GAS CONTENT OF A FOAM BED AT REDUCED PRESSURES

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The gas content of a foam bed has been experimentally investigated using a 50 × 80 mm^2 column at the following parameters: pressure $P = 0.1-1.0$ bar, $W = 0.5-2.0$ m/sec, $H = 140-180$ mm. In all cases the gas phase was air and the liquid phase was water and aqueous solutions of ethanol and glycerol. It has been established that reducing the pressure causes a considerable decrease in gas content, leading to an increase in the depth of the starting layer of liquid h_0. A formula that conforms with the experimental data to within ± 10% is obtained for the gas content.

As previously shown [1-3], the high efficiency of heat transfer surfaces in a gas–liquid foam bed at relatively low gas and liquid flow rates suggests the desirability of designing compact foam-bed heat exchanges.

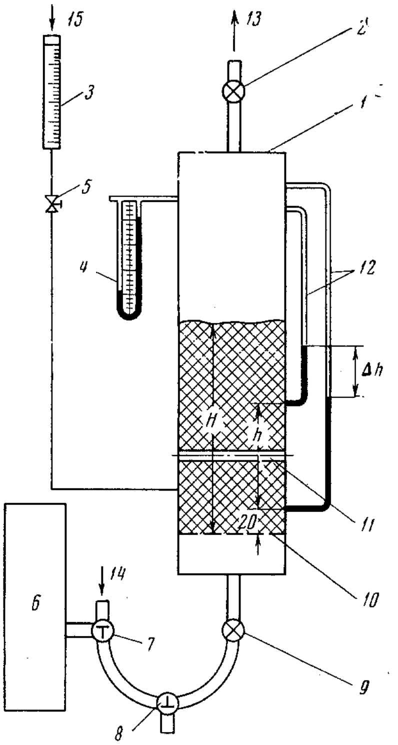

Fig. 1

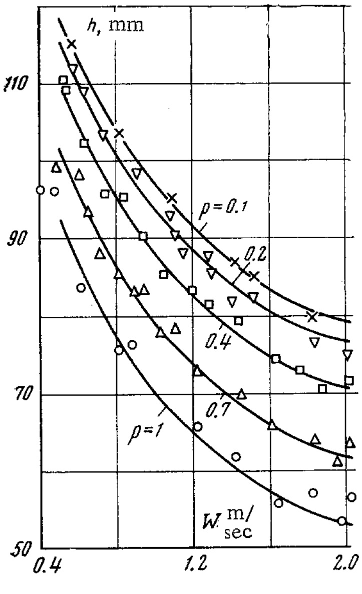

Fig. 2

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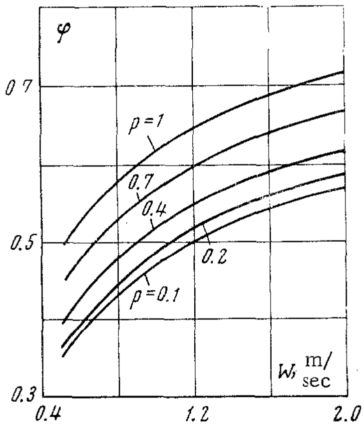

Fig. 3

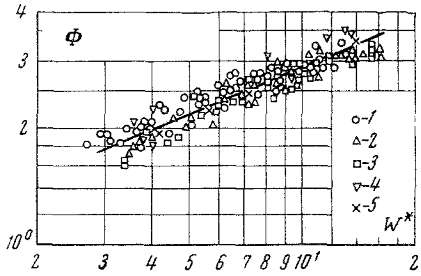

Fig. 4

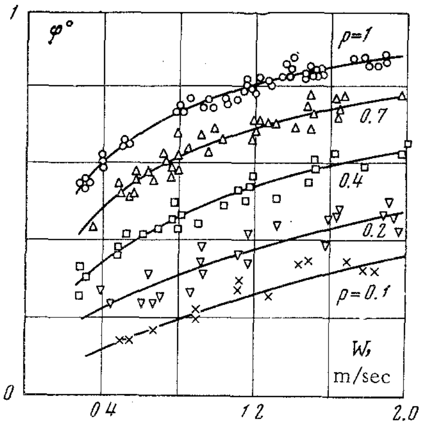

Fig. 5

First, however, it is necessary to know the mean gas content of the bed, which determines the depth of the starting layer of liquid needed to cover the tube bundle with foam at a given gas velocity in the clear cross section of the column W.

Such laws and design formulas already exist for the bubbling regime at pressures P = 1-40 bar [2, 4, 5].

We have investigated the gas content of a foam bed in the developed foam regime (W = 0.5-2.0 m/sec) at pressures from 0.1 to 1.0 bar and relatively small bed depths (up to 0.18 m). In all cases the gas phase was air, and the liquid phase was water and aqueous solutions of ethanol (g_M = 40, 80%) and glycerol (g_M = 60, 80%).

The experimental apparatus is shown schematically in Fig. 1. In order to permit visual observation of the process, the column 1 was made of Plexiglas (cross section 50 × 80 mm^2, height 500 mm, wall thickness 10 mm).

The foam was formed at a perforated plate 10, 2 mm thick (d_0 = 2 mm, m = 6 mm, s_0 = 8%). Water 15 was supplied from a graduated cylinder 3 and the flow controlled by a valve 5. In the reduced pressure experiments, the air flow in the column was maintained by a vacuum pump 13. Valves 2 and 9 were used to regulate the flow, the pressure was measured with a differential mercury manometer 4 (DT-50). The flow rate of the air 14 was determined volumetrically. The pressure in the gas reservoir 6 was kept equal to atmospheric. The other components include: 7) three-way valve for measuring the air flow rate, 8) three-way valve for draining the liquids, 10) perforated plate, 11) electric calorimeter, 12) manometric tubes.

The mean gas content φ was found from the depth of the foam H and the starting layer of liquid h_0 [4]

$$\varphi = 1 - h_0/H \qquad (1)$$

In Figs. 2 and 3 the depth of the starting layer of liquid and the mean gas content are shown as functions of the pressure and the gas velocity in the clear cross section of the column for the water–air system at H = 0.18 m.

The correlation of the experimental data on the gas content for system 1 (air–water), 2 and 3 (air–aqueous solutions of ethanol, g_M = 40 and 80%, respectively) and 4 and 5 (air–aqueous solutions of glycerol, g_M = 60 and 80%, respectively) is presented in Fig. 4 in the parameters

$$W^* = W\left(\frac{\rho' - \rho''}{g\sigma}\right)^{0.25}, \qquad \Phi = \varphi\left(\frac{\rho'}{\rho''}\right)^{0.15}\left(\frac{\mu'}{\mu''}\right)^{0.1}$$

In [5] a relation was obtained for the gas content in the bubbling regime. Using the method proposed in [5] and introducing a term taking into account the effect of phase viscosity, we obtained Eq. (2), which generalizes the data for the developed foam regime with an accuracy of ± 10% (Fig. 4):

$$\varphi = 1.1\left[W\left(\frac{\rho' - \rho''}{g\sigma}\right)^{0.25}\right]^{0.4}\left(\frac{\rho''}{\rho'}\right)^{0.15}\left(\frac{\mu''}{\mu'}\right)^{0.1} \tag{2}$$

An analogous formula for the bubbling regime was obtained by V. N. Sokolov.

Eliminating the viscosity ratio from Eq. (2) leads to an increase in the scatter of the experimental data to ± 25%.

The gas content φ_0 in the region of the cylindrical calorimeter 11 (Fig. 1) was determined by means of manometric tubes 12 [6, 7]

$$\varphi_0 = \Delta h / h \tag{3}$$

where Δh is the difference of the liquid levels in the tubes, and h is the distance between the centers of the tubes.

In Fig. 5 φ_0 is shown as a function of the gas velocity in the clear cross section of the column for a water–air system at H = 0.18 m and various pressures. Clearly, as the pressure falls, there is a substantial decrease in the gas content of the foam bed.

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