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STUDY OF FLOW PATTERNS AND DISSOLUTION KINETICS IN BUBBLE COLUMNS

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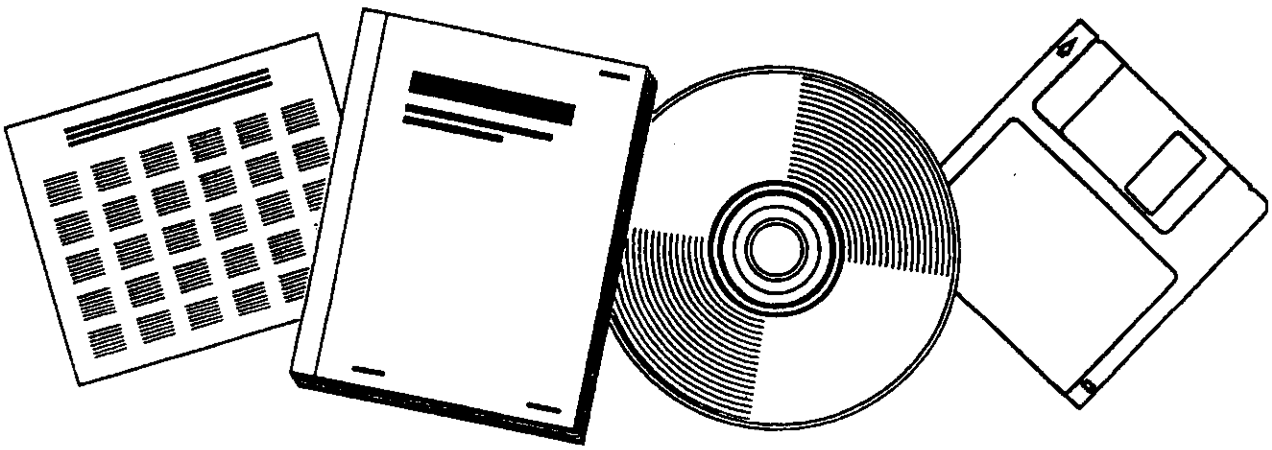

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A Study of Flow Patterns and Dissolution Kinetics in Bubble Columns

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DISCLAIMER

Research Objectives

- *Study liquid and gas phase flow patterns in a bubble column reactor*
  - *compare observations made with reported observations and hydrodynamic models*
- *Study mixing of two miscible liquid solutions with and without solid suspension in a bubble column reactor*

Research Objectives (Con't)

- *Study the kinetics of dissolution of a reactive solid phase suspended in the liquid phase in a bubble column reactor*
- *Calculate mass transfer coefficients and apparent reaction rate from suitable mathematical models*

Observations

- Eddy flow in the bubble column reactor does show liquid phase recirculation
- Recirculation is not observed at small superficial gas velocity near the sparger hole
- Recirculation did occur under conditions of large superficial gas velocity

Observations (con't)

- *Increasing Reynolds number near the sparger hole increases the turbulence intensity of recirculation in the bubble column*
- *Clear eddy circulation patterns could occasionally be seen*

Observations (con't)

- *Mixing can be important at bubble or particle diameter length scale, when physical mixing is happened and cross-interface mass transfer is the rate limiting step*
- *Mixing can be important at the molecular length scale, when a chemical reaction occurs and the reaction kinetics is the rate limiting step*

Observations (con't)

- *Most observed eddy circulation patterns show interference between adjacent cells in both liquid and gas phases*
- *Diameter of a circulation eddy can be greater than 1/2 of the column diameter. This observation is different from the assumption of Zehner(1986) and Joshi(1982)*

Observations (con't)

- The degree of mixing of miscible solutions depends on the distance between the point of solution injection and the point of measurement of reactant concentration
- When the superficial gas velocity near the sparger orifice is 2.35 ft/sec, the flow in the bubble column is in the laminar flow regime

Observations (con't)

- *There is a foam-like layer of bubbles at the top of the liquid layer in the bubble column. This layer of bubble is excluded from the measurement of the height of the liquid phase*

Observations (con't)

- *Each bubble cluster consists of 18 to 20 bubbles and there is 10 inch spacing between each bubble cluster*
- *Each bubble cluster has 3 to 4 different bubble size ranges*

Observations (con't)

- *The zone of the greatest bubble coalescence is located below the gas injector exit*
- *The zone for the greatest bubble breakage is located above the gas injector exit*
- *Breakage and coalescence in bubble swarms continues as the swarm rises*

Conclusion

- *Layer interaction flow and eddy flow are both found in the bubble column reactor*
  - *layer flow is demonstrated by indirect reasoning based on observation*
  - *Eddy flow is shown by visualization from the photos*

Conclusion (con't)

- *Reynolds number for the gas phase based on the single sparger hole diameter can be conveniently used as an indicator of flow regime (laminar, transition, or turbulent), because the gas is not distributed uniformly as it is in the case of multiple sparger holes*

...nclusion (con't)

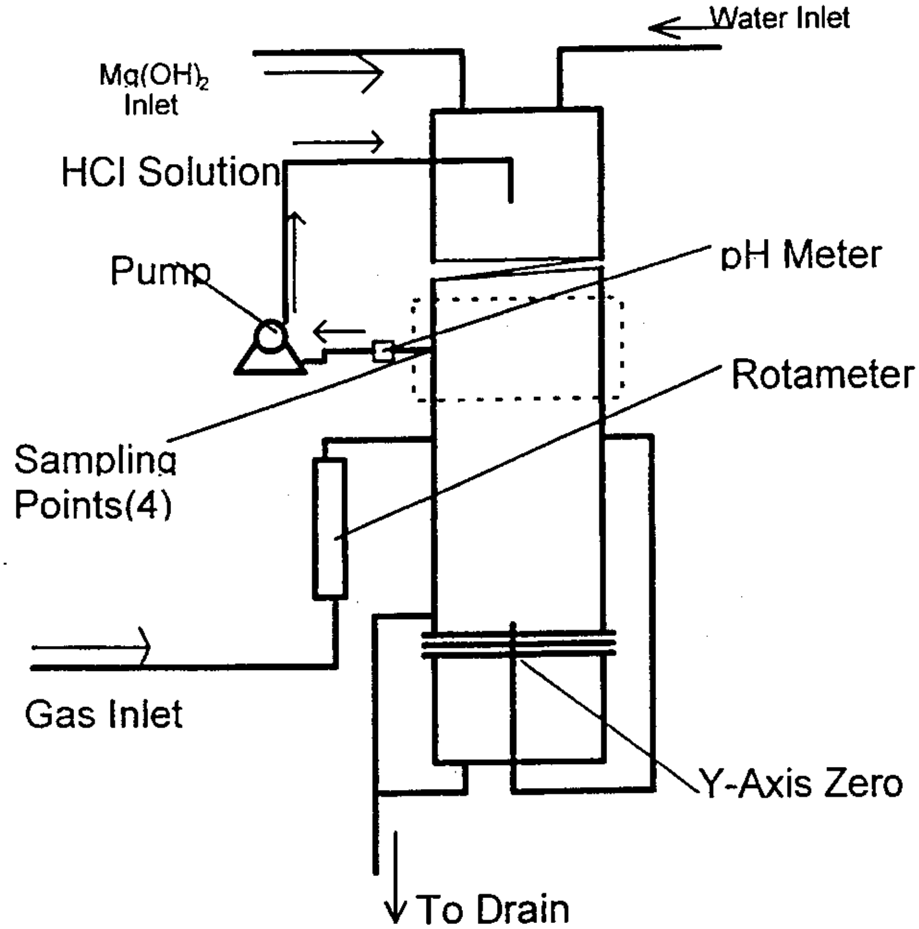
- In laminar flow, particularly, at very low superficial gas velocity near the sparger hole, recirculation is not observed
- Recirculation flow of both gas and liquid phases is found in transition flow
- Recirculation flow of both gas and liquid phases is found in turbulent flow

Conclusion (con't)

- *Re = pvD/u*
- *p = gas phase density*
- *v = superficial gas velocity near the sparger hole*
- *D = sparger hole diameter*
- *u = gas phase viscosity*

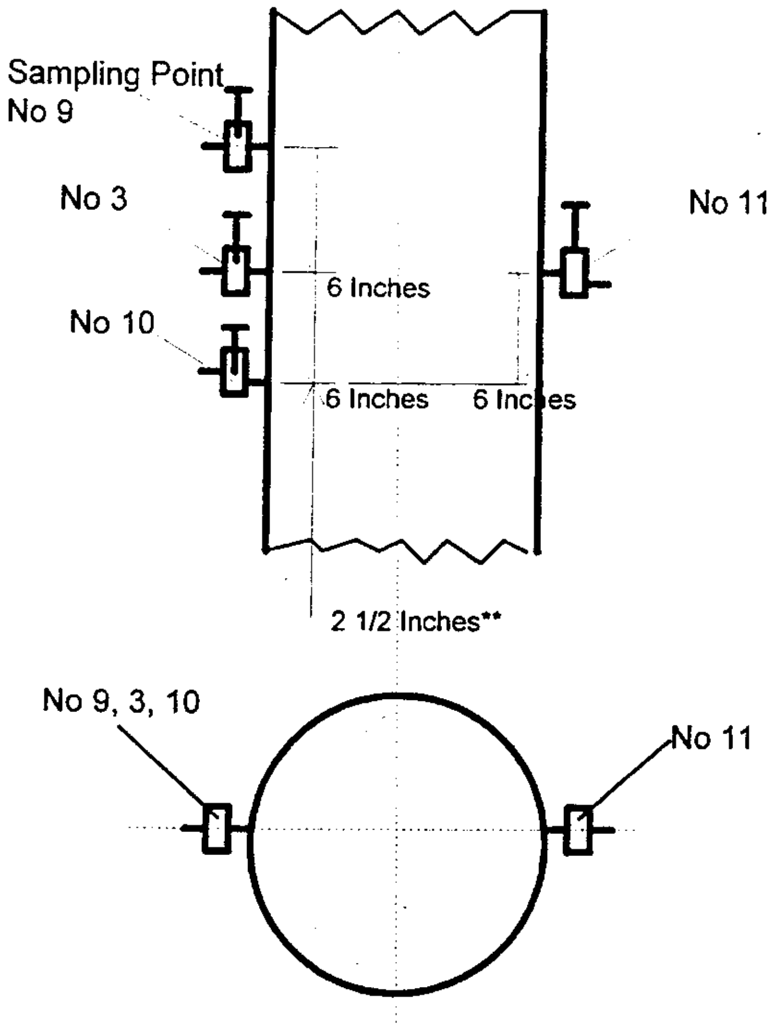
Conclusion (con't)

- The bubble rising velocity depends on the bubble size and not on the superficial gas velocity near the sparger hole
- When an intrinsically fast reaction (such as the strong acid/strong base reaction) is used, the apparent reaction rate is limited by the mixing time scale more than the intrinsic kinetics



This Dash Rectangle Will Be Detailed

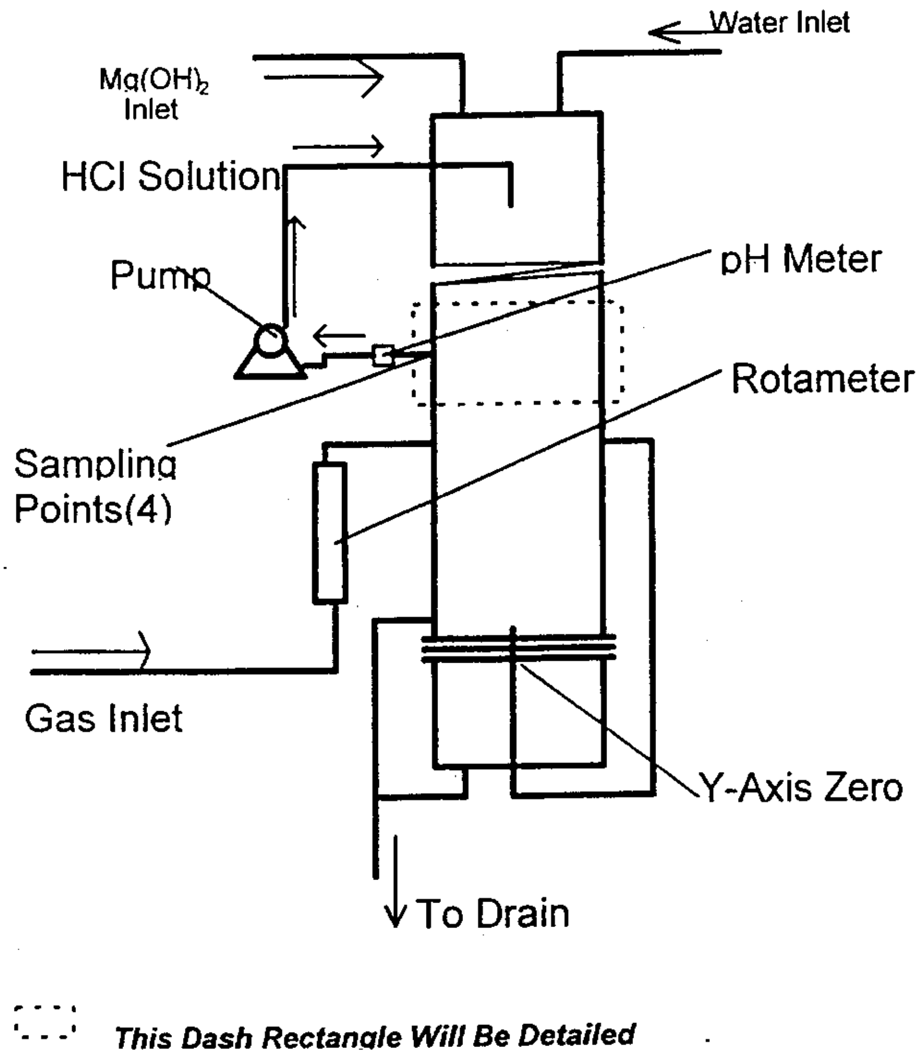
Bubble Column Apparatus



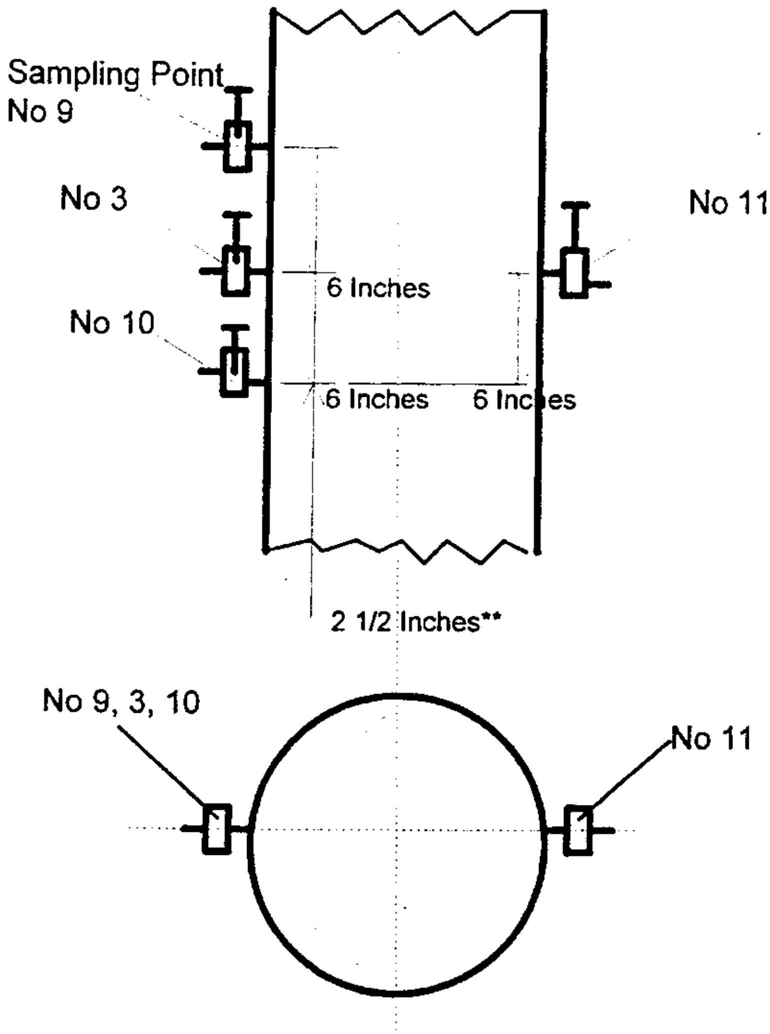
* This is the case with the plate assembled.

** The height is from the top of the lower flange.

Sample Point Locations on Bubble Column*



Bubble Column Apparatus



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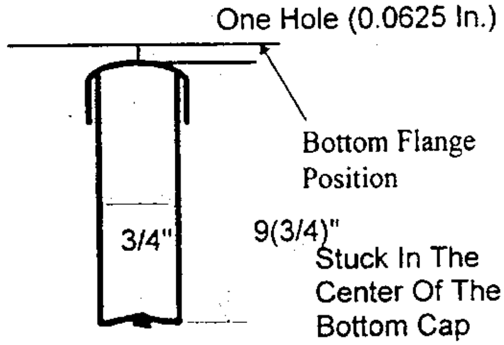
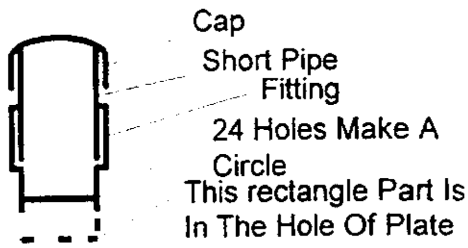
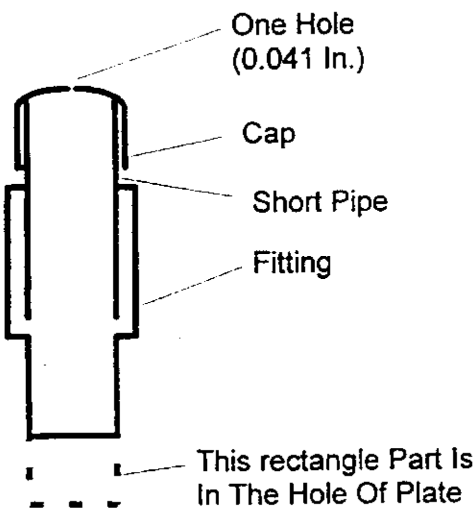
Sample Point Locations on Bubble Column*



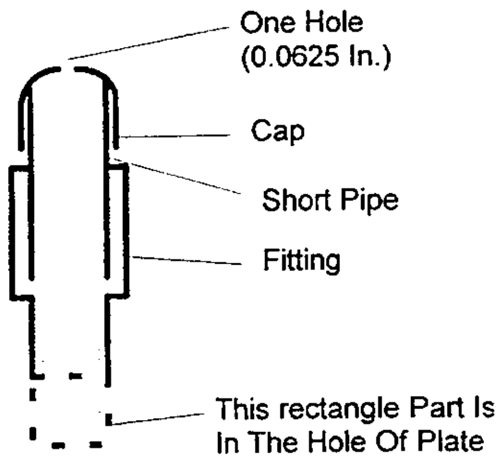
The First Sparger



The Second Sparger

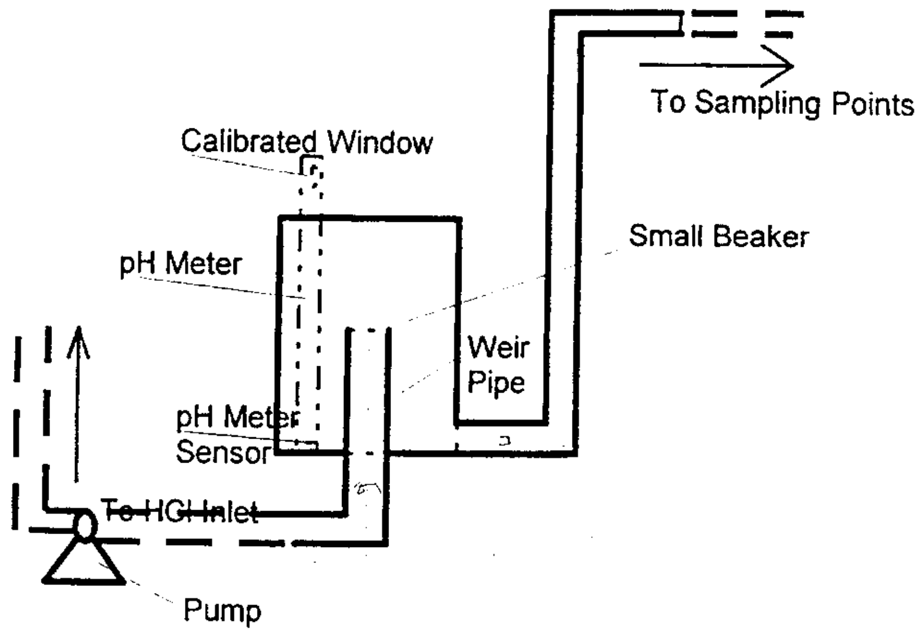


The Third Sparger

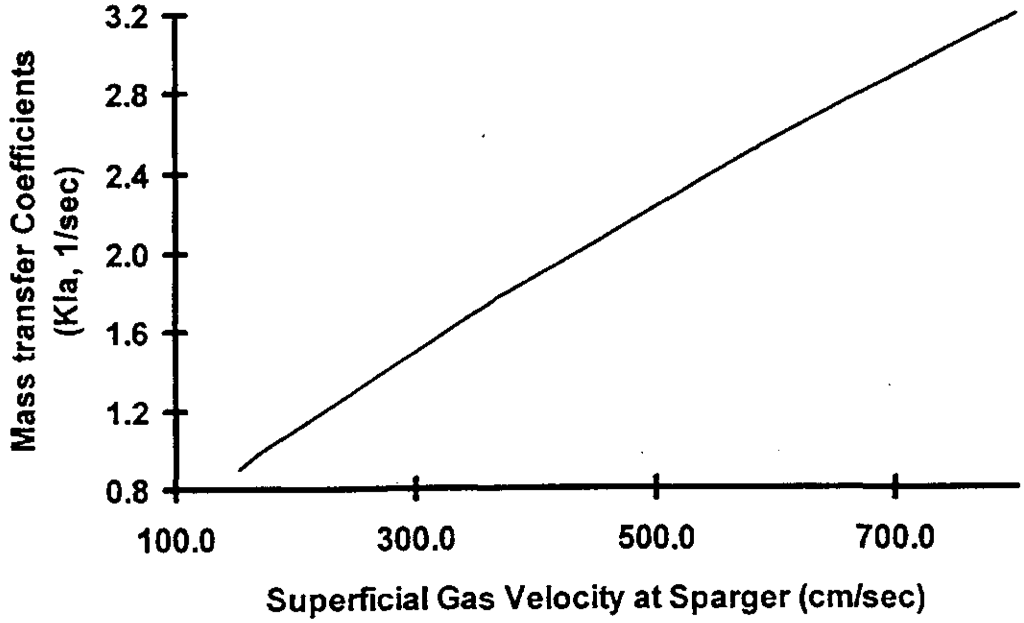


The Fourth Sparger

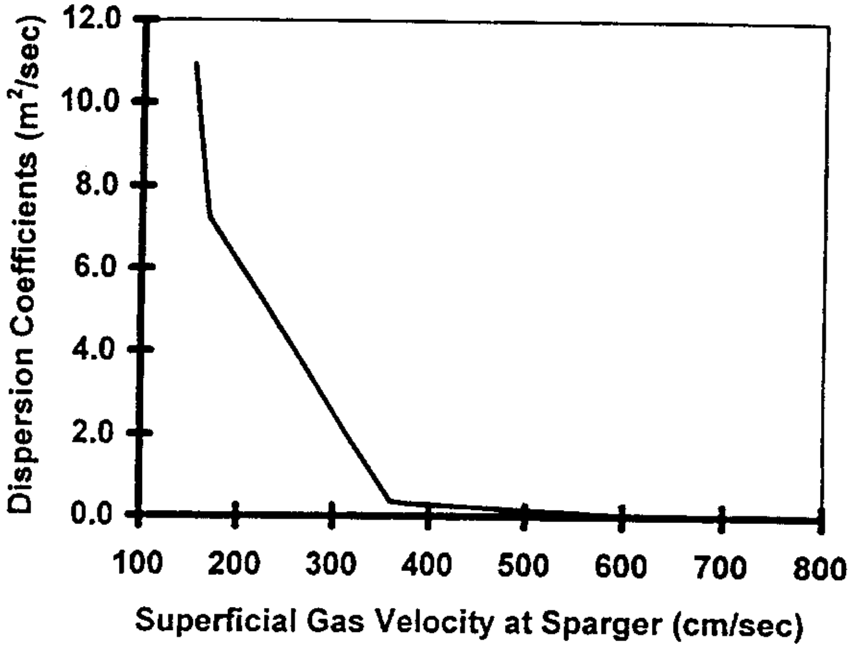
Sparger Configurations in Bubble Column



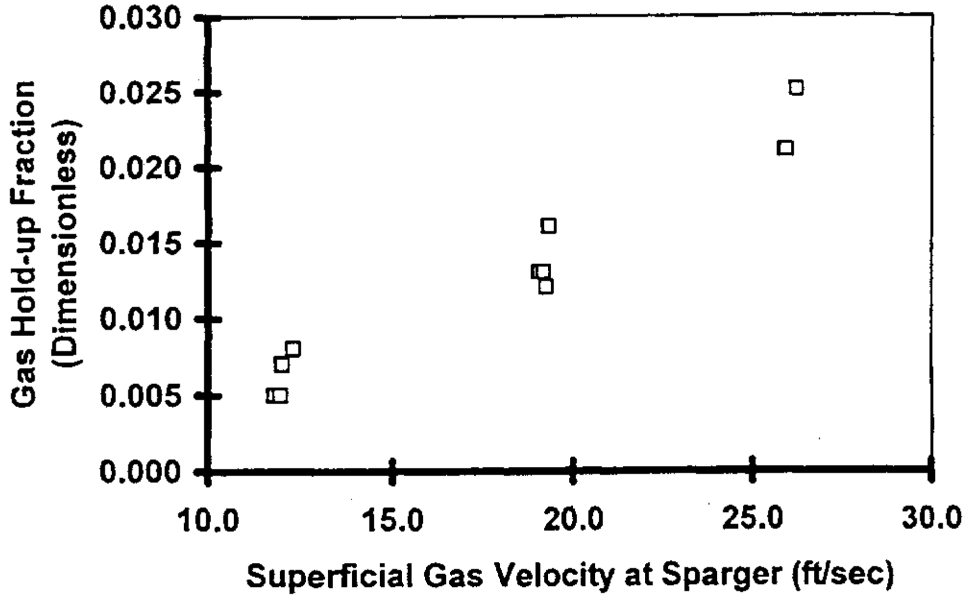
Feed Apparatus to Sample Points on Bubble Column



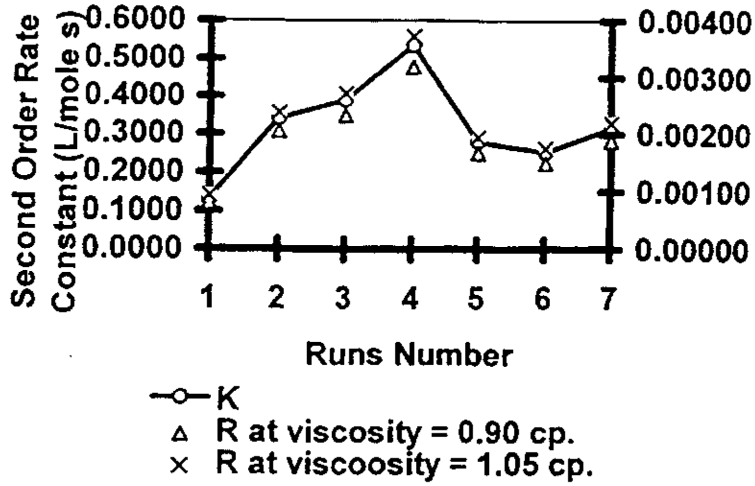
Mass Transfer Coefficients versus Superficial Gas Velocity (Run #18)



Dispersion Coefficients vs. Superficial Gas Velocity (Run #18)

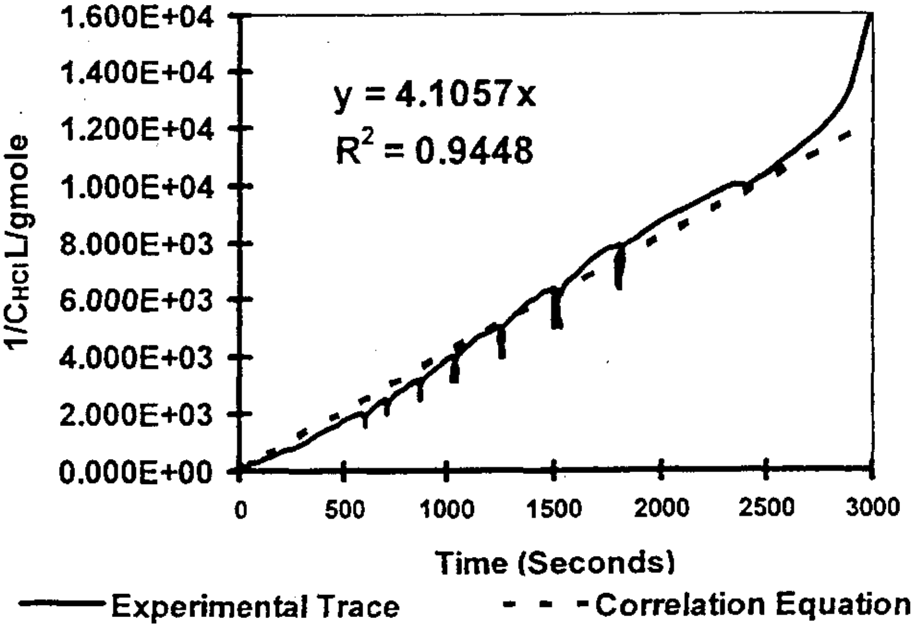


Gas Hold-up Variation with Superficial Gas Velocity
(Run #18)

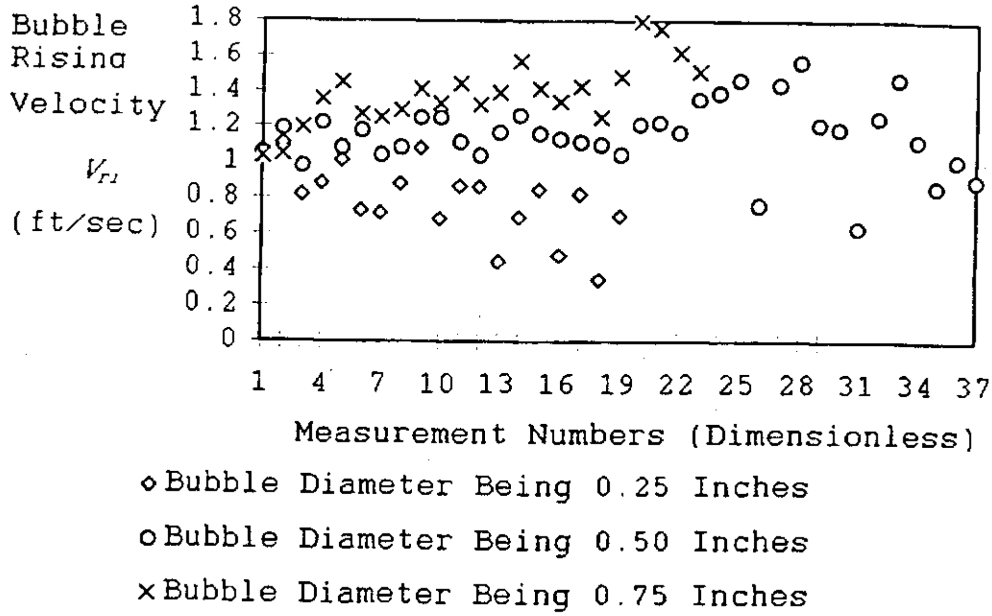


Variation of 2^{nd} Order Rate Constant (Hanuby, 1992) Reaction Zone Radius with Run Number

Run Numbers Note: 1=#31, 2=#32, 3=#34, 4=#35, 5=#36, 6=#37, 7=#38.



Apparent $Mg(OH)_2$ Dissolution Kinetics for HCl Reaction (Run #28)



Bubble Rising Velocity at Different Bubble Sizes