Table 1. Properties of the materials used in the three-phase experiments.

material	ρ (g/cm^3)	μ (cm^{-1})	σ (μS/cm)	ω (μF/cm)
polystyrene	1.04	0.0866	$< 10^{-10}$	2.3×10^{-7}
glass	2.41	0.209	5.9×10^{-11}	$\approx 5 \times 10^{-7}$
water/$NaNO_3$	0.997	0.0856	242 - 432	$\approx 7 \times 10^{-6}$
air	0.00106	0.0000819	$\approx 10^{-10}$	8.86×10^{-8}

Table 2. Average gas volume fractions for three-phase experiments from the EIT/GDT system.

Particle Type		U_G (cm/s)						
	$\bar{\varepsilon}_S^{nom}$	2.9	5.8	8.8	11.7	17.5	23.4	29.2
40-100 μm	0.00			0.181	0.214	0.263	0.304	
glass	0.05	a	a	0.141	0.185	0.242	0.283	
	0.10	a	a	0.144	0.197	0.244	0.282	
	0.15	a	a	a	0.168	0.223	0.268	
120-200 μm	0.00					0.246	0.290	0.321
glass	0.05	a	a	a	a	0.245	0.280	0.317
	0.10	a	a	a	a	0.229	0.277	0.307
	0.15	a	a	a	a	0.231	0.267	0.298
170-260 μm	0.00	0.090	0.149	0.193	0.220	0.256	0.288	
polystyrene	0.05	0.101	0.166	0.199	0.221	0.256	0.283	
	0.10	0.106	0.177	0.216	0.243	0.279	0.308	
	0.15	f	0.171	0.213	0.242	0.275	0.298	
200-700 μm	0.00	0.089	0.147	0.190	0.222			
polystyrene	0.05	0.088	0.143	0.179	0.207			
	0.10	0.089	0.147	0.180	0.210			
	0.22	0.090	0.152	0.181	0.207			
	0.30	f	0.149	0.189	0.215			
water	0.00	0.075	0.117	0.137	0.167	0.213	0.249	

a = air flow rate inadequate to loft all solids

f = head of foam from surfactant in particle coating expanded to top of column

Figure 1. Schematic diagram of GDT system applied to a circular domain showing lateral and radial coordinate systems.

Figure 2. Conceptual diagram of an EIT system applied to a circular domain.

Figure 3. EIT strip electrode array. The bottom scale is in inches.

Figure 4. Schematic diagram of Lexan bubble column (19-cm I.D.) used in three-phase flow experiments showing measurement locations.

Figure 5. Size distribution of medium polystyrene beads (diameter 170 – 260 μm, density 1.04 g/cm^3).

Figure 6. Size distribution of large polystyrene beads (diameter 200 – 700 μm, density 1.04 g/cm^3).

Figure 7. Size distribution of small glass beads (diameter 40 – 100 μm, density 2.41 g/cm^3).

Figure 8. Size distribution of medium glass beads (diameter 120 – 200 μm, density 2.41 g/cm^3).

Figure 9. Comparison of nominal slurry concentration, $\bar{\varepsilon}_S^{nom}$, and slurry concentration at measurement plane from combined GDT/EIT measurements.

Figures 10 (a)-(d). Phase volume fraction profiles as a function of superficial gas velocity: (a) 5.8 cm/s, (b) 11.7 cm/s, (c) 17.5 cm/s, and (d) 23.4 cm/s. The solid phase is 170-260 μm polystyrene beads at a nominal slurry concentration of 0.10.

Figures 11 (a)-(d). Phase volume fraction profiles as a function of nominal slurry concentration, $\bar{\varepsilon}_S^{nom}$: (a) 0.00, (b) 0.05, (c) 0.10, and (d) 0.15. The superficial gas velocity is 17.5 cm/s and the solid phase is 120-200 μm glass beads.

Figure 12. Phase volume fraction profiles where the solid phase is 40-100 μm glass beads, the superficial gas velocity is 17.5 cm/s, and the nominal slurry concentration is 0.10.

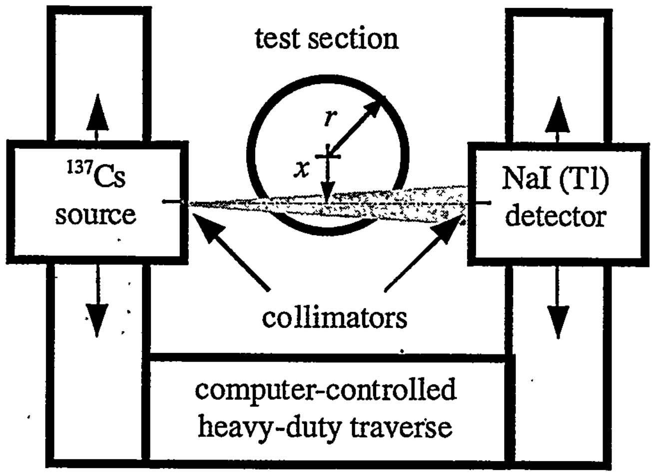
Figure 13. Phase volume fraction profiles where the solid phase is 200-700 μm polystyrene beads, the superficial gas velocity is 11.7 cm/s, and the nominal slurry concentration is 0.10.

Figure 14. Radially-averaged gas volume fraction as a function of superficial gas velocity.

Figure 15. Gas volume fraction as a function of nominal slurry concentration, $\bar{\varepsilon}_S^{nom}$, for glass particles: 40-100 μm particles are open symbols and the 120-200 μm particles are closed symbols. The solid lines are the correlation of Equation 24.

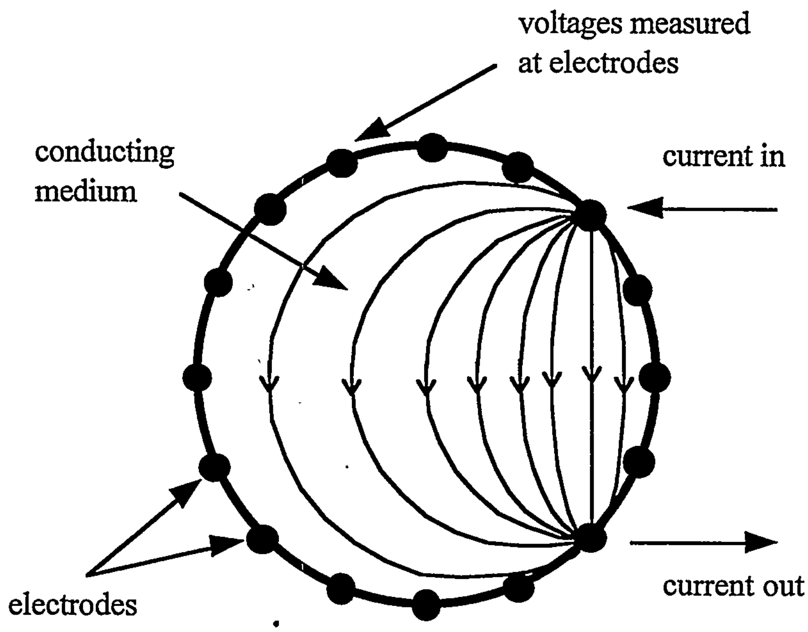
Figure 16. Gas volume fraction as a function of nominal slurry concentration, $\bar{\varepsilon}_S^{nom}$, for polystyrene particles: 170-260 μm particles are open symbols and the 200-700 μm particles are closed symbols. The solid lines are the correlation of Equation 24.

Figure 1.



test section
r
x
^{137}Cs
source
NaI (Tl)
detector
collimators
computer-controlled
heavy-duty traverse

Figure 2.



voltages measured
at electrodes
conducting
medium
current in
electrodes
current out

Figure 3.

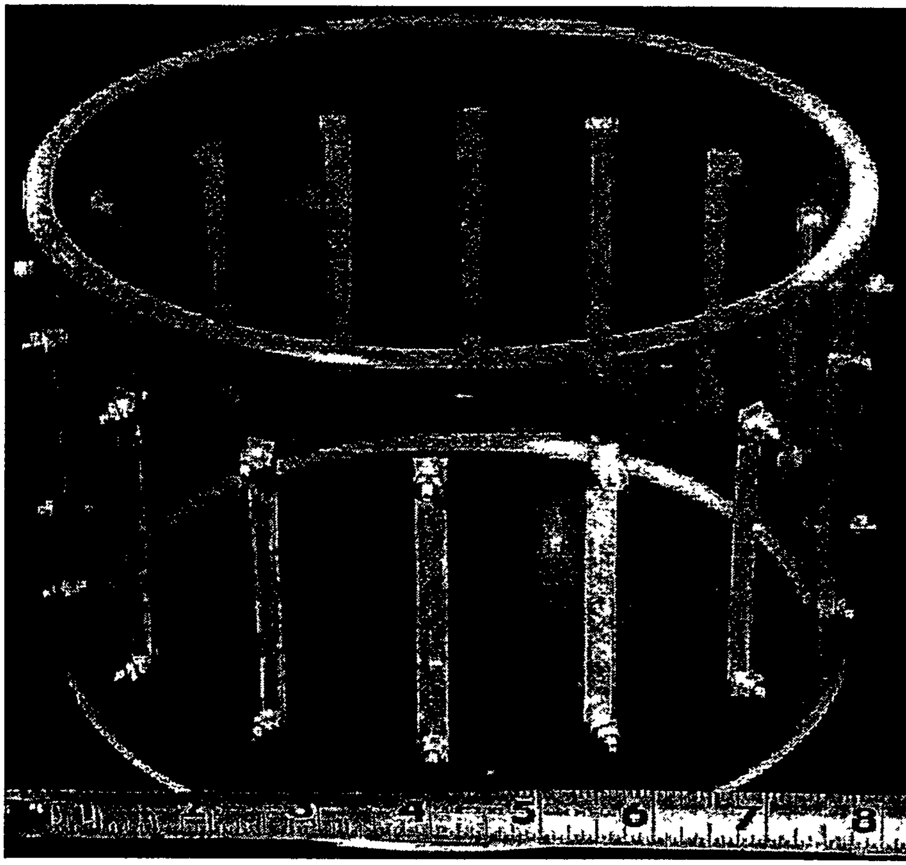


Figure 4.

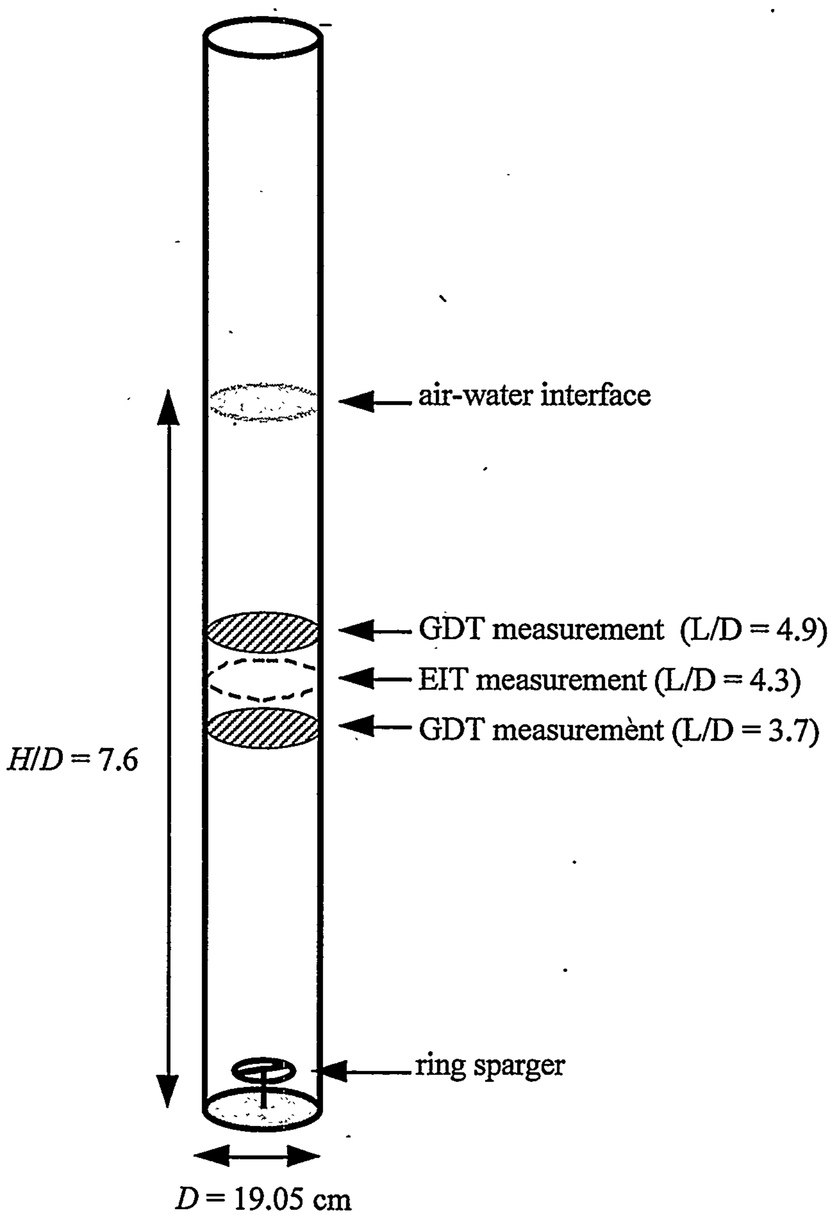
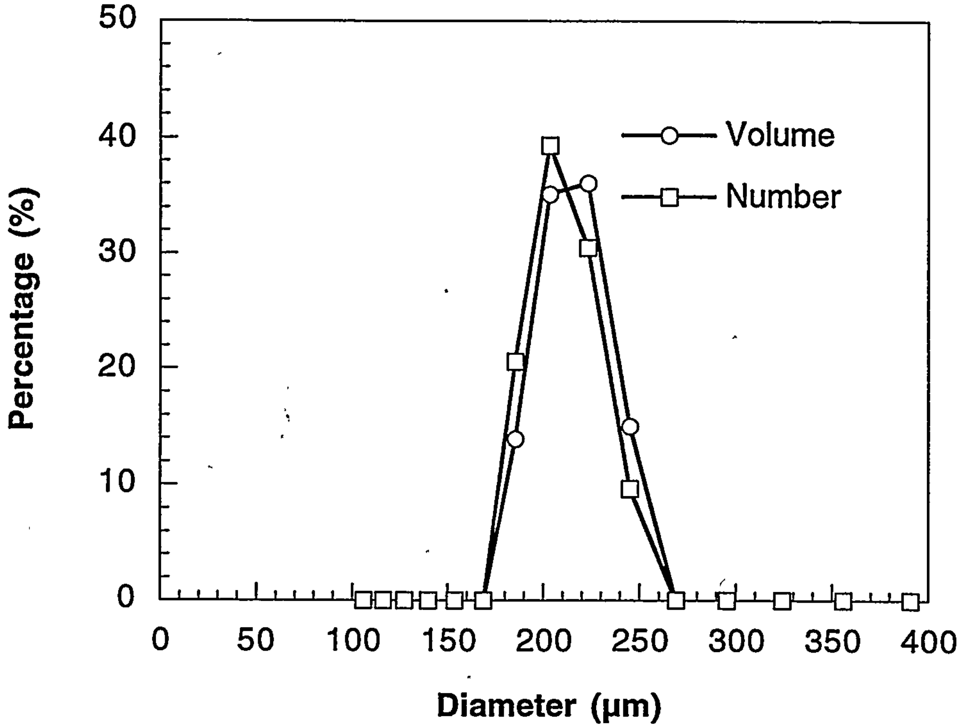
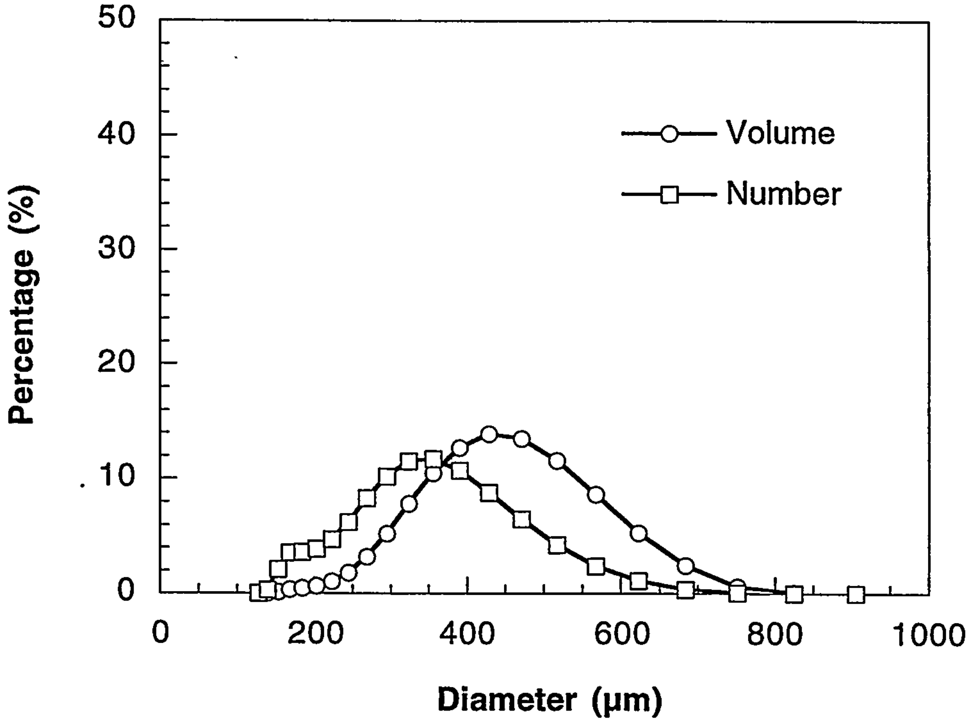

air-water interface
GDT measurement (L/D = 4.9)
EIT measurement (L/D = 4.3)
GDT measurement (L/D = 3.7)
H/D = 7.6
ring sparger
D = 19.05 cm

Figure 5.



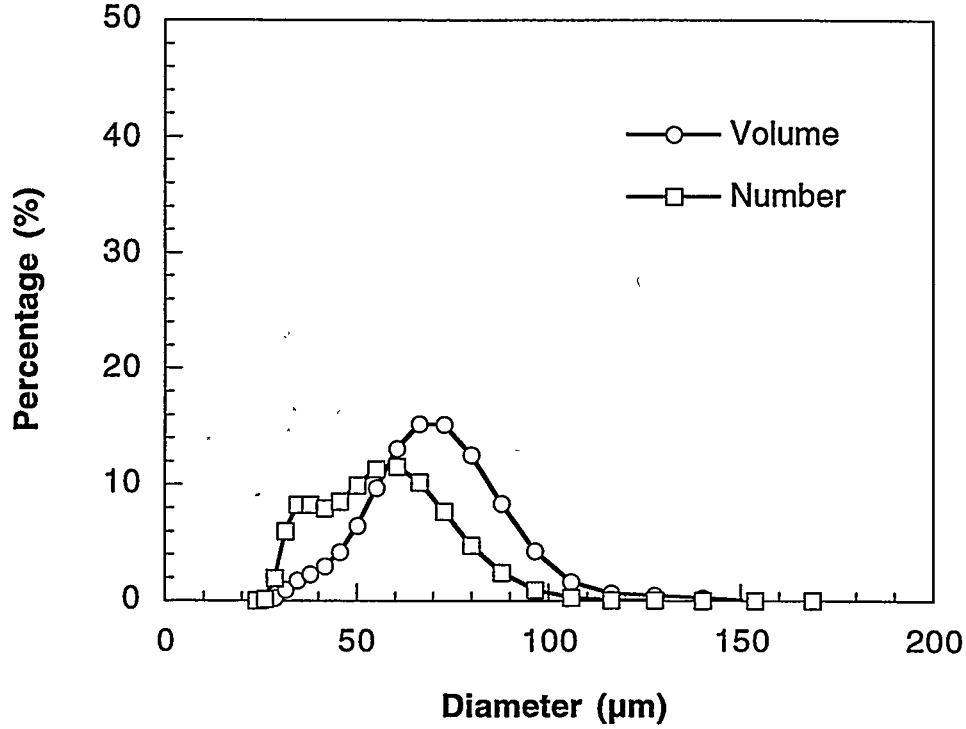
50
40
30
20
10
0
Percentage (%)
Volume
Number
0
50
100
150
200
250
300
350
400
Diameter (µm)

Figure 6.



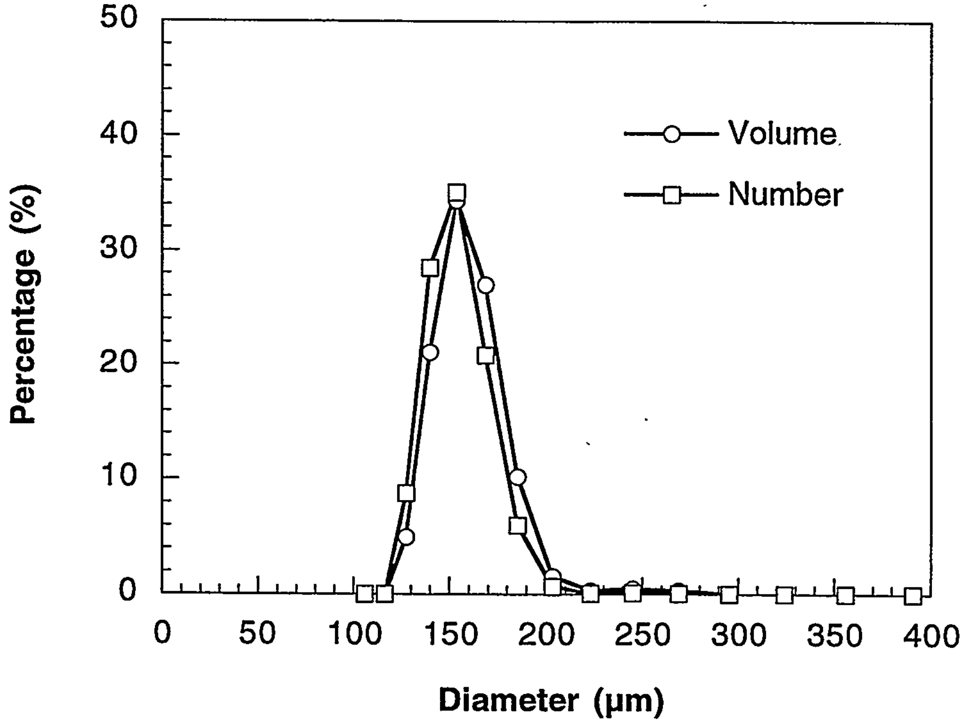
50
40
30
20
10
0
Percentage (%)
Volume
Number
0
200
400
600
800
1000
Diameter (μm)

Figure 7.



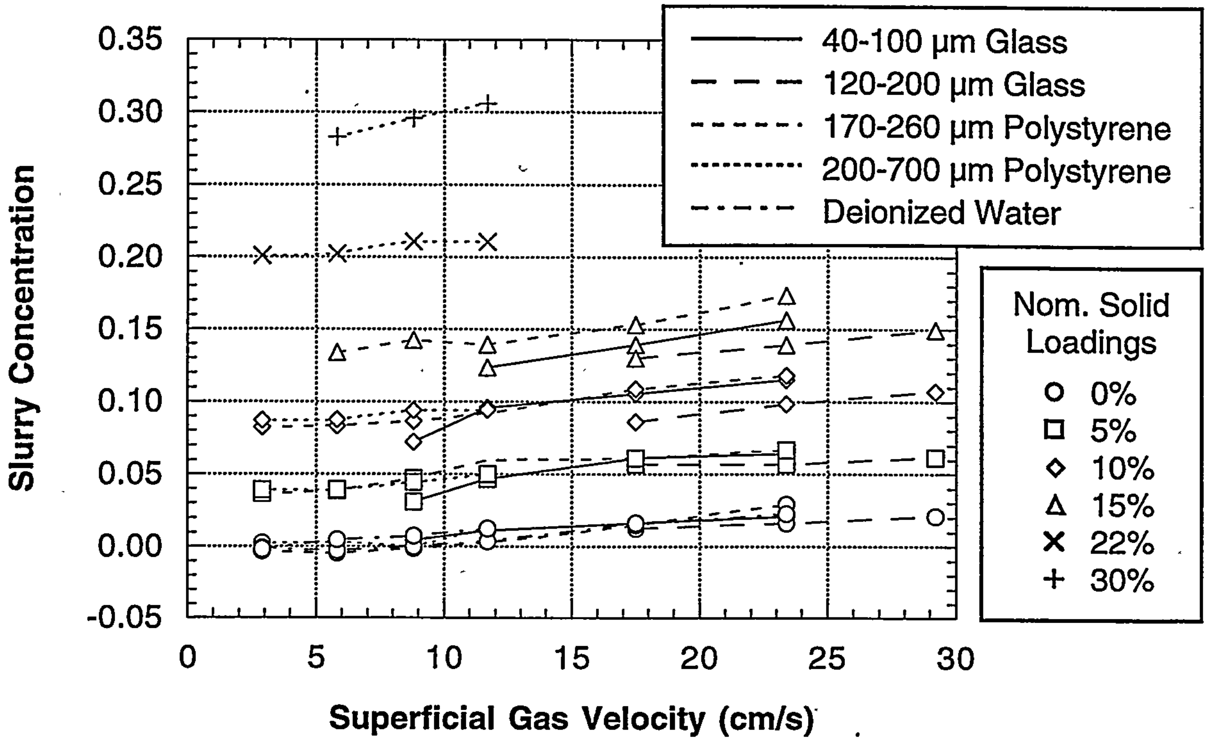
50
40
30
20
10
0
Percentage (%)
Volume
Number
0
50
100
150
200
Diameter (µm)

Figure 8.



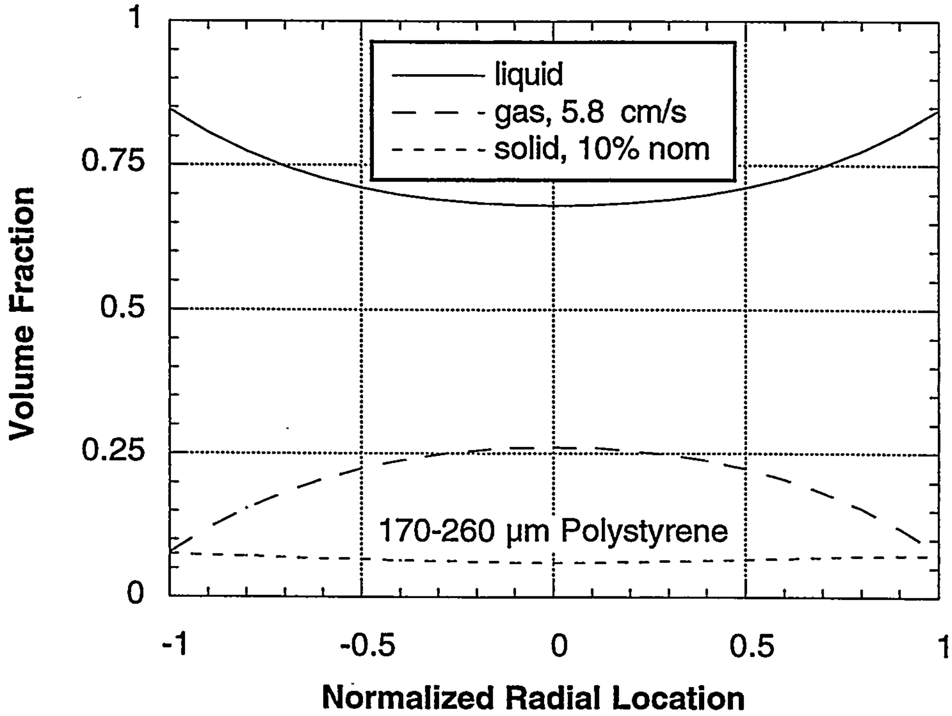
Volume
Number
Percentage (%)
Diameter (μm)
0
10
20
30
40
50
0
50
100
150
200
250
300
350
400

Figure 9.



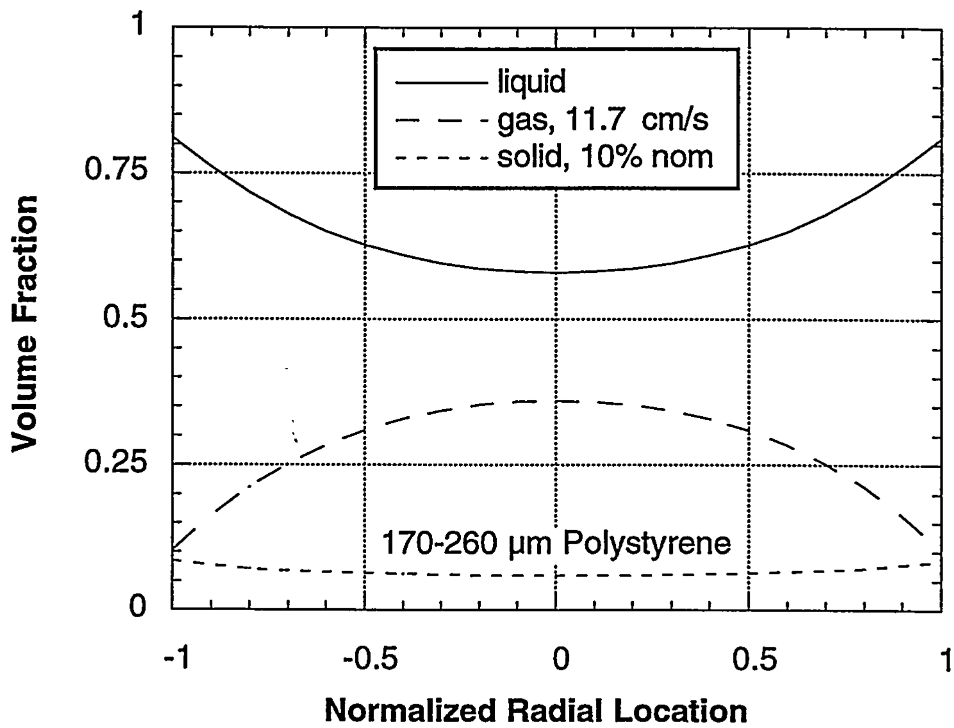
40-100 µm Glass
120-200 µm Glass
170-260 µm Polystyrene
200-700 µm Polystyrene
Deionized Water
Nom. Solid Loadings
0%
5%
10%
15%
22%
30%
Slurry Concentration
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0
5
10
15
20
25
30
Superficial Gas Velocity (cm/s)

Figure 10 (a).



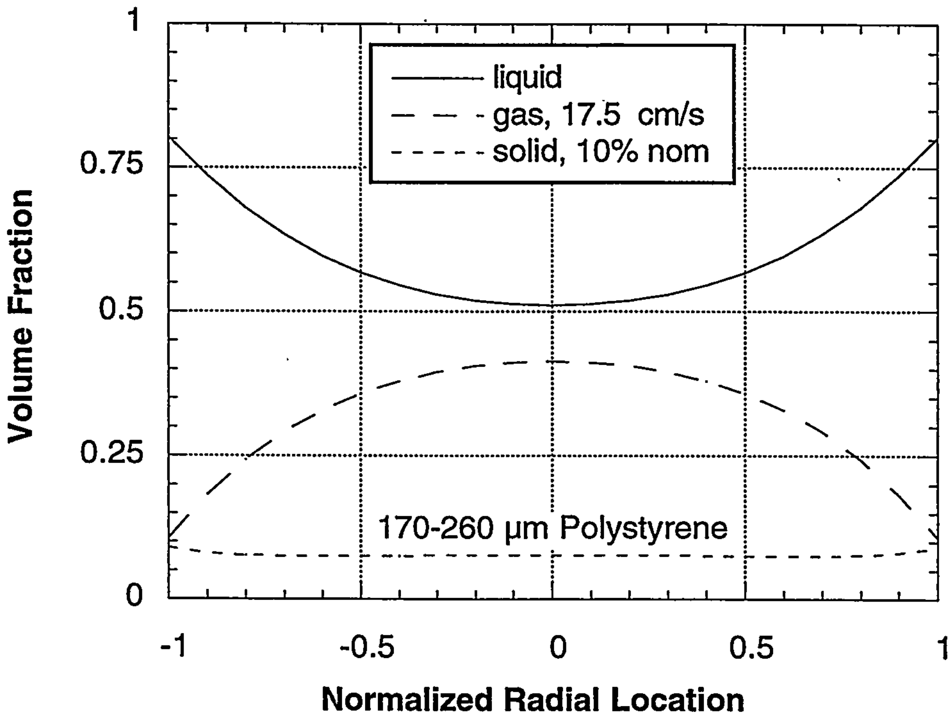
1
0.75
0.5
0.25
0
Volume Fraction
liquid
gas, 5.8 cm/s
solid, 10% nom
170-260 μm Polystyrene
-1
-0.5
0
0.5
1
Normalized Radial Location

Figure 10 (b).



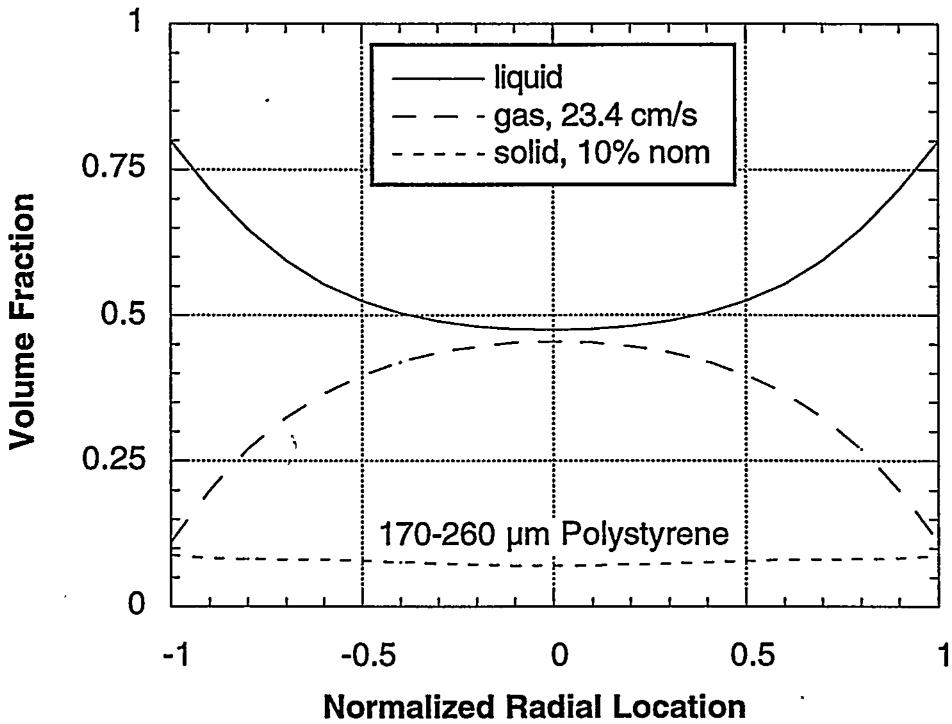
1
0.75
0.5
0.25
0
Volume Fraction
liquid
gas, 11.7 cm/s
solid, 10% nom
170-260 μm Polystyrene
-1
-0.5
0
0.5
1
Normalized Radial Location

Figure 10 (c).



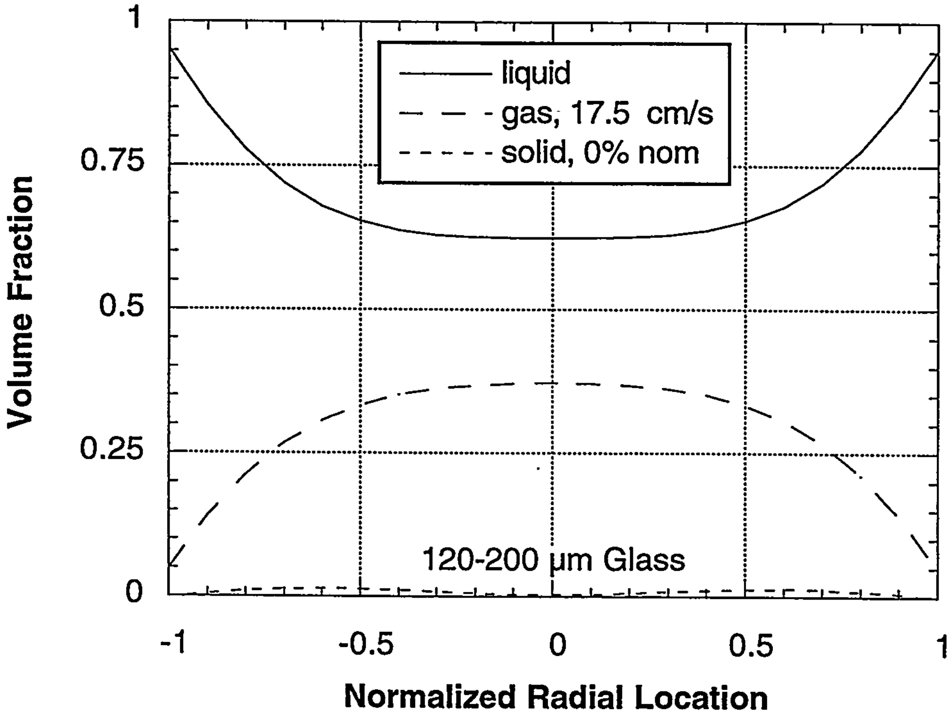
liquid
gas, 17.5 cm/s
solid, 10% nom
170-260 μm Polystyrene
1
0.75
0.5
0.25
0
Volume Fraction
-1
-0.5
0
0.5
1
Normalized Radial Location

Figure 10 (d).



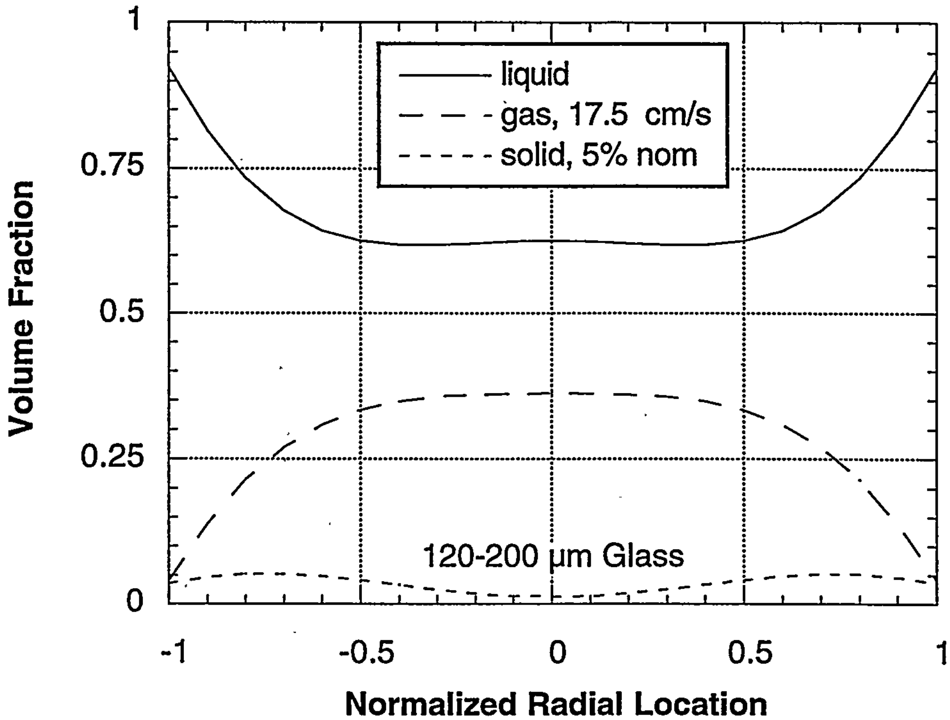
1
0.75
0.5
0.25
0
Volume Fraction
liquid
gas, 23.4 cm/s
solid, 10% nom
170-260 µm Polystyrene
-1
-0.5
0
0.5
1
Normalized Radial Location

Figure 11 (a).



liquid
gas, 17.5 cm/s
solid, 0% nom
120-200 μm Glass
Volume Fraction
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1
Normalized Radial Location

Figure 11 (b).



1
0.75
0.5
0.25
0
Volume Fraction
liquid
gas, 17.5 cm/s
solid, 5% nom
120-200 μm Glass
-1
-0.5
0
0.5
1
Normalized Radial Location

Figure 11 (c).

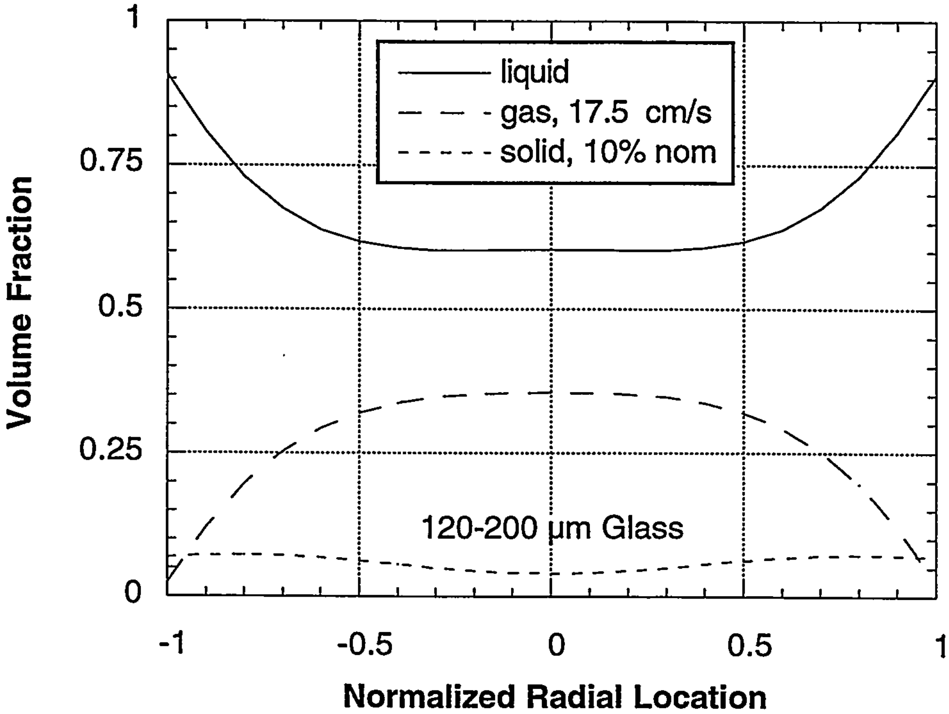

liquid
gas, 17.5 cm/s
solid, 10% nom
120-200 µm Glass
Volume Fraction
Normalized Radial Location
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1

Figure 11 (d).

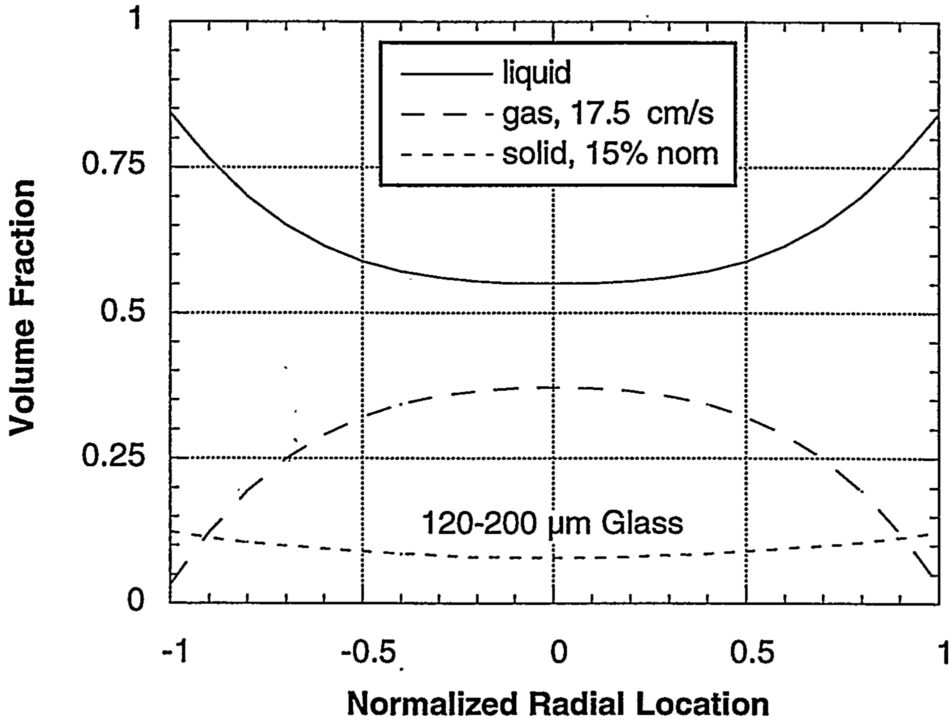
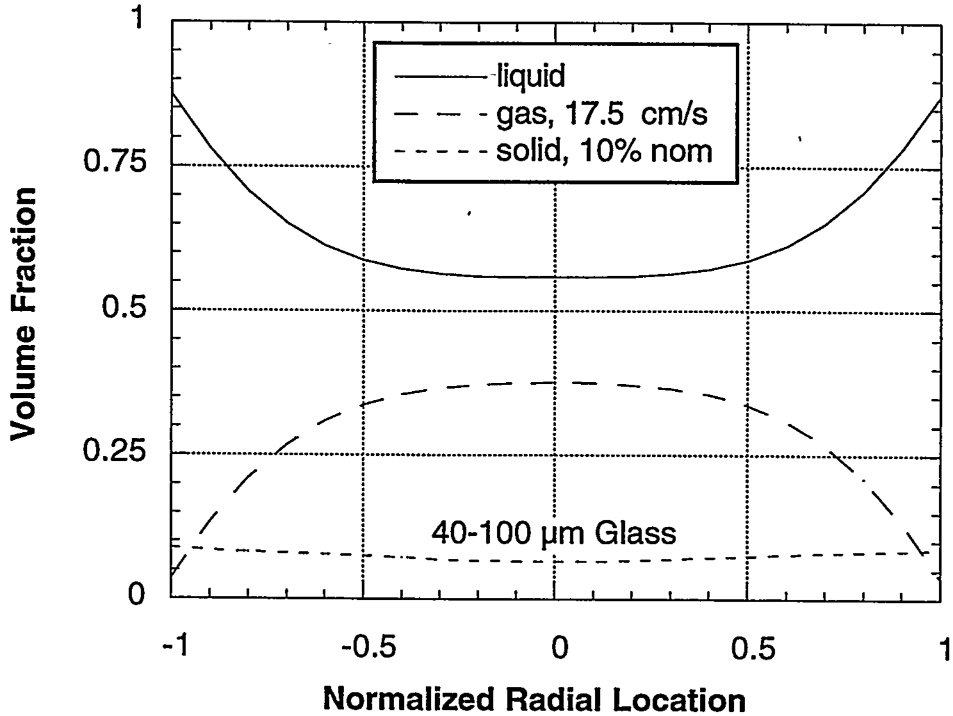
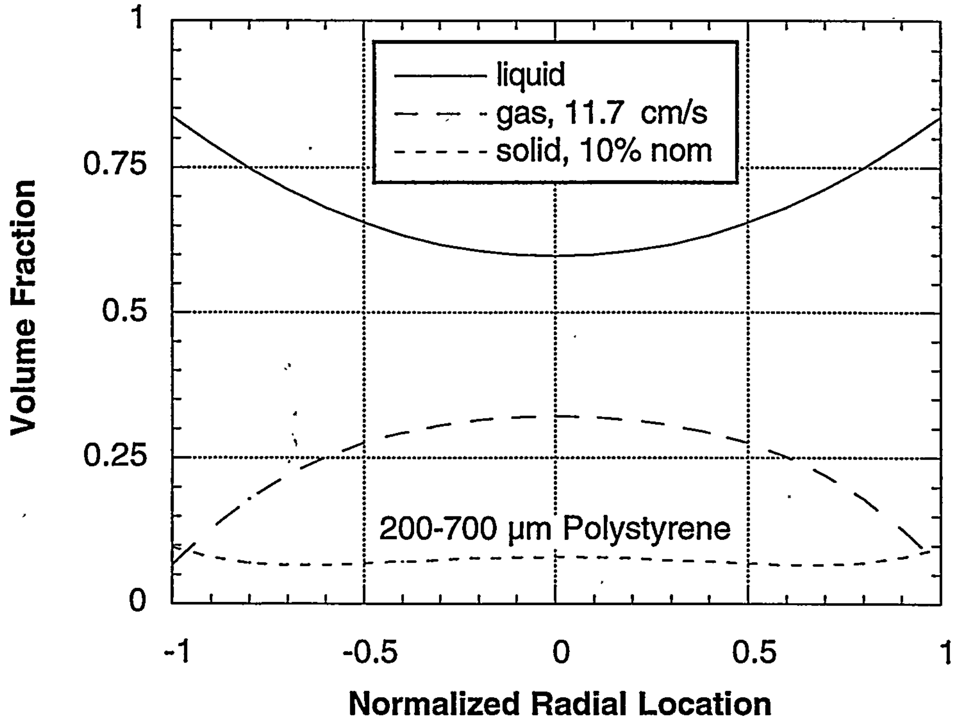

liquid
gas, 17.5 cm/s
solid, 15% nom
120-200 μm Glass
Volume Fraction
Normalized Radial Location
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1

Figure 12.



liquid
gas, 17.5 cm/s
solid, 10% nom
40-100 μm Glass
Volume Fraction
Normalized Radial Location
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1

Figure 13.



liquid
gas, 11.7 cm/s
solid, 10% nom
200-700 µm Polystyrene
Volume Fraction
Normalized Radial Location
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1

Figure 14.

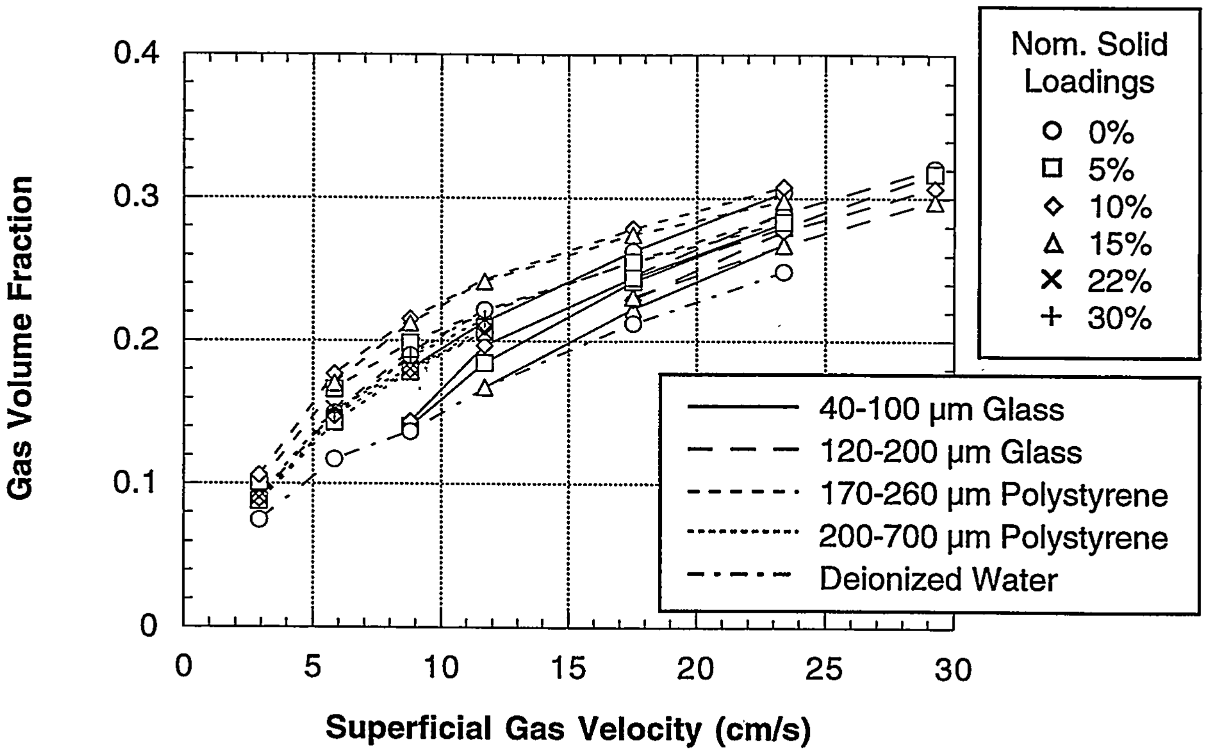
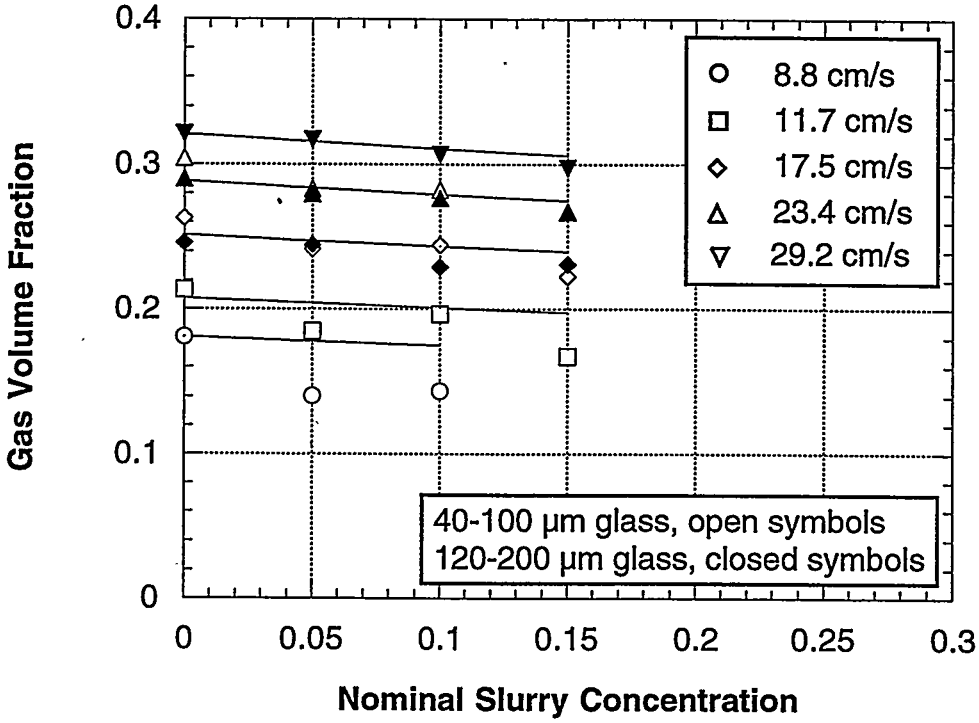
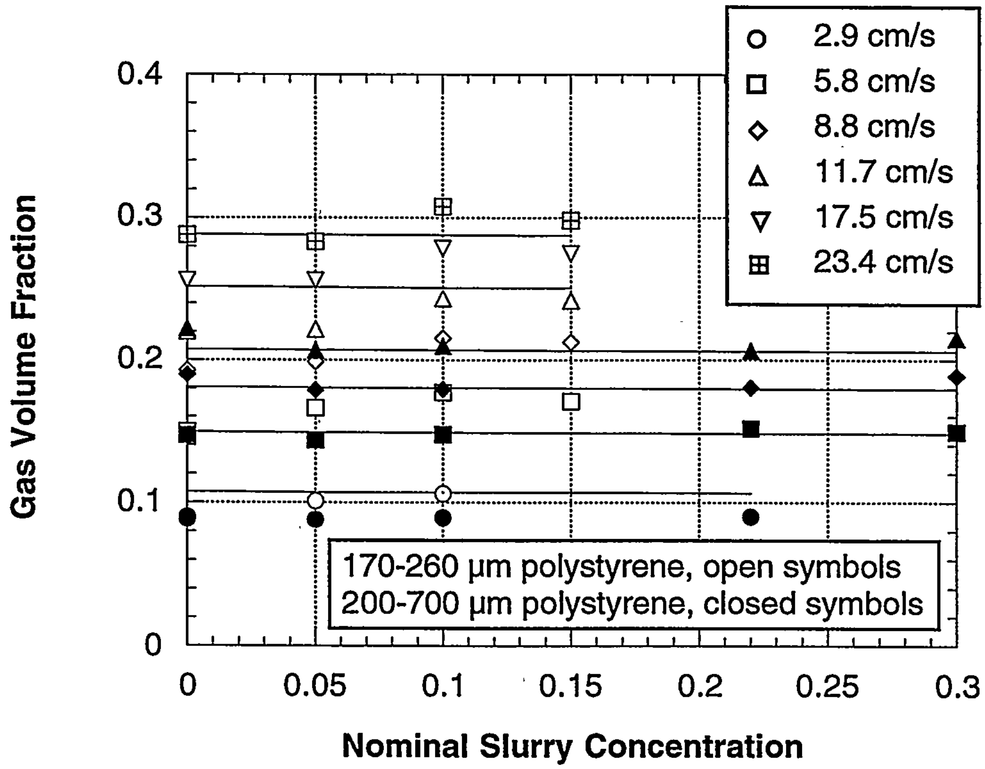

Nom. Solid Loadings
0%
5%
10%
15%
22%
30%
40-100 μm Glass
120-200 μm Glass
170-260 μm Polystyrene
200-700 μm Polystyrene
Deionized Water
Gas Volume Fraction
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
Superficial Gas Velocity (cm/s)

Figure 15.



0.4
0.3
0.2
0.1
0
Gas Volume Fraction
8.8 cm/s
11.7 cm/s
17.5 cm/s
23.4 cm/s
29.2 cm/s
40-100 μm glass, open symbols
120-200 μm glass, closed symbols
0
0.05
0.1
0.15
0.2
0.25
0.3
Nominal Slurry Concentration

Figure 16.



2.9 cm/s
5.8 cm/s
8.8 cm/s
11.7 cm/s
17.5 cm/s
23.4 cm/s
170-260 μm polystyrene, open symbols
200-700 μm polystyrene, closed symbols
Gas Volume Fraction
0
0.1
0.2
0.3
0.4
0
0.05
0.1
0.15
0.2
0.25
0.3
Nominal Slurry Concentration