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Initial motion of a bubble in a fluidized bed

Part 2. Experiment

By B. A. PARTRIDGE AND E. LYALL
Chemical Engineering Division, U.K. Atomic Energy Authority Research Group, A.E.R.E., Harwell

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Introduction

Experiments have been carried out to observe the motion of an initially stationary circular bubble in a two-dimensional bed of spherical particles fluidized by air. Theoretical work is given in the preceding paper (part 1) by Murray (1967). The experimental problem is similar to that of Walters & Davidson (1962) who devised a technique for releasing a circular air bubble in a two-dimensional bed of water, but it is made more difficult by the requirement that the stationary void, and any boundary used to maintain it, should here be permeable to the fluidizing gas flow. Two different experimental techniques were used.

Experiment A

The two-dimensional bed was made from two acrylic plates $\frac{3}{8}$ in. thick, 1 ft. wide and 2 ft. high separated by vertical rubber-covered spacers 0·58 in. thick. The bottom of the bed was fitted with a uniform metal distributor plate through which the fluidizing air was passed. The bed was filled to a depth of 18 in. with $280\,\mu$ diameter glass spheres ('Ballotini') of density 2·94 g/cm^3 and the bed was fluidized without bubbles forming naturally by a uniform upwards air velocity of 7·3 cm/sec. The rear face of the bed was fitted with a central hole, $\frac{3}{16}$ in. diameter, 6 in. above the distributor, through which a pulse of air was injected to form the void in the bed. The duration of the air pulse was controlled by a fast-acting solenoid valve situated close to the bed and operated by an electronic timer. The pressure of the air supplied to the valve was 30 lb/in.^{2} gauge and the valve opened for 0·062 sec to admit the pulse of air to the bed. The subsequent motion of the void so formed was recorded by a 35 mm ciné camera running at 225 frames per sec.

The motion of a typical bubble is shown in figure 1 (plate 1), the time zero being taken as the instant when the solenoid valve closes and the air injection ends. The void initially formed is not precisely circular but is close to that shape and has a mean radius of 4·1 cm. The upper margin of the bubble is uneven with a small daughter bubble being finally formed on the right-hand side, but the wake is clearly seen to form rapidly as the bubble rises and to be fully formed after about 0·16 sec when the bubble has moved through about $1\frac{1}{2}$ diameters. This is in fair agreement with the theory given by Murray in part 1 which predicts that the wake should be developed in a time of order $(r_0/g)^{\frac{1}{2}}$, i.e. 0·065 sec in this case.

The variation of the rate of rise with distance cannot be measured precisely because of the uneven and changing shape, but a measure of the bubble displacement can be obtained by following the movement of a point (arrowed in figure 1 (*i*)) on the bubble roof which is well defined in frames (*c*) to (*m*) of the sequence. The displacement–time relationship is shown in figure 2 and reveals a uniform rise velocity of 40 cm/sec over the period of observation. The theory predicts an

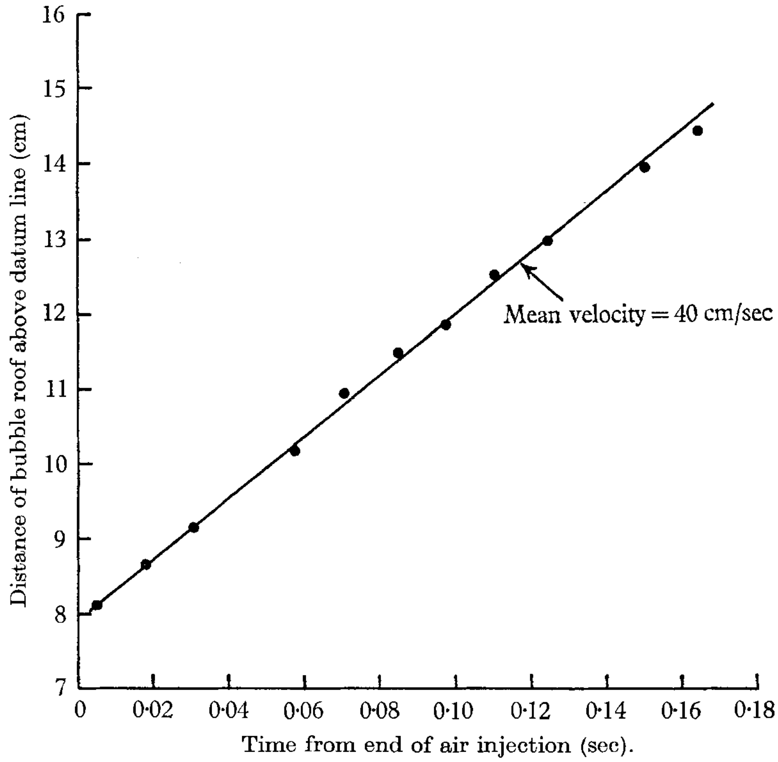


FIGURE 2. Rate of rise of bubble of figure 1, measured using point on bubble roof.

initial acceleration of g for a bubble which starts from rest and this would require a bubble movement of only 0·8 cm in order to attain the observed steady velocity of 40 cm/sec. The method of formation of the void in this experiment will clearly affect this very short initial acceleration period so that no definite conclusion can here be drawn about the magnitude of the acceleration except that the present theoretical prediction is not inconsistent with experimental observation.

Experiment B

The experiment just described is unsatisfactory because the formation of the void causes a sudden disturbance of the fluidized system. In the second experimental method a circular void was artificially maintained in the bed by means of a thin cylindrical barrier which retained the particles but offered a negligible resistance to the gas flow. The experimental arrangement is shown in figure 3. Initially particles were prevented from flowing into the void by the cylinder of

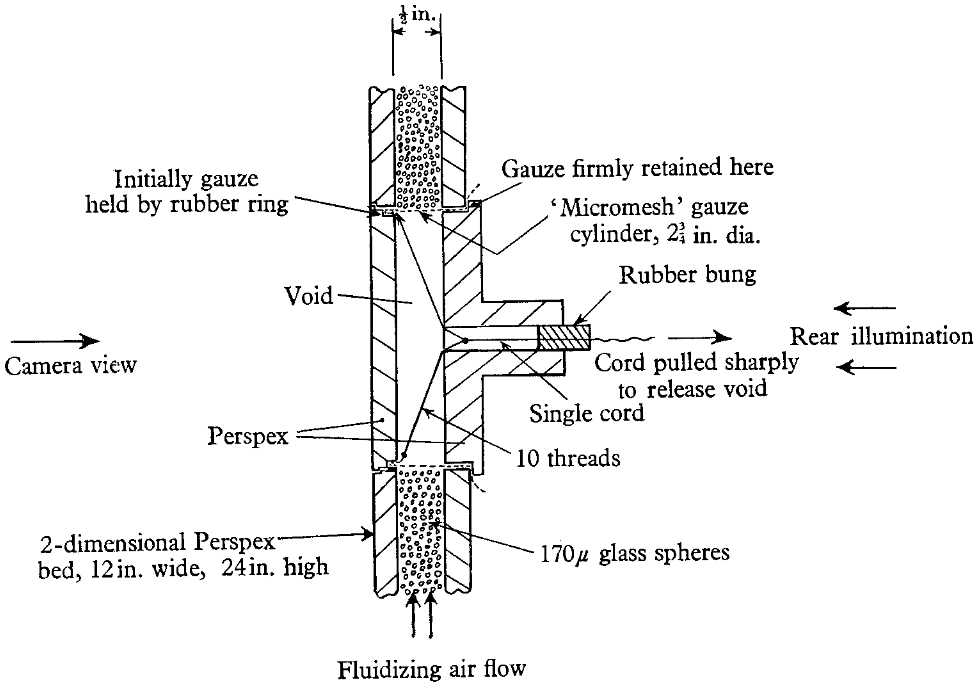


FIGURE 3. Stationary void apparatus for experiment B.

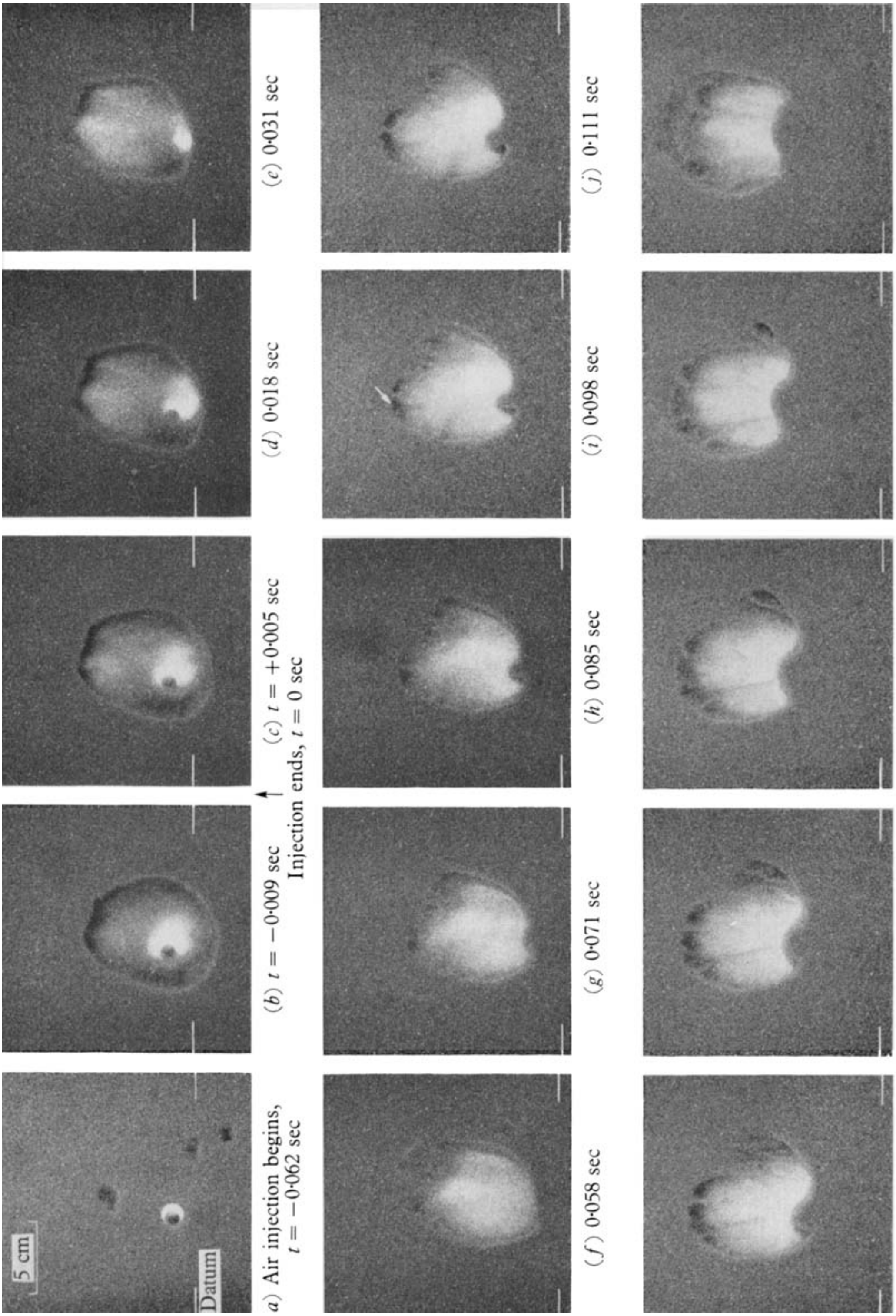
finely woven 'Micromesh' cloth held firmly at one face of the bed and gripped lightly at the other between a Perspex plug and a rubber ring. Ten fine threads connected the free end of the gauze cylinder to a single cord which passed out of the bed through a gas-tight seal. The void was released by sharply pulling the cord to free the gauze from the front face to stretch it over the rear plug and to draw the surplus material into the recess. This also prevented subsequent movement of particles into the recess. The diameter of the gauze cylinder was $2\frac{3}{4}$ in. and its centre was $6\frac{1}{2}$ in. above the distributor. For this experiment the thickness of the two-dimensional bed was reduced to 0·50 in. and the particle size of the fluidized material was 120μ.

The sequence of events on releasing the void is shown in figure 4 (plate 2). The optical contrast between the bubble and the particles in this case was not good and for the sake of clarity in the reproduced sequence the bubble outline has been marked in. It is seen that the void formed initially is closely circular but that almost immediately a secondary bubble begins to form at its upper boundary. This is eventually overtaken, however, by the motion of the main void and finally a single bubble is formed. While the movement of the roof of the bubble is indistinct and uneven the formation of the wake is clearly seen and is very similar in manner and rate to that of experiment A, shown in figure 1.

REFERENCES

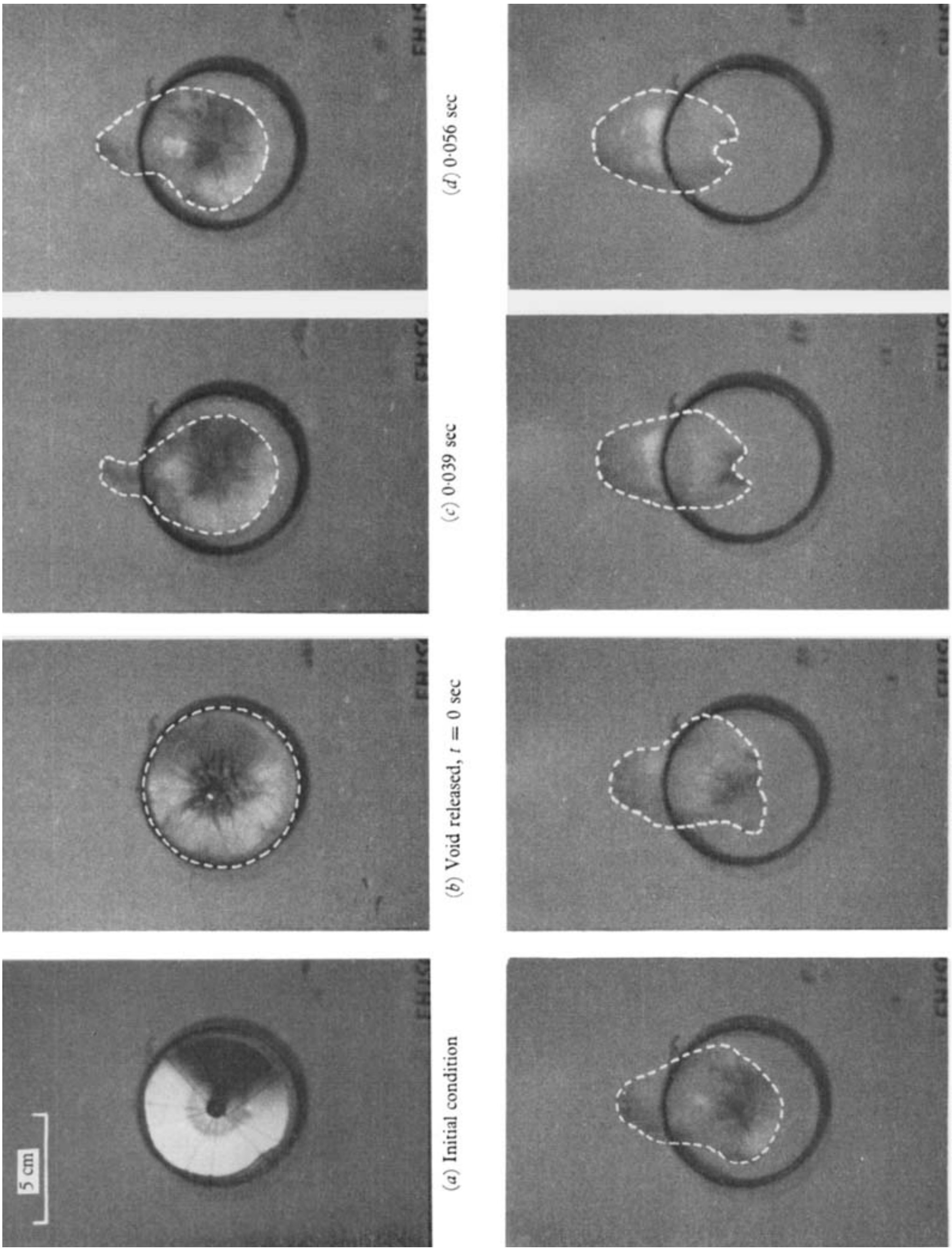
MURRAY, J. D. 1967 *J. Fluid Mech.* **28**, 417

WALTERS, J. K. & DAVIDSON, J. F. 1962 *J. Fluid Mech.* **12**, 408.



(*a*) Air injection begins, $t = -0.062$ sec
(*b*) $t = -0.009$ sec
Injection ends, $t = 0$ sec
(*c*) $t = +0.005$ sec
(*d*) 0·018 sec
(*e*) 0·031 sec
(*f*) 0·058 sec
(*g*) 0·071 sec
(*h*) 0·085 sec
(*i*) 0·098 sec
(*j*) 0·111 sec
(*k*) 0·125 sec
(*l*) 0·151 sec
(*m*) 0·165 sec
(*n*) 0·178 sec
(*o*) 0·205 sec

FIGURE 1. Experiment A: motion of void formed by air injection.



(*a*) Initial condition
(*b*) Void released, $t = 0$ sec
(*c*) 0·039 sec
(*d*) 0·056 sec
(*e*) 0·073 sec
(*f*) 0·090 sec
(*g*) 0·107 sec
(*h*) 0·125 sec

FIGURE 4. Experiment B: motion of void formed initially by gauze cylinder.