

## The Effects of Design and Operating Parameters on The Flooding of a Gas-Liquid Mechanically- Agitated, Compartmented Column

Mohd. Sobri Takriff, W.R. Penney  
& J.B. Fasano

### ABSTRAK

*Pembanjiran turus untuk aliran lawan arus gas dan cecair dalam turus berpetak diandaikan tidak munasabah kerana perbezaan ketumpatan antara fasa yang tinggi. Meskipun demikian, pengalaman di Chemineer Inc. berbeza. Lantaran itulah karya ini dilakukan untuk menyiasat fenomena pembanjiran di dalam turus berpetak teraduk. Kesan halaju pendesak, garis pusat pendesak dan kadar alir cecair dikaji. Halaju pembanjiran gas melalui lubang antara peringkat didapati meningkat dengan halaju pendesak dan menurun dengan kadar alir cecair. Halaju pembanjiran dicerap lebih tinggi bagi pendesak yang lebih besar pada halaju hujung pendesak yang lebih rendah. Pada halaju hujung pendesak yang lebih tinggi, kesan saiz pendesak terhadap halaju pembanjiran menurun.*

### ABSTRACT

*Column flooding for counter current flow of gas and liquid in compartmented columns was assumed not to be possible due to large density difference between the phases, however, experience at Chemineer Inc. shows otherwise. For this reason this work is carried out to investigate the flooding phenomena in an agitated-compartmented column. The effects of impeller speed, impeller diameter and liquid flow rate on column were investigated. Gas flooding velocity through the interstage opening was found to increase with impeller speed and decrease with liquid rate. The flooding velocity was observed to be higher for larger impeller at lower impeller tip speed. At higher impeller tip speed, the effect of impeller size on flooding velocity diminishes.*

### INTRODUCTION

Column flooding is a concern in the counter current operation of liquid-liquid and gas-liquid systems in an agitated-compartmented column. Sarkar and Phillips, (1985) stated that the flooding rate represents the maximum volumetric capacity of the column under a given set of conditions. For a liquid-liquid system, flooding has typically been defined as rejection of the dispersed phase as a dense layer of droplets. However, there is no consistent definition used in the literature, for example, Kirou et al. 1988 defined column flooding as occurring when a fraction of the dispersed phase was rejected. On the other hand, Sarkar and Phillips (1985) defined column flooding as a condition when the dispersed phase was completely rejected.

The flooding rate depends upon the phase flow rates, impeller energy input and system properties. Experimental data from Kirou et al. (1988) and Sarkar and Phillips (1985) showed that for a given flow rate of the continuous phase, the flooding rate of the dispersed phase decreased with increasing impeller speed and superficial velocity of the continuous phase.

For a gas-liquid system it is reasonable to use Kirou's et al. (1988) definition for column flooding as the condition for which a fraction of the liquid entering the column exits with the gas due to the upward flow of the gas. Under such conditions, a certain amount of the liquid bypasses the stages through an overflow line without counter current contact with the gas phase. No work has been done to investigate column flooding for gas-liquid systems perhaps due to the assumption that the density difference between gas and liquid is so large that column flooding is not very likely to occur (Sullivan 1969; Sullivan & Treybal 1972). However, experience at Chemineer Inc. shows otherwise. For this reason this work was undertaken to determine the column flooding phenomena in gas-liquid compartmented column.

### MATERIAL AND METHODS

The experimental work was conducted in a two-stage column with 24.15 cm inside diameter. Each stage was 24.15 cm high with centre hole opening. Two opening diameters of 2.54 cm and 5.207 cm were used. Each stage was fully baffled and agitation was provided by a centrally mounted 6-bladed disk impeller. Two 6 bladed-disk impellers with diameters of 8.89 cm and 12.7 cm were used in this study. A schematic of the experimental unit is presented in Figure 1 (Fasano et al. 1992 and Rewatkar & Joshi 1993).

The liquid flow rate used in this study ranged from 0.0 cm<sup>3</sup>/s to 60 cm<sup>3</sup>/s. While the maximum gas flow rate available was 4.0 scfm. The column was operated at fixed agitator speed and liquid flow rate while the gas flow rate was varied. The column was considered flooded if 20% to 35% of the entering liquid exited the top of the column by visual estimation.

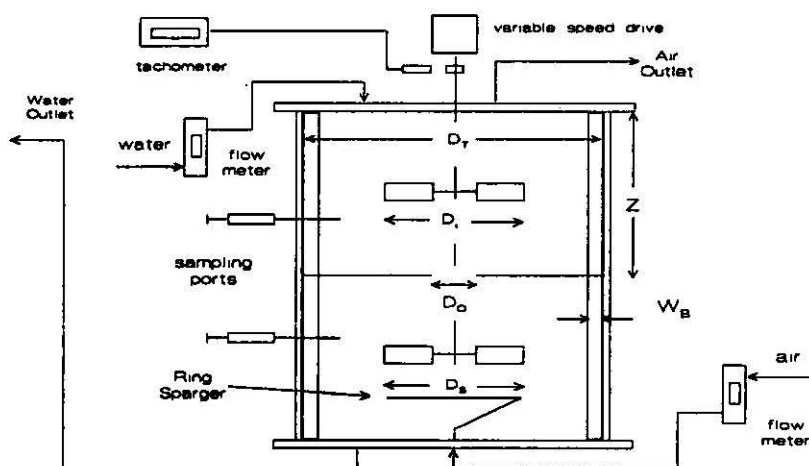


FIGURE 1. Schematic of experimental apparatus

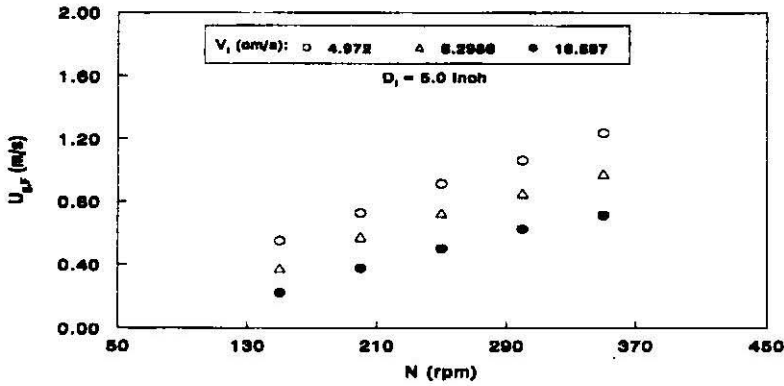


FIGURE 2. Effects of impeller speed on column flooding

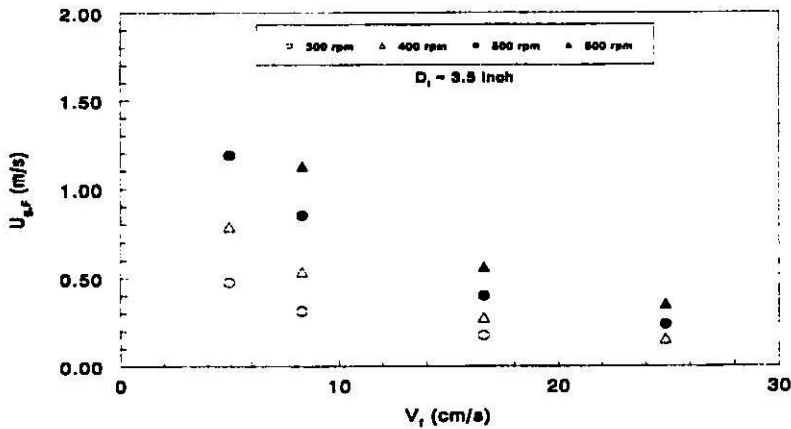


FIGURE 3. Effects of liquid flow rate on column flooding

## RESULTS AND DISCUSSION

The flooding point as defined here marks the maximum gas velocity that may flow through the interstage opening for a given liquid flow rate, impeller speed, impeller diameter, etc. without excessive liquid flowing out the top of the column. This phenomena is identified as the condition where a continuous stream of liquid exits the column through the overhead overflow tube with the gas. The data collected in this work are presented in Figures 2, 3 and 4.

Figure 2 shows the effect of impeller speed on the flooding gas velocity for the 12.7 cm impeller diameter. The gas flooding velocity was found to increase with impeller speed. At higher impeller speed, the gas is dispersed evenly throughout the stage thus reducing the upward force at the interstage opening. As such higher gas rate is required to flood the column.

The gas flooding velocity was found to decrease with liquid velocity as illustrated in Figure 3. At higher liquid flow rate the residence time of the liquid phase in the column is lower. For this reason any slight resistance at the interstage opening by the gas phase forces the liquid to find the quickest

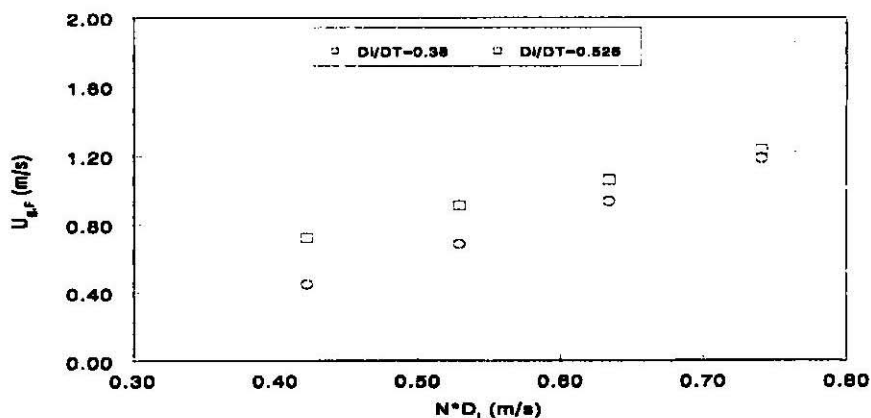


FIGURE 4. Effects of impeller diameter on column flooding

exit point. Thus, the liquid bypasses the whole column and exited through the gas exit line, which was just on the other side of the top plate of the column from the liquid entry line.

The flooding data collected at various impeller tip-speed are presented in Figure 4 for both 8.89 and 12.7 cm diameter impellers. This figure shows that at lower impeller tip-speed, higher gas velocity was required to flood the column for the larger impeller. However, at higher impeller tip-speeds,

$D_i/D_T$  does not affect gas flooding velocity. At lower tip speed, the larger impeller imparts more power into the liquid to give greater dispersion of the gas phase. As the gas is dispersed to the side of the column, the upward force of the gas stream at the interstage opening is less compared to if the gas flow straight upward in the direction of the interstage opening. This situation explains for the higher gas flooding velocity for the larger impeller.

Figure 4 also shows that at higher impeller tip speed, the effect of  $D_i/D_T$  on flooding velocity diminishes. The gas dispersion in the liquid is limited by the impeller flooding point. If the impeller is flooded or nearly flooded, the impeller is overwhelm by the gas and unable to dispersed the gas. This situation probably explain why at higher impeller tip-speed the effect of  $(D_i/D_T)$  on gas flooding velocity diminished.

## CONCLUSION

Column flooding is a real concern for counter current flow of a gas and a liquid in an agitated-compartmented column despite the early assumptions that the density difference is so large that column flooding is not possible. The flooding point was found to increase with impeller speed and decrease with liquid rate. The dependency on impeller size is only observed at low values of impeller tip speed.

## NOMENCLATURE

$D_H$	Holes diameter, cm
$D_i$	Impeller diameter, cm
$D_O$	Interstage opening diameter, cm
$D_R$	Outside diameter of ring sparger, cm
$D_T$	Vessel diameter, cm
$N$	Impeller speed, rps
$N \cdot D_i$	Impeller tip speed, m/s
$Q_g$	Gas flow rate, m <sup>3</sup> /s
$U_{gF}$	Flooding gas velocity (m/s)
$V_f$	Forward velocity, cm/s
$W_B$	Baffle width, cm
$Z$	Stage height, cm

## REFERENCES

- Fasano, J. B., Penney, W. R. & Xu, B. 1993. Design and scaleup of compartmented stage process equipment with emphasis on interstage backmixing, *14th Bi-Annual Engineering Foundation Mixing Conference*, Santa Barbara.
- Kirou, V. I., Tevalarides, L. L., Bonnet, J. C. & Tsouris C. 1988. Flooding, holdup and drop size measurement in a multistage column extractor, *AIChE Journal* 34(2): 283-292.
- Rewatkar, V. B. & Joshi, J. B. 1993. Role of Sparger design on gas dispersion in mechanically agitated gas-liquid contactors. *The Canadian Journal of Chemical Engineering* 71: 278.
- Sarkar, S. & Phillips, C. R. 1985. Characterisation of hydrodynamic parameters in rotating disc and oldshue-rushton columns: Hydrodynamic modelling, drop size, holdup and flooding. *The Canadian Journal of Chemical Engineering*, 63: 701-705.
- Sullivan, G. A. 1969. *Axial mixing and gas absorption in multistage, mechanically agitated column*, Ph.D dissertation, New York University.
- Sullivan, G. A. & Treybal, R. E. 1972. Axial mixing and gas absorption in a mechanically agitated absorption tower. *The Chemical Engineering Journal* 1: 302-309.

Mohd. Sobri Takriff  
 Department of Chemical & Process Engineering  
 Faculty of Engineering  
 Universiti Kebangsaan Malaysia  
 43600 UKM Bangi, Selangor D.E., Malaysia

W.R. Penney  
 Department of Chemical Engineering  
 Faculty of Engineering  
 University of Arkansas  
 Fayetteville, AR 72701, USA

J.B. Fasano  
 Chemineer Inc.  
 5870 Poe Avenue  
 Dayton, OH45414, USA