AN ASPECT OF THE OPERATION OF A BUBBLER SYSTEM UNDER CONDITIONS OF VIBRATION

A. E. Bershadskii

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This problem arose from the need to use the bubbler method in order to measure the density of a liquid in a vessel subject to vibration, and also from the need to test the performance of a pressure stabilizer under such conditions.

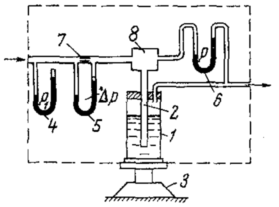

Fig. 1

The measurements were made with a vibration tester having a frequency f in the range 12-200 Hz and an amplitude A of 0.05-1.1 mm (measured with a Mir microscope). Figure 1 shows the system, in which 1 is the bubbler, 2 is the bubble tube, 3 is the vibration tester, and 4-6 are U-tube pressure gauges used to measure the input pressure p_1, the pressure drop Δp across throttle 7 (which defines the flow rate), and the drop in pressure p in the vessel. Chamber 8 serves to smooth out possible variations in the supply pressure.

The parts enclosed in the broken line in Fig. 1 were mounted on a single plate, which was attached to the vibration tester.

Vessel 1 was a glass cylinder of internal diameter 80 mm filled with tapwater. The glass bubble tube had an internal diameter of 4.6 mm and lay at the axis of the cylinder.

Tests were made of the effects of A and f on the pressure difference p* in the system during vibration; p uniquely characterizes the density [1], or the liquid level, or the stabilized pressure. The measurements were made with a constant p_1 corresponding to p = 110 mm water.

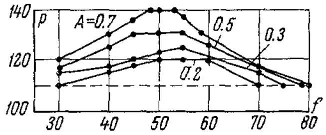

Fig. 2

Figure 2 shows p* (mm water) as a function of f (Hz) for A of 0.2, 0.3, 0.5, and 0.7 mm; p* increases with f and is maximum at 50 Hz, returning to the low-frequency value between 70 and 80 Hz.

The results for p* as a function of f and A are as follows.

$f =$	30	40	45	50	55	60	70	80	
$p^* =$	110	115	117.5	120	120	120	110	110	$(A = 0.2)$
$p^* =$	114	117	120	122	124	121	115	110	$(A = 0.3)$
$p^* =$	117	125	130	130	130	126	117	110	$(A = 0.5)$
$p^* =$	120	130	135	140	137	128	117	111	$(A = 0.7)$

The maximum p* at 50 Hz is 110-130% of p (dashed line in Fig. 2). Figure 2 also shows that the maximum p* increases with A.

Figure 3 shows the mass flow rate G (kg/hr) as a function of A and f. There is a pronounced minimum at 50 Hz and a rise above 80 Hz, the dashed line representing the absence of vibration. The dependence of G on A at 50 Hz is given below.

$A =$	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1
$10^3G =$	40	34	27	20	0	0	0	0	0	0

Thus G falls almost to zero at A = 0.6 mm, which persists up to A = 1.1 mm (the largest value available). It is clear from Figs. 2 and 3 that there are ranges in f and A where the vibration has a very marked influence. This reduction in G can be advantageous, e.g., if an expensive gas such as helium is used. No theoretical explanation of the effect is available.

Tests were done with the tube immersed at two different depths H, but the dependence of G on A and f was the same. The results with H expressed in mm water are given below.

$f =$	15	30	40	50	60	70	
$p^* =$	220	228	230	232	225	213	$(H = 200)$
$p^* =$	120	124	132	134	130	121	$(H = 100)$
$10^3G =$	40	33.5	25	11	25	45	$(H = 200)$
$10^3G =$	33.5	15	5	4	16	33	$(H = 100)$

Here A = 0.3 mm = constant.

The air bubble was split up into many small ones as f and A increased, and the entire volume of liquid in the cylinder became filled with small bubbles at 50 Hz. The liquid frothed vigorously at 80 Hz. At 50 Hz with A > 0.6 mm, the picture was as shown in Fig. 4, in which 1 is the vessel, 2 is water, 3 is the tube, and 4 is water in the tube. This picture was very unstable, the water fluctuating in position along the tube. This may be due to the production of reduced pressure in the period of negative acceleration. The vacuum produces the frothing (in part by evaporation) and also entry of liquid into the tube.

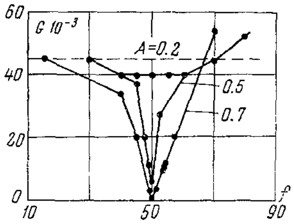

Fig. 3

It is possible that the mode of action of surface forces is altered under conditions of vibration; frothing occurs at the points where a vacuum is produced: contact of liquid with walls and tube, surface of liquid.

The liquid is also ruptured by the large forces set up in this apparatus; e.g., for f = 50 Hz and A = 0.5 mm the overload is

$$j = \frac{A\omega^2}{g} = \frac{0.5\times10^{-3}(2\times3.14\times50)^2}{9.81} = 5\ ,$$

in which $\omega = 2\pi f$ is circular frequency ($\sec^{-1}$).

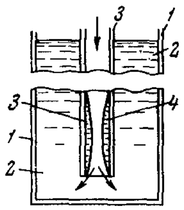

Fig. 4

The apparatus of Fig. 1 was also vibrated over a wide range in f and A without liquid at the same p_1; no effect on G was observed.

We are indebted to I. A. Charnyi for a discussion.

REFERENCE

1. A. E. Bershadskii and O. Z. Baskina, "A study of a bubble system," Sb. Mosk. Inst. Neftekhim. i Gaz. Prom., Izd. Nedra, no. 59, 1966.

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