For short pulses of widths of 26 to 84 sec., time constants of 50 to 45 sec., respectively, were found for the first-order systems as compared with 60 sec. found from sinusoidal forcing. These lie within the 25% limit which was proposed as a criterion by Dreifke (5). Pulses of larger widths fall outside of this criterion for this system. It was not possible to use shorter pulse widths than 26 sec. in this experimental study. Since the pulse heights used were constant and represented the maximum range of the valve opening, shorter pulse widths did not contain sufficient energy to produce measurable output signals.

Thus, in lieu of a mathematical model for a distillation process, the results of this study show that pulses may be used to determine the dynamic characteristics of the column used. However, pulse tests must be made on each new column, since the time constant, damping coefficient, natural frequency, and the order of the system will vary from column to column. In addition, some preliminary tests must be made to ascertain that the energy content of the input pulse is sufficient to energize the output signals.

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Development of a Two-Phase Contactor Without Pressure Drop

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Many operations in chemical engineering require the contact of two phases in multistage units under minimum pressure drop per stage. Low pressure drops are especially important for multistage reactors, distillators, or absorbers that handle heat sensitive materials under vacuum. Usually a compact multistage contactor is desirable from an economical point of view. To meet these requirements, a multistage contactor has been designed for gas-liquid contacting and a schematic cross section of the proposed unit is shown in Figure 1. The unit consists of contacting compartments and a common shaft with multiple impellers. As a result of the impeller action the gas is sucked from stage to stage through the openings provided in the trays. The impeller acts as an agitator for the dispersion and provides pumping for the gas. Thus, the gas is self-induced from the bottom of the vessel and is subdivided in each compartment into small size bubbles that are dispersed throughout the liquid phase. Consequently, the pressure drop across the liquid phase is eliminated and a negative pressure drop is established instead. By applying vacuum at the top, the lower pressure at the bottom of the unit allows heat sensitive materials to be handled under lower temperature conditions. Use of stators with radial vanes causes a very high shear on the liquid and incoming gas, resulting in a very small and relatively uniform diameter of bubbles with a high total surface area for diffusion. When entrainment problems are encountered and a compact unit is desirable, additional impellers may be installed between the stages to remove tiny drops from

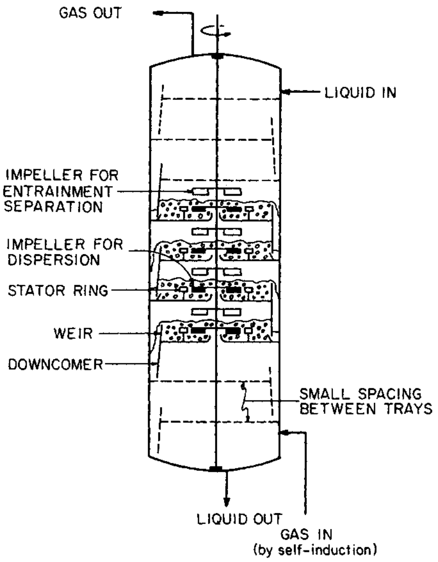

Fig. 1. Schematic cross section of proposed multistage contactor without pressure drop.

the gas phase and consequently the tray spacing may be significantly decreased.

To evaluate the characteristic properties of this unit and as part of a more general investigation of mass and heat transfer in dispersions (*2* to *5*), a one-stage unit has been constructed as shown schematically in Figure 2. Air and water were used in all runs. The vessel was constructed from a Lucite cylinder 13⅜ in. I.D. that was divided into contacting and draining compartments. The unit was equipped with a vaned disk impeller with impeller-to-tank diameter ratio of 0.3 and a stator with 3-mm. clearance between impeller tip and stator ring. The impeller and the stator were made of stainless steel and both were equipped with twelve radial vanes. The air was introduced underneath the impeller by self-induction through a ½-in. I.D. pipe that was extended 3½ in. above the bottom of the contacting compartment.

The experimental results show that the vacuum produced in the lower compartment under operating conditions is 6 to 10 cm. of water. A maximum suction of about 20 cm. of water has been obtained after the gas inlet had been closed. The liquid in the contacting compartment drains through the gas inlet pipe whenever the rotational speed of the impeller is reduced below a certain critical speed. This critical speed depends on the initial depth of gas-free liquid present in the contacting compartment. Semibatch and continuous flow systems have been operated and the experimental results show that the depth of the dispersion obtained is a function of impeller speed and varies from about 6 in. at 1,000 rev./min. to about 10 in. at 1,400 rev./min. If more liquid is added to the upper tray the hydrostatic pressure causes the excess of liquid to drain to the lower compartment, and finally a steady operation is established again. Easy control of the disperser without any drainage of liquid through the gas inlet pipe is possible at impeller speeds higher than 1,000 rev./min. Increasing of the rotational speed of the impeller increases the suction and gas flow rate. The result is that the ratio P_v/V_s remains almost constant at about 1,500 lb./cu. ft.

To evaluate the bubble size distribution in this type of disperser, photographs were taken of the dispersion through the transparent wall of the disperser with the same technique that was developed by Olney (*1*). An exposure time of ~ 0.005 sec. was used, which served to produce comparatively sharp bubble outlines. Bubble

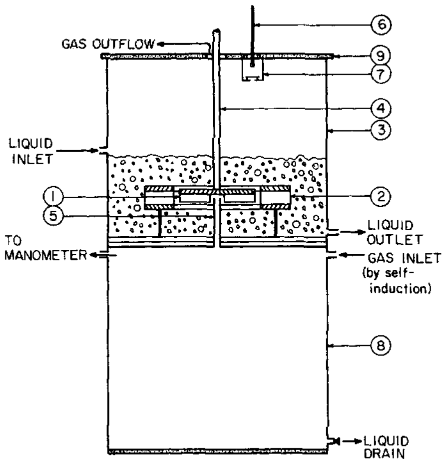

Fig. 2. Sectional view of one-stage gas-liquid contactor. *1*, vaned disk impeller; *2*, stator; *3*, contacting tank; *4*, impeller shaft; *5*, gas inlet pipe; *6*, gas outlet thermometer; *7*, thermometer pocket; *8*, drainage tank; *9*, lid.

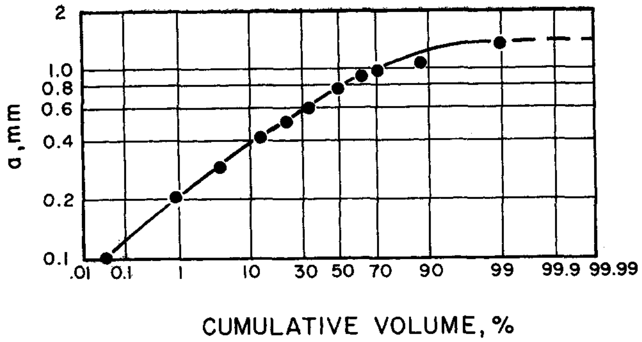

Fig. 3. Typical bubble size cumulative data for air-water contacting. Rotational speed of impeller is 1,130 rev./min.

sizes were determined from ~ 4× enlargements from the original negatives. Bubble counts in all runs were made from three replicate photographs. Highly distorted bubbles (which were few in number) with a major/minor axes ratio greater than 1.3 were neglected. Typical bubble size cumulative volume data are given in Figure 3. The data show that for 99% of the bubbles $0.1 \leqq a \leqq 1.4$ mm. The surface mean radius a_{32} for these data was found to be 0.07 cm. Other experimental results show that the size distribution and a_{32} are practically unaffected by impeller speed. This average bubble size is lower than the average size obtained with the common types of gas-liquid contactors (*6* to *8*). This is due mainly to the high shearing rates produced between the impeller and stator. Another reason is probably contributed by the lower pressure inside the bubble at the moment of its formation resulting in a slight compression due to hydrostatic pressure of the liquid bulk. Consequently, this disperser produces relatively high surface areas for mass and heat transfer that would give an efficient contacting operation. Experiments show also that the equipment is useful for the contact of three phases: gas, liquid, and suspended solids.

Further work is in progress in studying heat and mass transfer rates, transient responses, and average residence times of the bubbles in single and multistage units and the results will be reported in due time.

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NOTATION

a = radius of bubble
a_{32} = surface mean radius
P_v = power input under gassing condition (ft.)(lb.)/(min.)(cu. ft.)
V_s = superficial gas velocity, ft./min.

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