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BRIEF COMMUNICATIONS

Conic Plate Deflector

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Abstract—Results of experimental studying hydrodynamic resistance and interplate entrainment of a plate deflector with a perforated plate are presented. The diapason of operational stability of the perforated plate with a plate deflector was determined. Analytical dependences for the calculation of the hydrodynamic resistance and the interplate entrainment were obtained.

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It is known that entrainment of liquid drops by a gas (vapor) flow from contact plates of mass-transfer apparatus results in essential depression of driving force of transport processes. Therefore interplate entrainment is one of the major factors limiting rise of gas (vapor) rate in mass-transfer apparatus. To reduce drop entrainment at raised gas loads, it is necessary to increase either a column diameter or an interplate distance, i.e. the overall apparatus size, that obviously results in increasing general and energy expenditures. To reduce drop entrainment without essential increase in the interplate distances, entrainment separators of various constructions are placed above a mass-transfer plate [1].

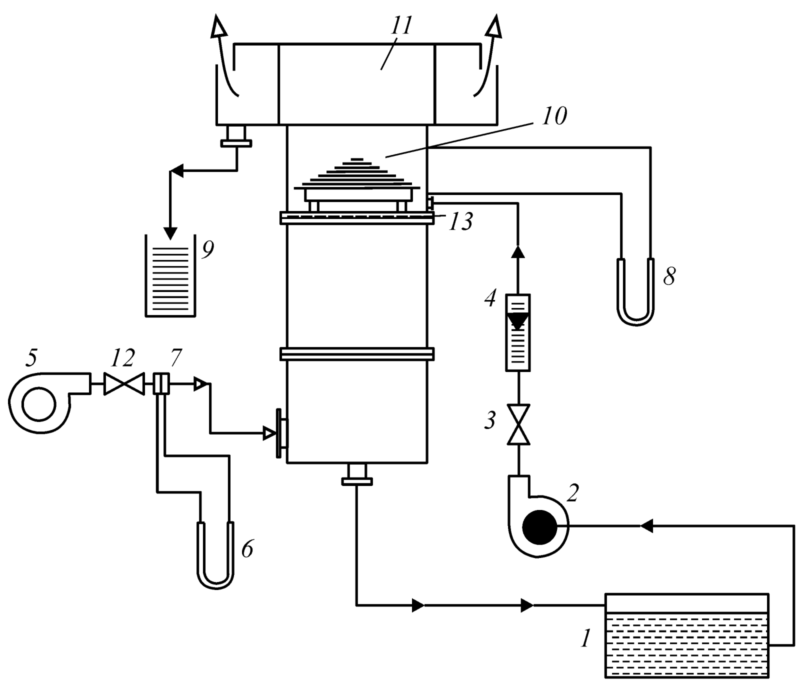

Fig. 1. Scheme of the installation: (*10*) cylindrical housing; (*11*) volume separator; (*13*) perforated plate; (*14*) rotameter; (*5*) gas pump; (*3*) cock; (*6, 8*) differential manometers; (*1*) container with initial liquid; (*9*) container with entrained liquid; (*7*) diaphragm; (*12*) latch, (*2*) pump.

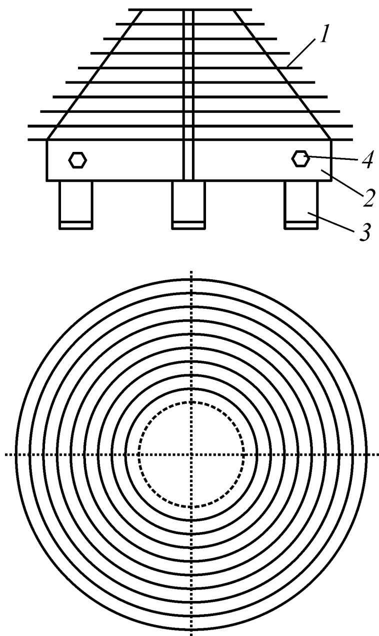

Fig. 2. Conic plate deflector. (*1*) ring; (*2*) basic slices; (*3*) rack; (*4*) bolt.

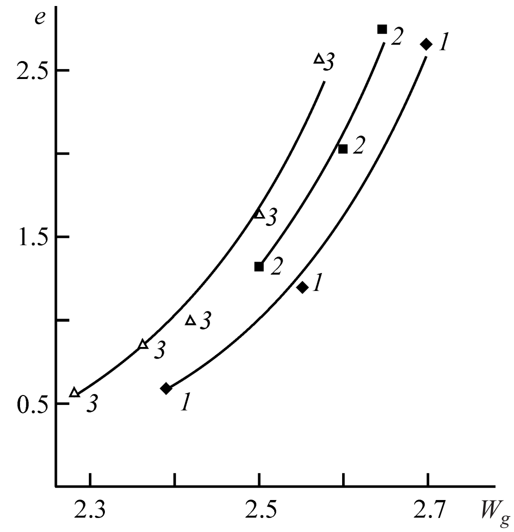

Fig. 3. Dependence of relative drop entrainment *e* (%) on the average rate of air W_g (m s^{-1}) in the apparatus with a conic plate deflector. Water concentration $q \times 10^3$ (m^3 m^{-2} h^{-1}): (*1*) 5.5, (*2*) 6.3, (*3*) 7.0; the same for Fig. 4.

system, we used a column with an internal diameter of 240 mm. The working section of the plate was 0.0452 m^2, the overflow perimeter, 0.168 m, and the share of the plate free section, 7%. The deflector consisted of rings of 0.02 m in width stacked in a distance of 0.01 m. The cone angle was 45°. The gas flow through the column section varied from 0.6 up to 3.2 m s^{-1}, and a liquid phase load was within the limits of the variation of the linear water concentration from 1 up to 9 m^3 m^{-2} h^{-1}. The scheme of the installation for studying hydrodynamic parameters is presented in Fig. 1. Liquid moves in the apparatus from container *1* by means of pump *2*. Flow control of the liquid is carried out by cock *3*, the consumption is determined by rotameter *4* with the use of a corresponding calibration graph. Gas (air) moves in the column by means of gas pump *5*. The gas phase consumption is measured by means of a calibration graph using the registration of differential manometer *6* coupled with measuring diaphragm *7*. The hydrodynamic resistance of the conic plate deflector is measured by differential manometer *6*.

The object of the study was a conic plate deflector, the scheme of which is presented in Fig. 2. The deflector consists of a raw of stacked parallel coaxial plane thin rings *1* forming a truncated cone. The rings are rigidly attached to two crossly perpendicular basic slices *2*. Slices *2* are located above a perforated plate at the height of 50 mm (position *13* in Fig. 1), being fasten to racks

Another important characteristic of the operation of a contact mass-transfer plate is its hydrodynamic resistance. Its value affects not only energy expenditures for transporting gas (vapor) through the apparatus, but also the variation of the conditions of carrying out the mass-transfer process along the height of the columned mass-transfer apparatus [2].

EXPERIMENTAL

To determine hydrodynamic parameters of the perforated plate with a conic plate deflector on the air-water

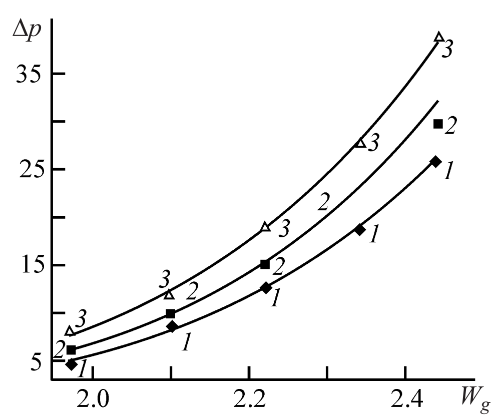

Fig. 4. Dependence of the hydrodynamic resistance of a conic plate deflector Δp (mm of water column) on the average air flow W_g in the apparatus (m s^{-1}).

3 by means of bolts *4*. A series of parallel clearances is formed between rings *1* for passing a gas phase together with the entrained liquid.

A virtue of this construction of the conic plate deflector is the axially symmetric location of rings *1* that provides uniform gas-liquid flowing in the column section and prevents a local overshoot of gas with a liquid.

The gas phase moves along the column from bottom upwards and is bubbled through a layer of liquid fed on a perforated plate. On a plate a layer of froth is formed and a mass-transfer occurs. Therewith a part of the liquid is carried away upwards by a gas stream in the form of drops and splashes. The stream, occurring in clearances between rings *1*, twice changes a driving direction by 90°. Owing to a greater time lag, liquid phase drops have no time to change the driving direction on output from the clearances between rings *1* and are rejected to a surface of the apparatus housing, forming a film draining off downwards. Gas separated from drops passes into a volume separator (position *11* in Fig. 1) where fine drops of liquid not caught in the plate deflector are separated from the gas.

The effect of water concentration q and gas average flow W_g in a column on the value of interplate entrainment was studied experimentally. The obtained data are presented in Fig. 3 in the form of the plot of the relative drop entrainment e vs. average air flow W_g in the apparatus at various water concentrations q.

The obtained results were approximated on a computer to give the calculated dependence of the relative drop entrainment e on the average air flow W_g and water concentrations q

$$e = 0.575 W_{\mathrm{g}}^{12.27} q^{2.053}.$$

Root-mean-square difference between experimental and calculated data is 6.2%, and the maximal difference does not exceed 10.2%. During the experiments we have found visually the origination of so-called reentrainment. Separated liquid was rejected to the apparatus housing, striked it to form “secondary” drops, and a part of them was picked up by the ascending gas stream and was carried away upwards. All this has led to a decline of separating capacity of the deflector.

Hydrodynamic resistance of the plate deflector was studied at various water concentrations q and gas flows W_g in the apparatus section [*3–4*]. The data obtained are presented as the plot of the deflector hydrodynamic resistance Δp vs. average air flow in the apparatus at various water concentrations (Fig. 4).

By computer approximating the experimental data we have obtained the following calculation dependence of the plate deflector hydrodynamic resistance Δp on the average air flow W_g and water concentration q

$$\Delta p = 99.58 W_{\mathrm{g}}^{7.662} q^{1.575}.$$

The root-mean-square difference between experimental and calculated data is 5.9%, the maximum difference does not exceed 11.5%.

CONCLUSIONS

(1) As the average air rate W_g in the apparatus increases the interplate entrainment and the hydrodynamic resistance increase, which results from the increase in the dynamic pressure on drops of a liquid from the gas stream side.

(2) As the water concentration increases the interplate entrainment and the hydrodynamic resistance also increase, which results from the decrease in a flow area of gas, and consequently, from an increase in the air flow and its dynamic pressure on drops of a liquid.

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