z = 60$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| 0.05 | 0.0 | 0.07 | 0.65 | 0.44 | 0.49 | 10.05 | 12.83 | 4.46 |
| 20.10 | 6.99 | 10.70 | 20.37 | 10.84 | 18.47 | 21.28 | 18.04 | 15.98 |
| 0.37 | 13.26 | 9.28 | 9.34 | 23.09 | 7.85 | 14.17 | 11.04 | 15.35 |
| $Z = 50$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |

Table 4. Bubble frequencies (in 'B' mode) = min$^{-1}$, bed depth = 82 cm

*Porosint plate distributor without tube-bank*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| <0.1 | <0.1 | <0.1 | 1.16 | 0.66 | <0.1 | 1.76 | 0.40 | <0.1 |
| 1.68 | <0.1 | 8.9 | 4.97 | 0.2 | 2.22 | 19.58 | 0.1 | 2.52 |
| 1.55 | 11.44 | 26.25 | 29.38 | 3.12 | 28.45 | 36.88 | 1.87 | 38.60 |
| $Z = 70$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 1.12 | 4.1 | <0.1 | <0.1 |
| <0.1 | <0.1 | 4.69 | 0.52 | <0.1 | 1.00 | 2.21 | <0.1 | 1.26 |
| 3.38 | 6.15 | 15.75 | 12.21 | 7.81 | 15.75 | 17.24 | 4.32 | 25.24 |
| $Z = 60$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| <0.1 | <0.1 | 1.62 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| 3.15 | 11.61 | 21.83 | 5.80 | 3.76 | 14.88 | 7.71 | 2.91 | 16.00 |
| $Z = 50$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |

Table 5. Bubble frequencies (in 'B' mode) = min$^{-1}$, bed depth = 82 cm

*Multiorifice distributor with tube-bank*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| <0.1 | 1.57 | 1.75 | 1.11 | 2.22 | 2.38 | 3.96 | 3.51 | 7.32 |
| 1.45 | 7.99 | 11.35 | 5.58 | 9.75 | 12.22 | 7.45 | 13.04 | 21.21 |
| 15.23 | 7.70 | 4.70 | 10.88 | 6.08 | 5.50 | 8.60 | 3.90 | 4.43 |
| $Z = 70$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| <0.1 | 1.15 | 3.10 | 0.37 | 5.14 | 9.10 | 3.31 | 4.93 | 5.15 |
| 3.07 | 8.07 | 7.19 | 6.80 | 10.60 | 12.23 | 9.06 | 11.70 | 20.15 |
| 6.47 | 11.19 | 6.28 | 8.92 | 8.96 | 6.87 | 9.71 | 7.07 | 8.77 |
| $Z = 60$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| <0.1 | <0.1 | 0.80 | <0.1 | 6.67 | 6.73 | 0.43 | 10.24 | 8.19 |
| 0.32 | 1.75 | 8.39 | 5.22 | 5.13 | 11.80 | 7.29 | 4.68 | 17.55 |
| 16.18 | 13.93 | 11.46 | 20.76 | 15.43 | 12.30 | 19.15 | 11.44 | 12.68 |
| $Z = 50$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |

Table 6. Bubble frequencies (in 'B' mode) = min$^{-1}$, bed depth = 82 cm

*Multiorifice distributor without tube-bank*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| <0.1 | 0.38 | 0.75 | <0.1 | 0.33 | 0.60 | 0.17 | 0.47 | 0.92 |
| <0.1 | 5.15 | 23.00 | 0.70 | 5.79 | 40.74 | 2.46 | 3.87 | 46.47 |
| 3.76 | 1.33 | 6.50 | 3.43 | 1.15 | 6.61 | 4.14 | 1.80 | 7.59 |
| $Z = 70$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 70$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| <0.1 | 0.60 | 1.57 | <0.1 | 0.93 | 0.95 | <0.1 | 0.57 | 1.12 |
| <0.1 | 2.25 | 19.59 | 0.10 | 4.28 | 34.5 | 0.77 | 2.96 | 39.16 |
| 1.89 | 2.65 | 6.81 | 1.55 | 0.97 | 9.19 | 2.37 | 1.32 | 10.38 |
| $Z = 60$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 60$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |
| <0.1 | <0.1 | 0.95 | <0.1 | <0.1 | 0.75 | <0.1 | <0.1 | 1.63 |
| <0.1 | 0.95 | 8.62 | <0.1 | 4.66 | 24.83 | 0.13 | 2.72 | 36.20 |
| <0.1 | 4.23 | 8.46 | 6.47 | 2.19 | 8.59 | 11.08 | 1.21 | 10.22 |
| $Z = 50$ cm<br>$U = 1.87$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 2.41$ cm s$^{-1}$ | | | $Z = 50$ cm<br>$U = 3.01$ cm s$^{-1}$ | | |

Table 7. Sum of the point frequencies in 'C' mode, $F_t$, at the nine sampling points, at three different elevations and three different superficial fluidizing velocities (with the multiorifice distributor)

| | $Z$ (cm) | | |
|---|---|---|---|
| $F_t$ (min$^{-1}$) | 50 | 60 | 70 |
| $F_t$ ($U = 1.87$) | 169 | 143 | 210 |
| $F_t$ ($U = 2.41$) | 351 | 347 | 445 |
| $F_t$ ($U = 3.01$) | 499 | 485 | 573 |

point frequencies in 'C' mode, at the nine sampling points, at three different elevations and three different superficial fluidizing velocities are listed in Table 7.

## CONCLUSIONS

In conclusion, introducing an array of tubes into a gas fluidized bed seems to have the following effects.

(1) The direction and the scale of the particulate phase circulation patterns (motion of solids) are changed. There is evidence that their scale is reduced and the direction of flow is sometimes reversed.

(2) Bubble frequency distribution across the bed cross-section is much more uniform when a tube-bank is immersed in the bed. The tube-bank seems to help redistribute the bubbles across the bed cross-section. Very few 'dead' zones are found in the bed.

(3) Bubble size distributions are not greatly affected by the presence of a solid obstacle in the bed. In these experiments, immersing a staggered tube array seems not to disrupt bubble size variation along the vertical direction in the bed. The bubbles seem to slide off the tubes. When they hit the tubes frontally and are consequently split, they seem to reform immediately above the tubes, so as not to affect the size distribution greatly. The tube-bank used in these experiments was not very densely packed (pitch:diameter ratio of 3.5). It is possible that denser arrays might substantially alter bubble size distributions, but any conclusions here must await further experimentation.

*Acknowledgements*—The author wishes to thank Dr D. H. Glass of the Chemical Engineering Department, University of Edinburgh, for his advice and encouragement. Thanks are also due to Mr K. Sipilä, Director of the Laboratory of Fuel Processing and Lubrication Technology, Technical Research Centre of Finland, for his permission to use the laboratory facilities.

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# EFFET D'UN ARRANGEMENT DE TUBES IMMERGES DANS UN LIT FLUIDISE GAZEUX

**Résumé**—Les propriétés des bulles dans un lit gazeux fluidisé tridimensionnel sont décrites avec ou sans arrangement horizontal de tubes. Cet arrangement étagé de tubes de 1,9 cm de diamètre a un rapport pas: diamètre de 3,5. Deux plateaux différents distributeurs de gaz sont utilisés et les résultats sont comparés pour des conditions de fluidisation identiques. La vitesse d'ascension des bulles et les distributions de fréquence sont mesurées. Les plus grandes vitesses correspondent à un lit sans obstacle solide pour le deux distributeurs. La répartition en taille des bulles ne semble pas être fortement affectée par la présence des tubes horizontaux dans le lit.

# DER EINFLUSS EINES ROHRBÜNDELS AUF EINE GASWIRBELSCHICHT

**Zusammenfassung**—Es wird über die Blaseneigenschaften in einer dreidimensionalen Gaswirbelschicht mit und ohne eingebautem horizontalen Rohrbündel berichtet. Das Rohrbündel besteht aus versetzt angeordneten Rohren mit einem Durchmesser von 19 mm. Das Teilungsverhältnis der Rohre ist 3,5. Zwei unterschiedliche Gasverteilerplatten, eine aus gesintertem Metall und eine gelochte Platte wurden benutzt. Ergebnisse bei gleichen Fluidisierungsbedingungen wurden verglichen. Die Aufstiegsgeschwindigkeit der Blasen sowie die Verteilungen der Blasengrößen und Blasenfrequenzen wurden gemessen. Mit beiden Verteilerplatten wurden für eine Schicht ohne feste Einbauten größere Blasenaufstiegs-Geschwindigkeiten gemessen. Die Blasengrößenverteilung wird durch das Rohrbündel nicht stark beeinflußt.

# ПАКЕТ ТРУБ В ПСЕВДООЖИЖЕННОМ СЛОЕ ГАЗА

**Аннотация**—Описаны свойства пузырька в трехмерном свободно кипящем псевдоожиженном слое газа с горизонтальным пучком труб и без него. Пучок представляет собой решетку из расположенных в шахматном порядке труб, имеющих диаметр 1,9 см, с отношением шага к диаметру, равным 3,5. Использовались два различных распределителя газа: один металлический, полученный спеканием, другой в виде перфорированной пластины. Сравниваются результаты при одинаковых условиях псевдоожижения. Измерены скорости подъема пузырька, его размер и частотное распределение. Большие скорости подъема пузырьков зарегистрированы в слое без твердотельных препятствий для обоих распределителей. Горизонтальный пакет труб в слое не влияет существенно на распределение пузырьков по размерам.