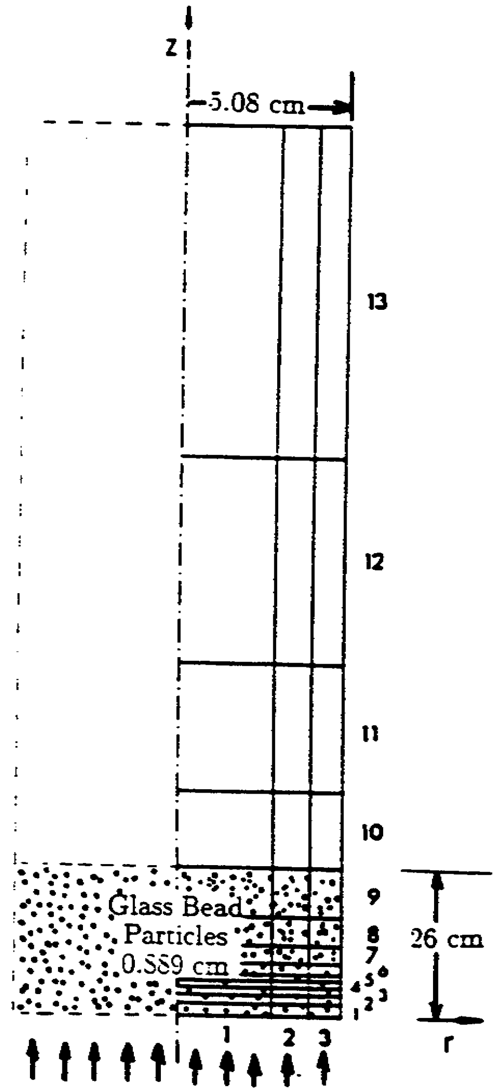
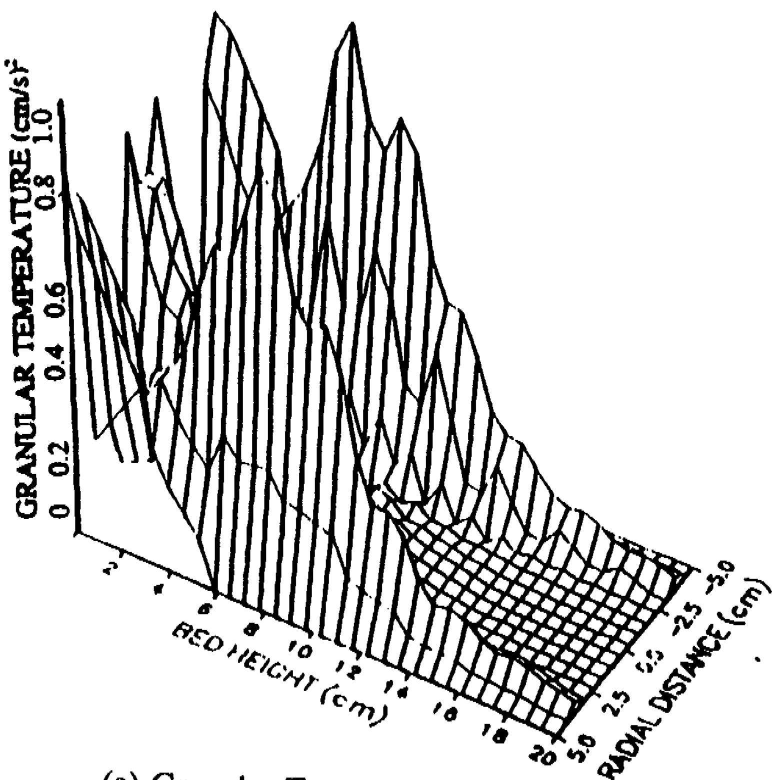


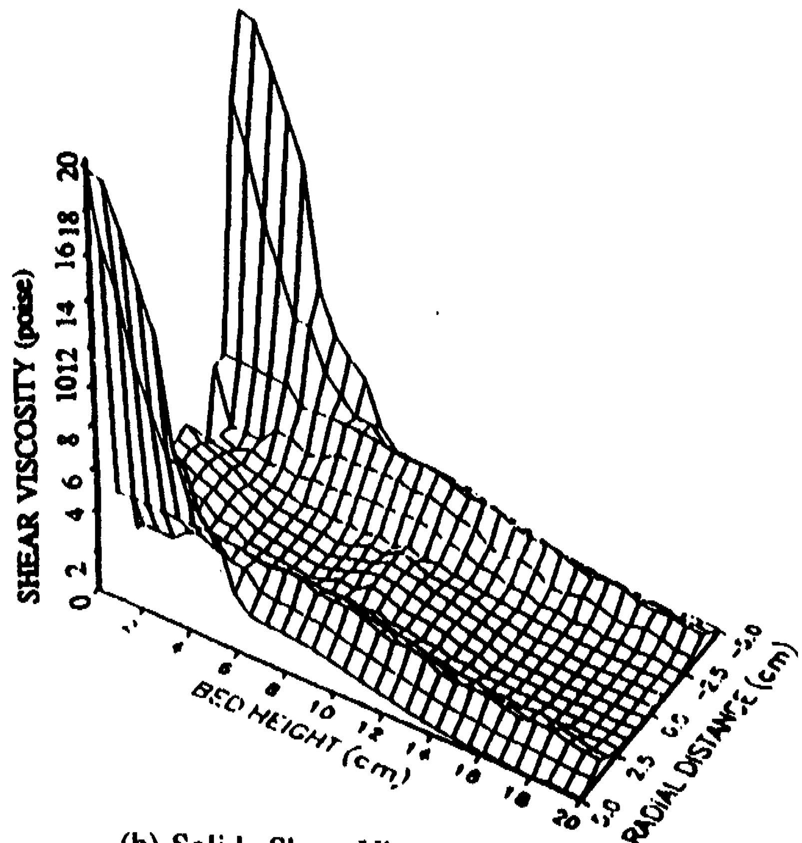
LIQUID / GAS

Inlet Gas Volume Fraction	0.03
Superficial Liquid Velocity	7.6 cm/sec
Density of Liquid (Dimethyl Phthalate)	2.49 g/cm^3
Density of Particles	1.19 g/cm^3

FIGURE 1. Three-Phase Fluidization System for Simulation of Dispersed Bubble Regime.



(a) Granular Temperature



(b) Solids Shear Viscosity

FIGURE 2. Computed Granular Temperature and Solid Shear Viscosity for Case 1 in Dispersed Bubble Regime.

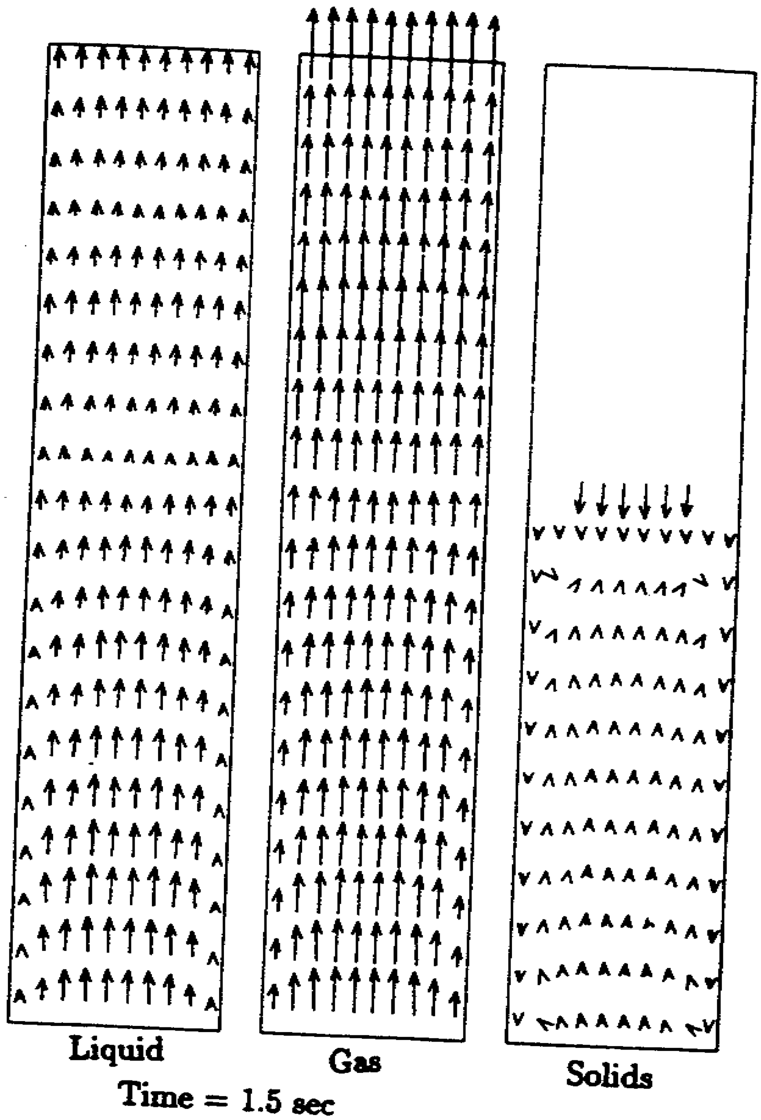


FIGURE 3. Computed Velocity Patterns for Dispersed Bubble Regime.

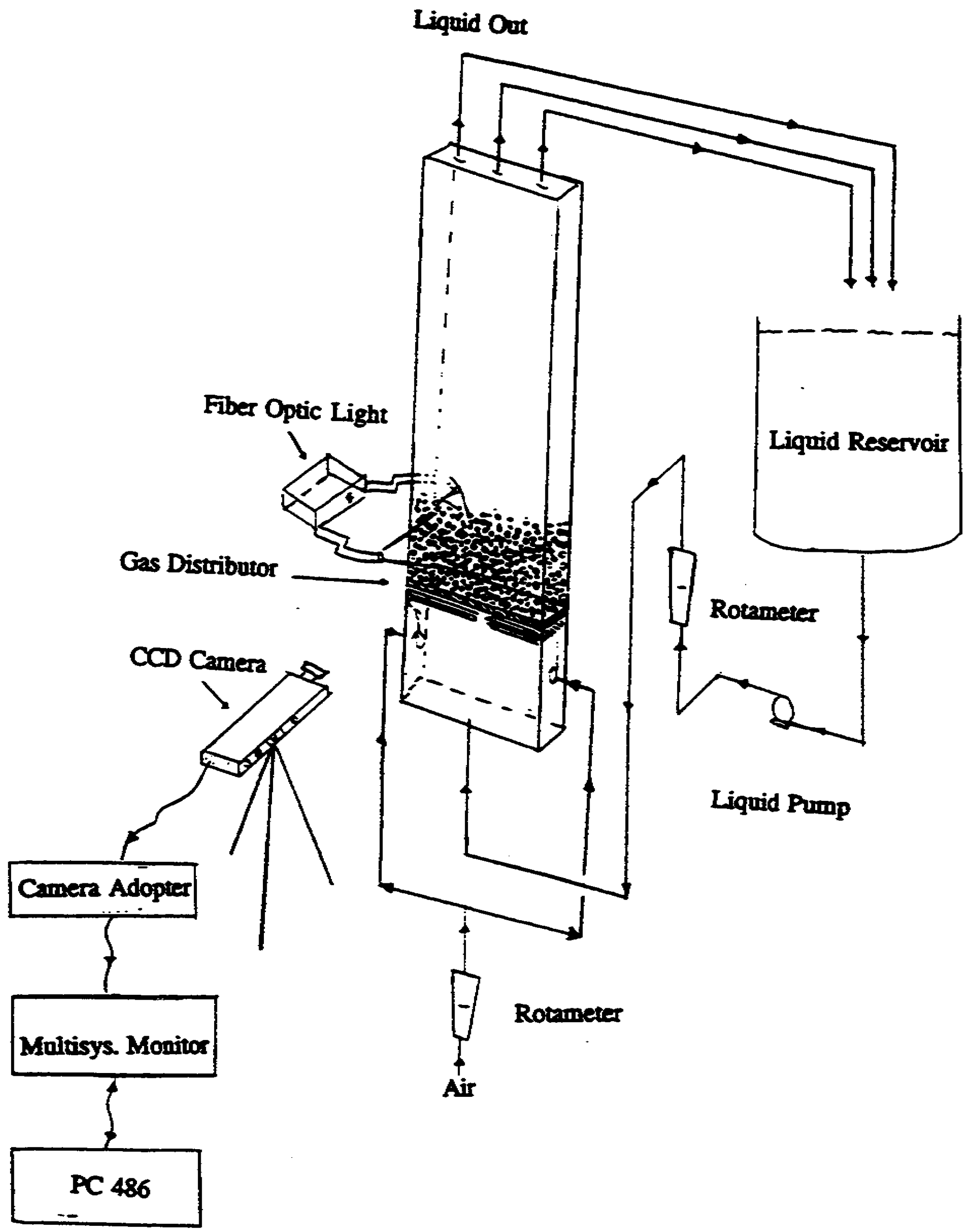


FIGURE 4. Schematic Diagram for Three-Phase Fluidization Apparatus and Video-Digital Camera Unit for Bubbly Coalesced Regime Experiments.

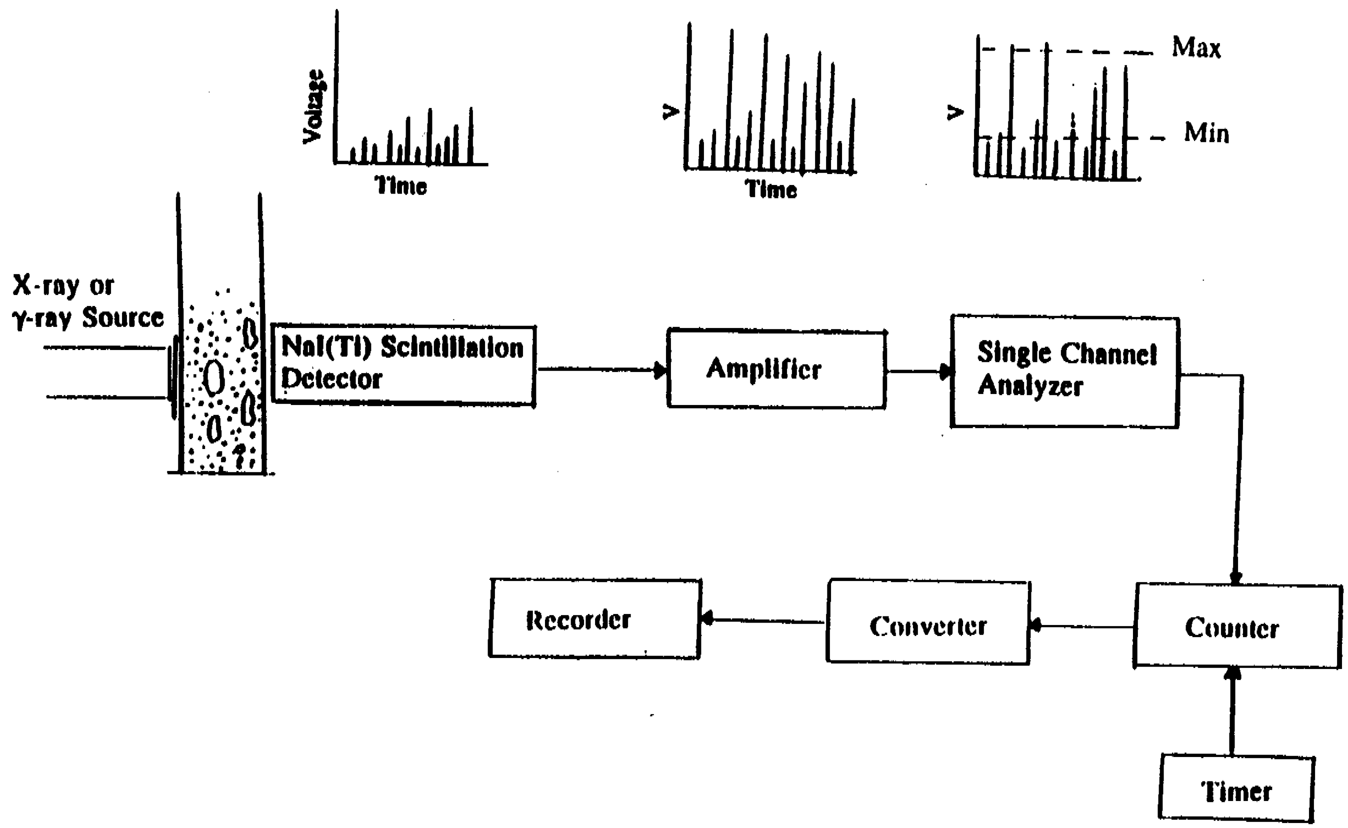
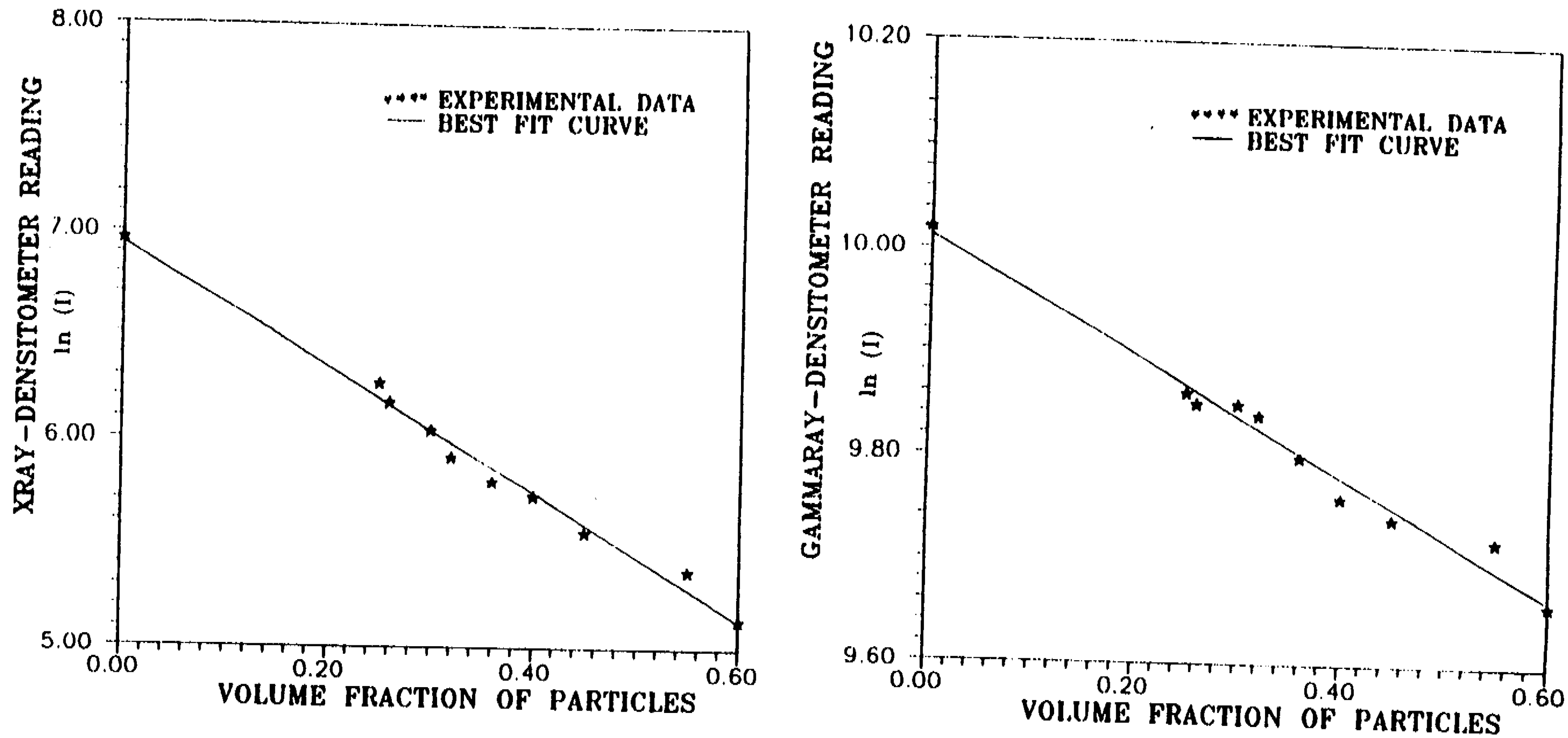


FIGURE 5. Schematic Diagram for Source-Detector-Recorder Assembly for X-Ray and γ-Ray Densitometers.



(a) X-Ray

(b) γ-Ray

FIGURE 6. (a) X-Ray, and (b) γ-Ray Calibration Curves for Lead Glass Beads in a Three-Phase Fluidized Bed.

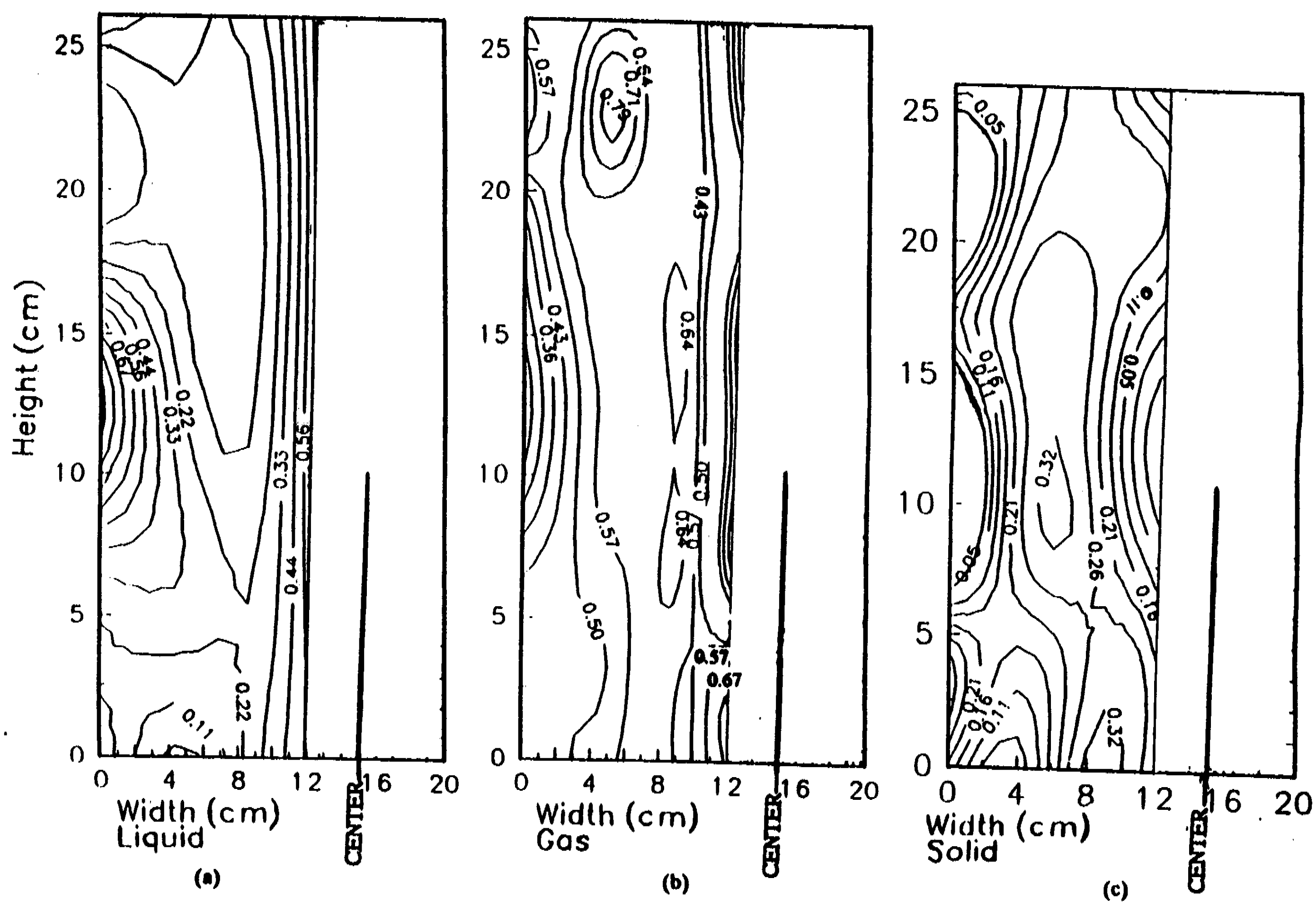
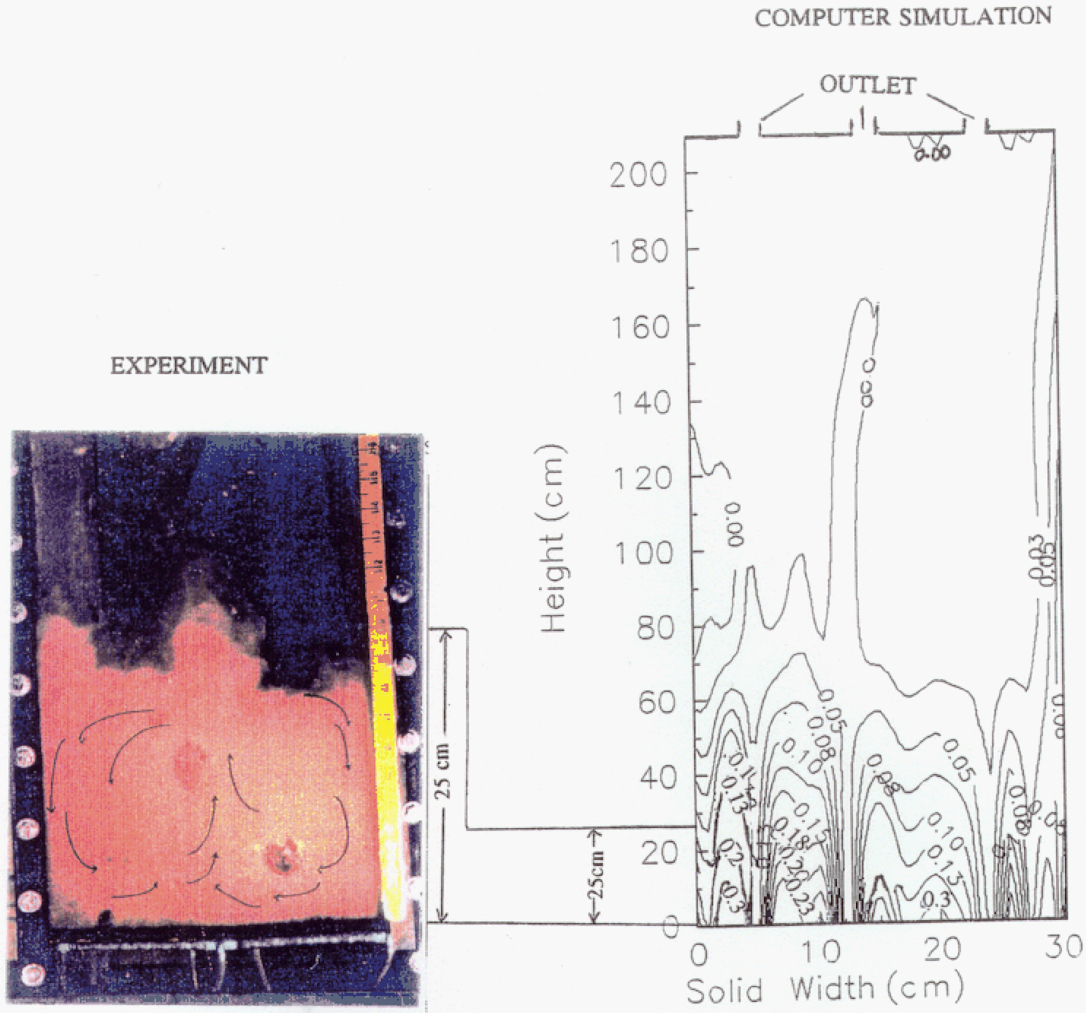


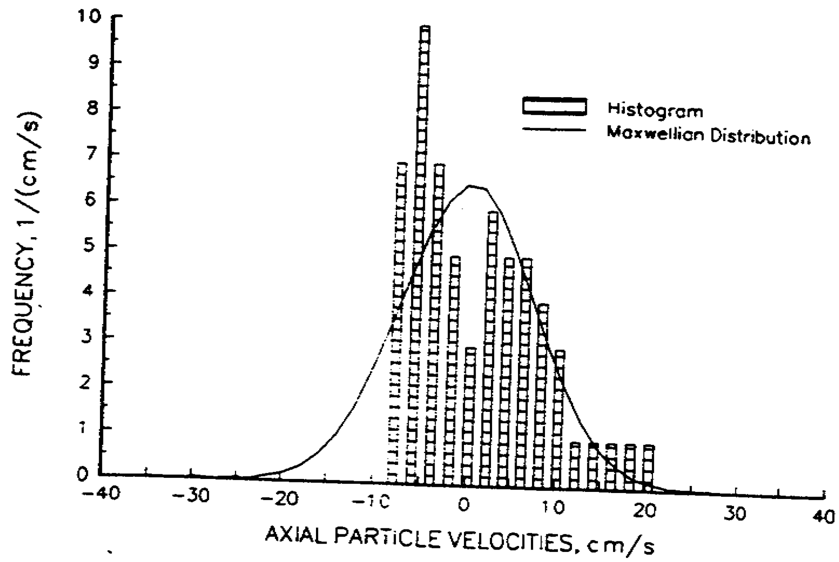
FIGURE 7. Experimental Time Average Volume Fraction Contours for Bubbly Coalesced Regime.



(a) Photograph of Experiment

(b) Simulated Time Average Solids Volume Fraction Contours

FIGURE 8. (a) Experimental, and (b) Simulated Bubble Coalescence in Three-Phase Fluidized Bed at Superficial Gas Velocity of 3.7 cm/s and Superficial Liquid Velocity of 2.03 cm/s.



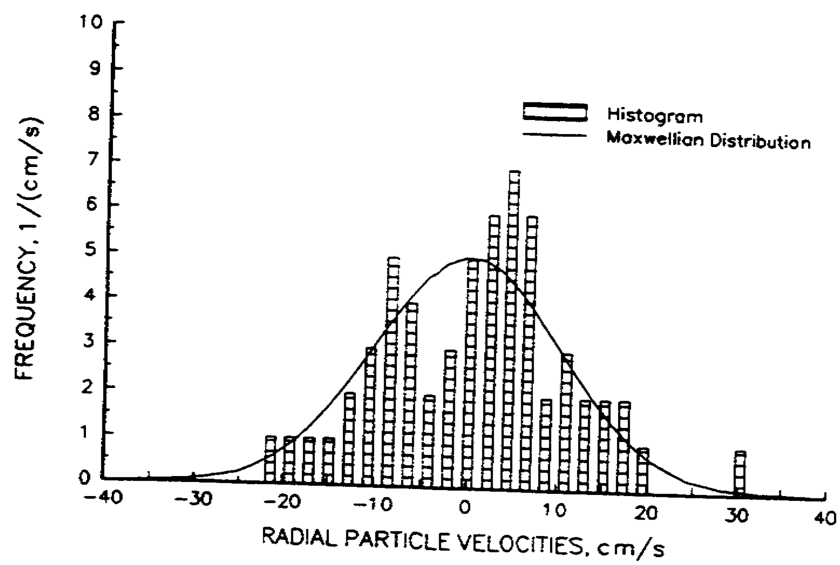


FIGURE 9. Frequency Distribution of (a) Axial, and (b) Radial Velocity Components of Particles at X = 4.0 cm and Y = 4.5 cm for Liquid-Gas-Solid Fluidized Bed at Sup. Liquid Velocity of 4.0 cm/sec and Sup. Gas Velocity of 3.36 cm/sec.

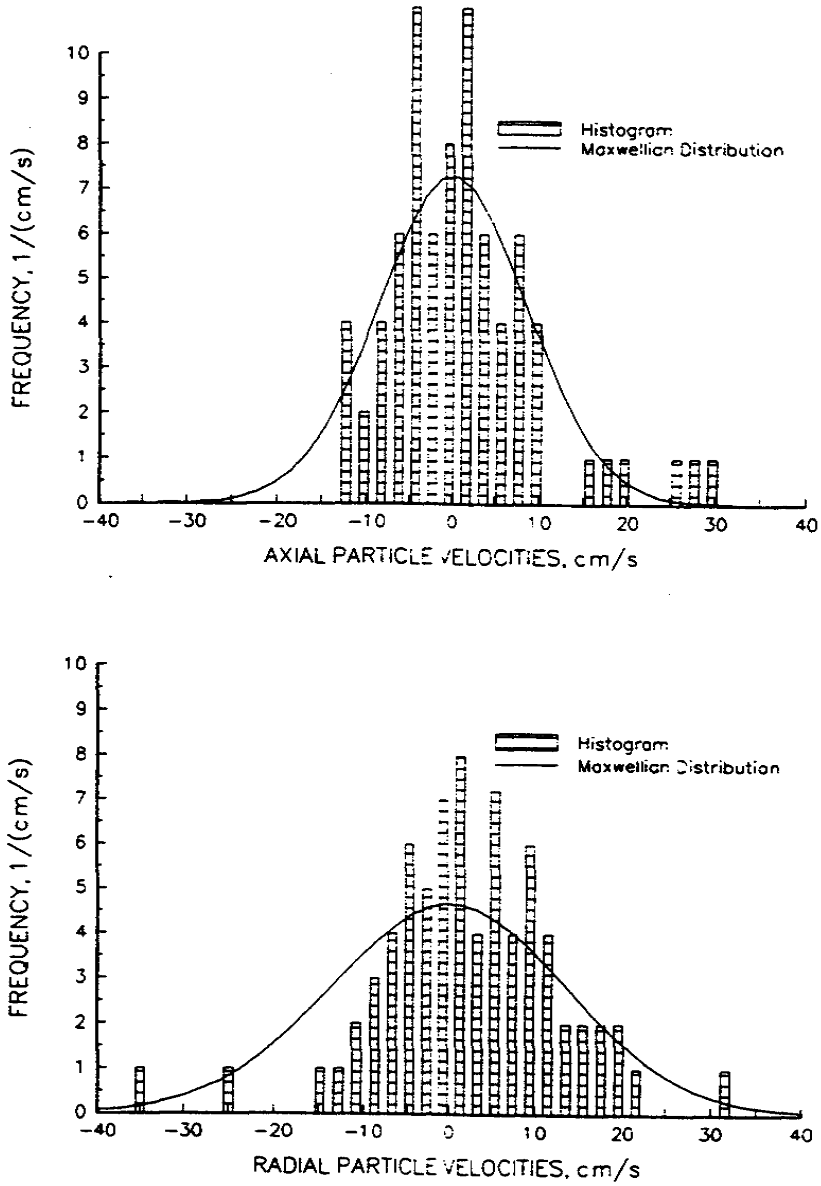


FIGURE 10. Frequency Distribution of (a) Axial, and (b) Radial Velocity Components of Particles at X = 4.0 cm and Y = 4.5 cm for Liquid-Solid Fluidized Bed at Sup. Liquid Velocity of 4.0 cm/sec.

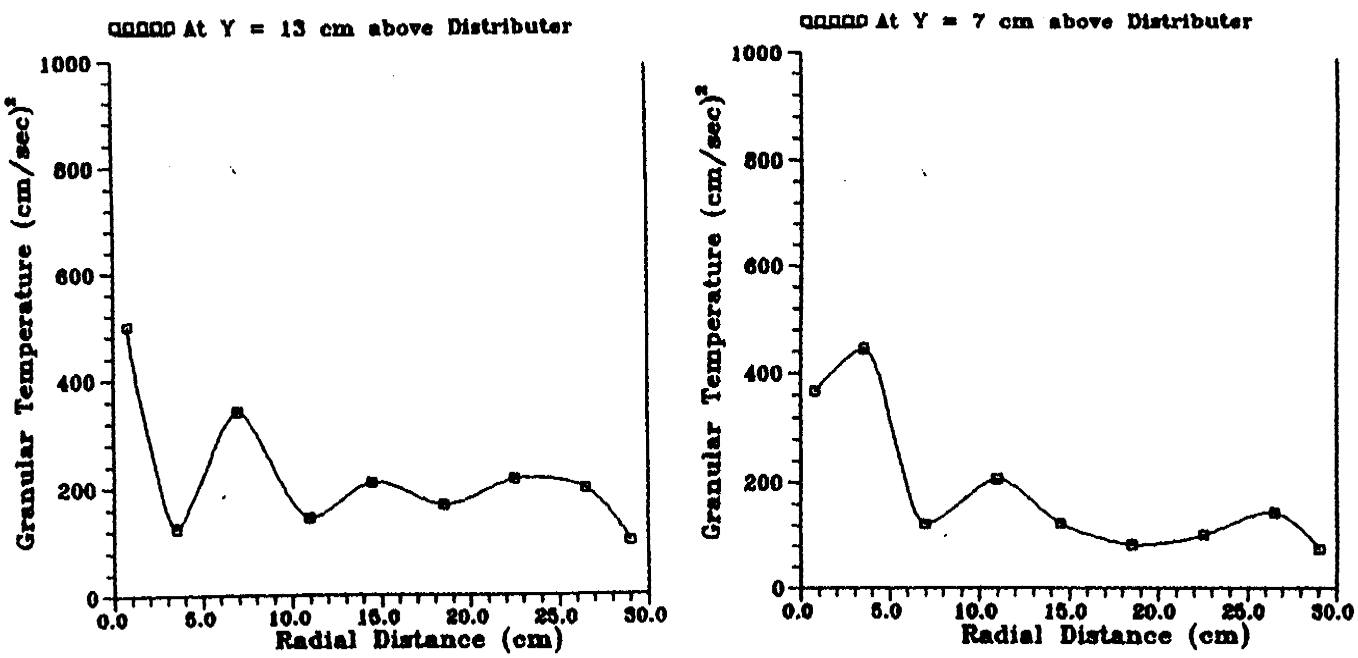


FIGURE 11. Granular Temperature vs. Radial Distance at Different Bed Heights in Gas-Liquid-Solid Fluidized Bed at Sup. Liquid Velocity of 4.04 cm/sec and Sup. Gas Velocity of 3.36 cm/sec.

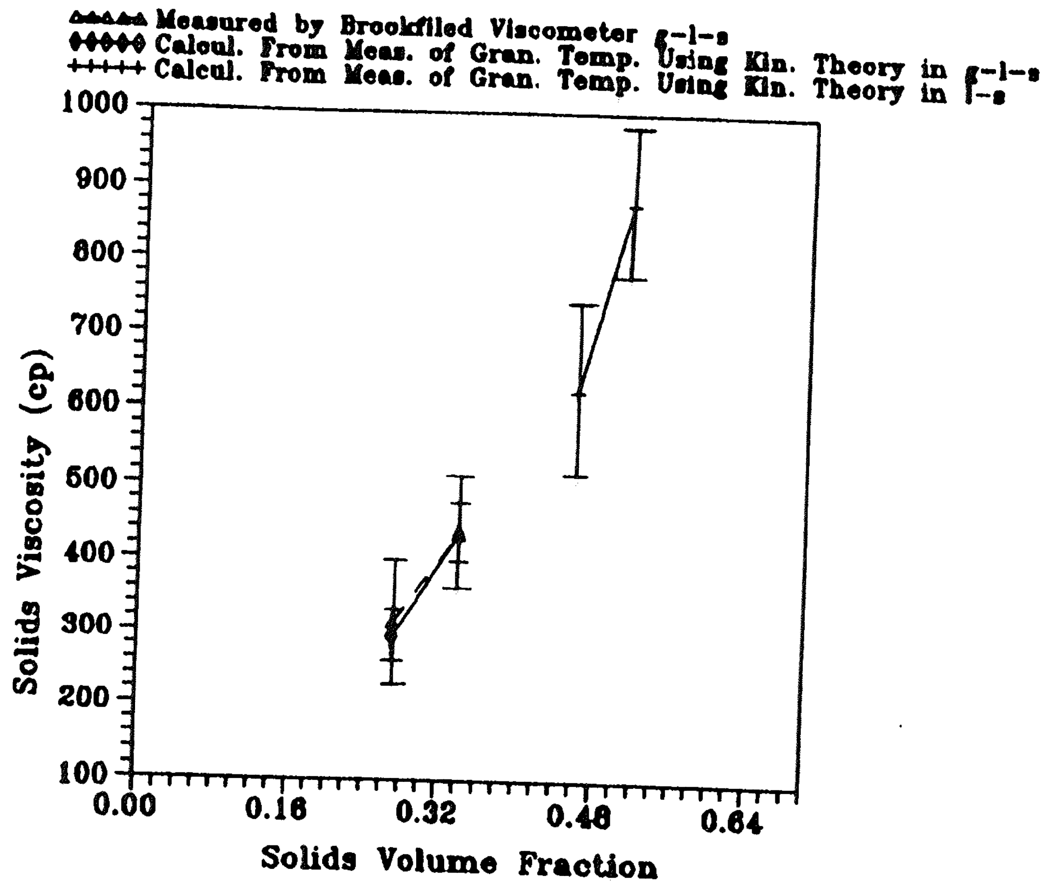
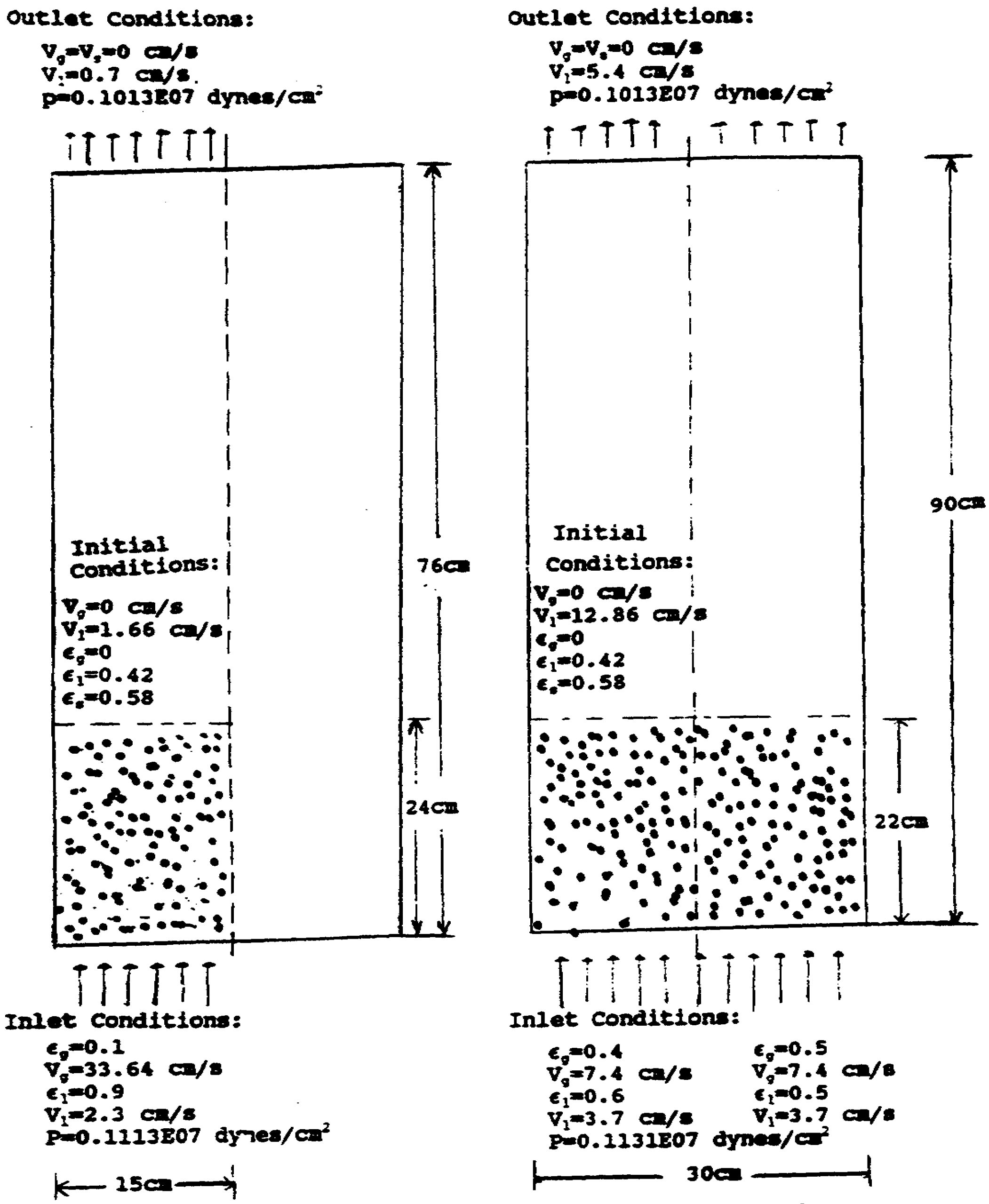


FIGURE 12. Comparison of Measured and Calaulated Solids Viscosity in Fluidized Bed with Uniform Distributor.



(a) Symmetric Mode

(b) Asymmetric Mode

FIGURE 13. Three-Phase Fluidization System for the Simulation of Bubbly Coalesced Regime in (a) Symmetric, and (b) Asymmetric Modes.

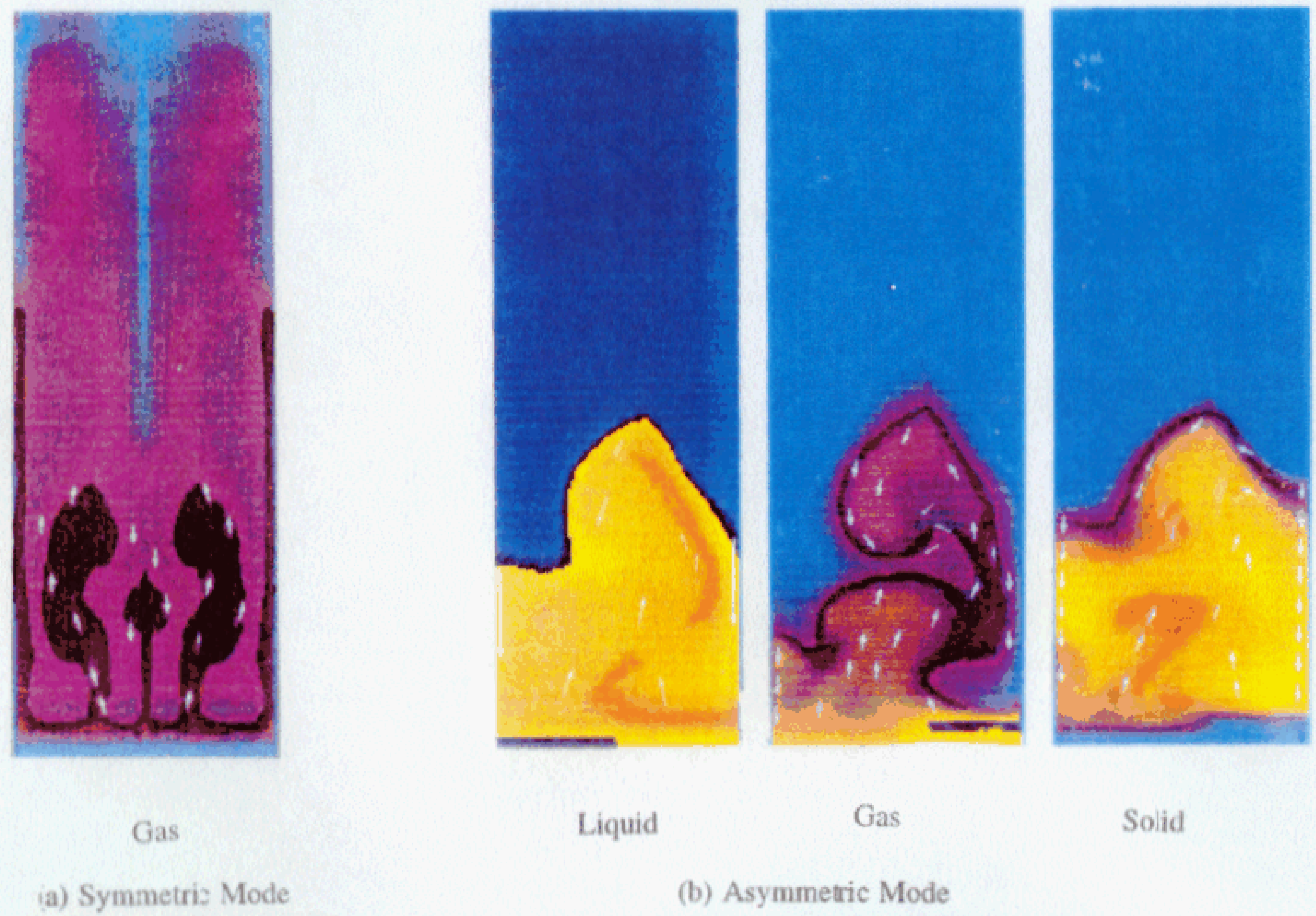


FIGURE 14. Computed Bubble Formation in Three-Phase Fluidized Bed in (a) Symmetric, and (b) Asymmetric Modes at Superficial Gas Velocity of 3.7 cm/s and Superficial Liquid Velocity of 2.03 cm/s.

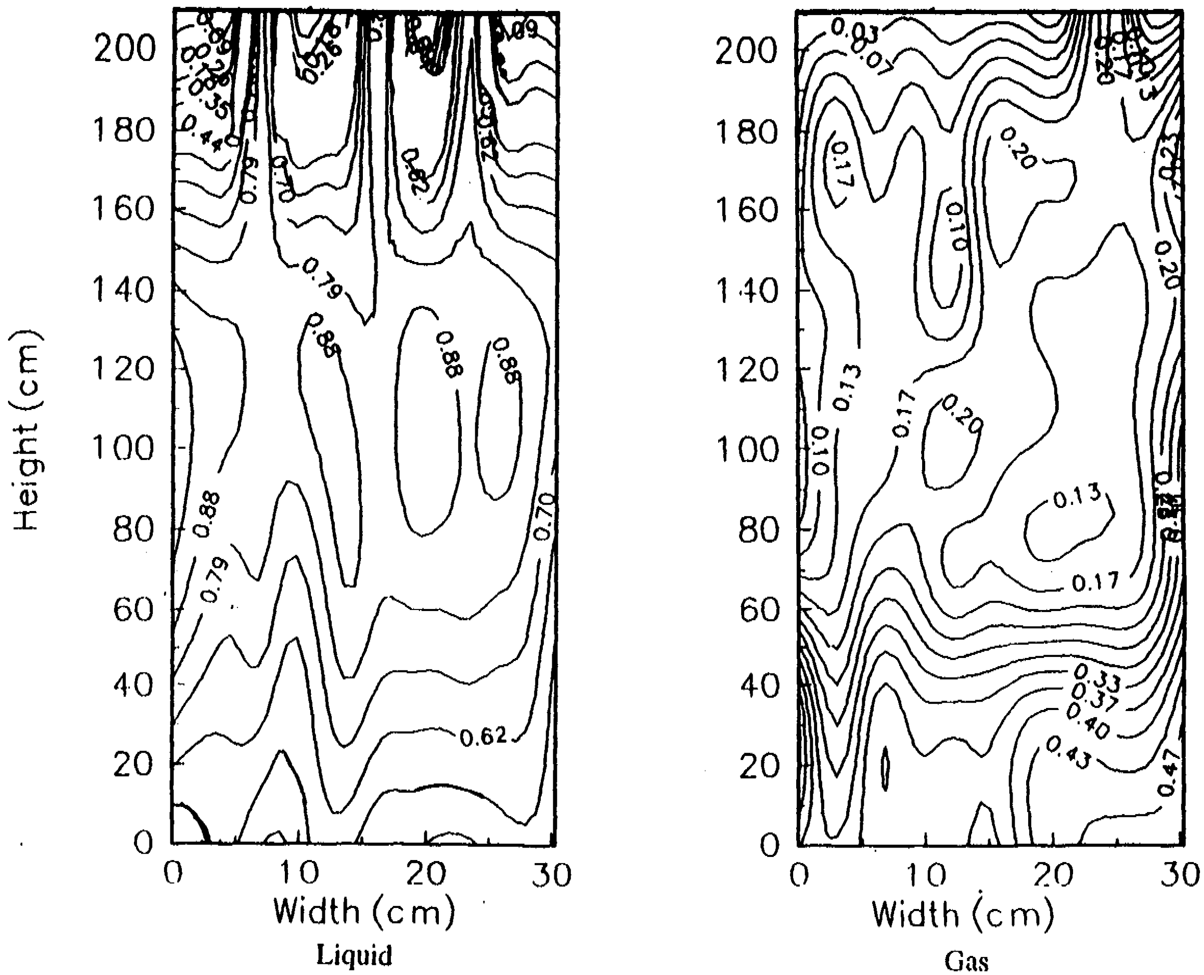


FIGURE 15. Computed Time Average Volume Fraction Contours for Bubbly Coalesced Regime in Asymmetric Mode Simulation.

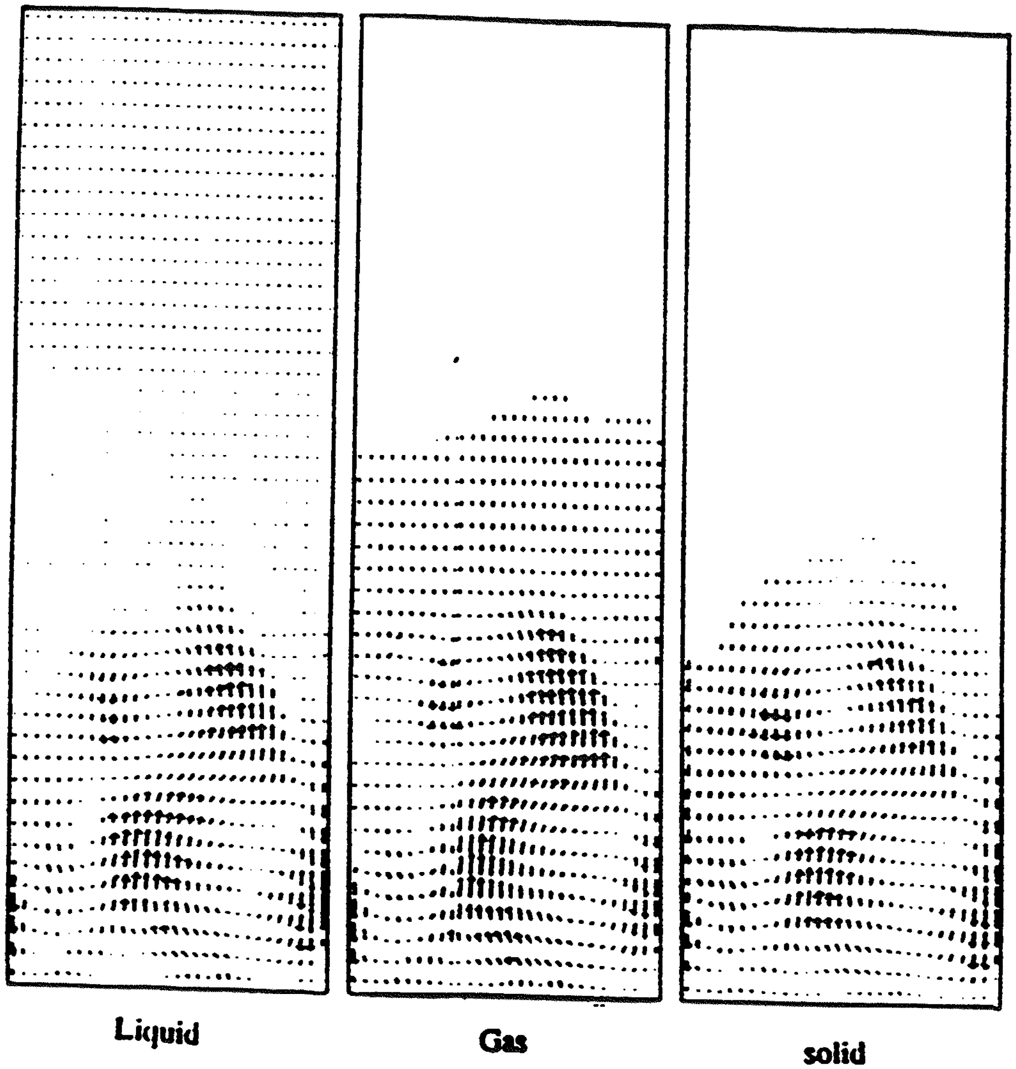


FIGURE 16. Computed Velocity Patterns for Bubbly Coalesced Regime in Asymmetric Mode Simulation.

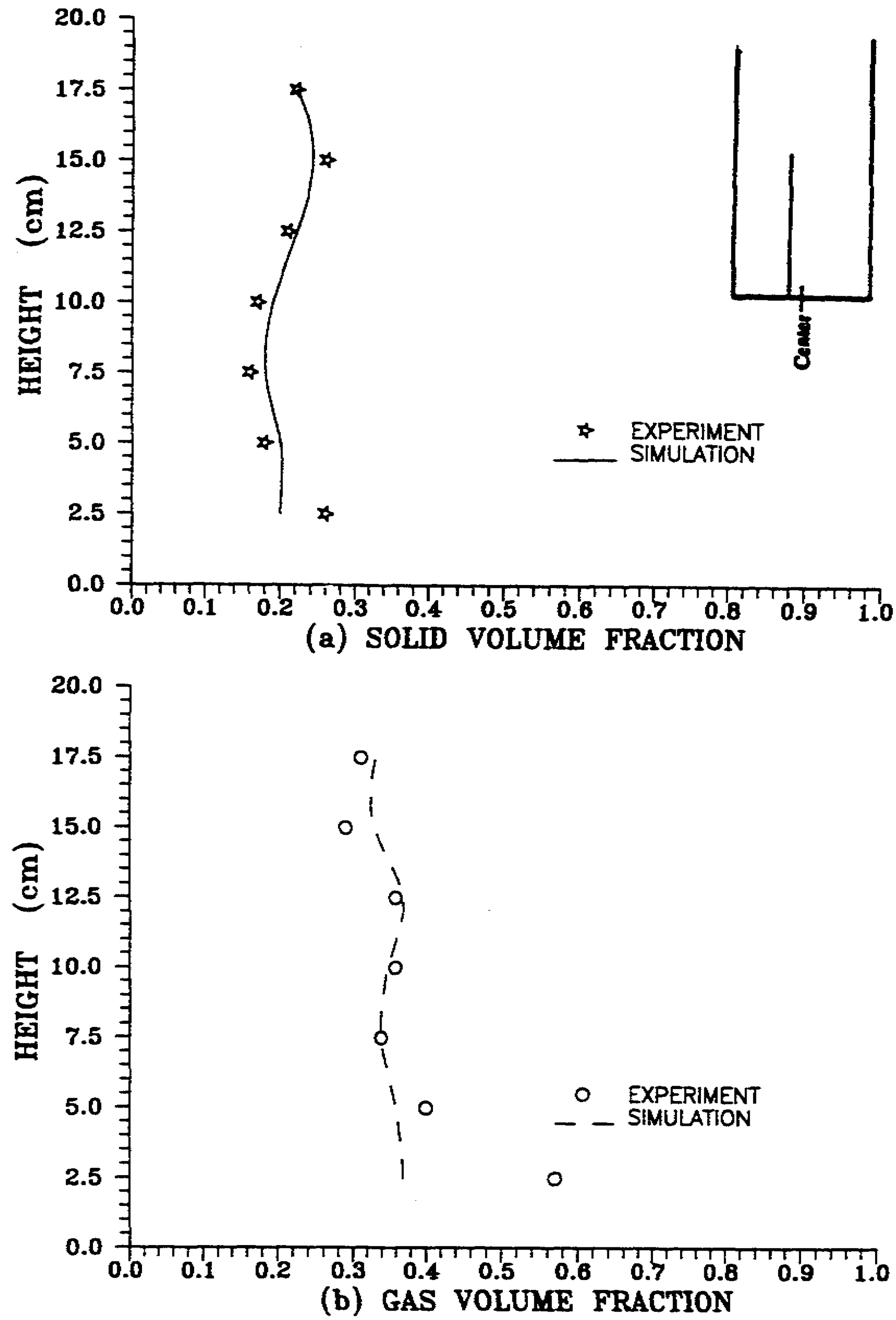


FIGURE 17. Comparison of Computational and Experimental Time Average Volume Fractions at Radial Position of 4.0 cm (Center Region) in Bubbly Coalesced Regime for Asymmetric Mode Simulation.

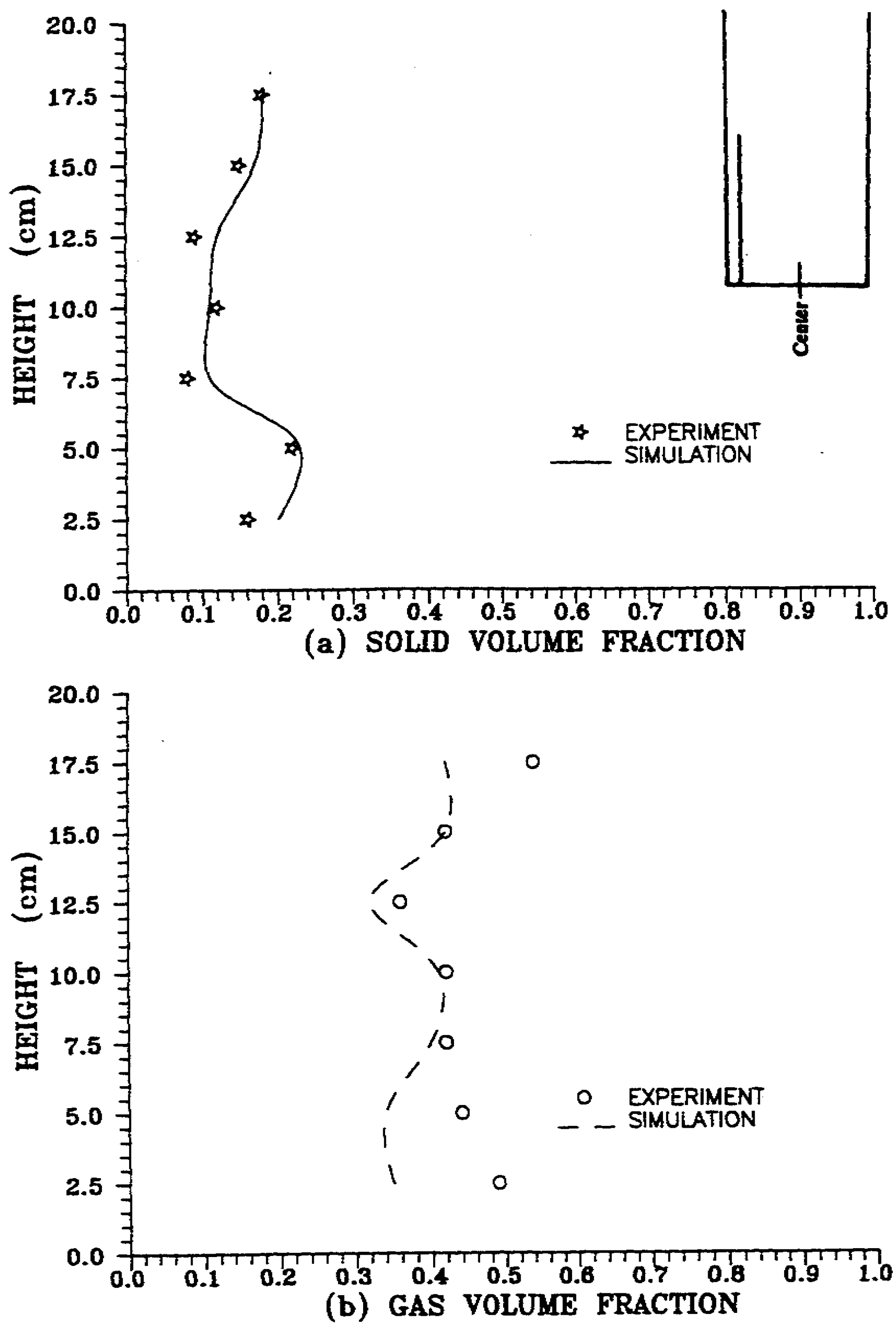


FIGURE 18. Comparison of Computational and Experimental Time Average Volume Fractions at Radial Position of 13.0 cm (Wall Region) in Bubbly Coalesced Regime for Asymmetric Mode Simulation.

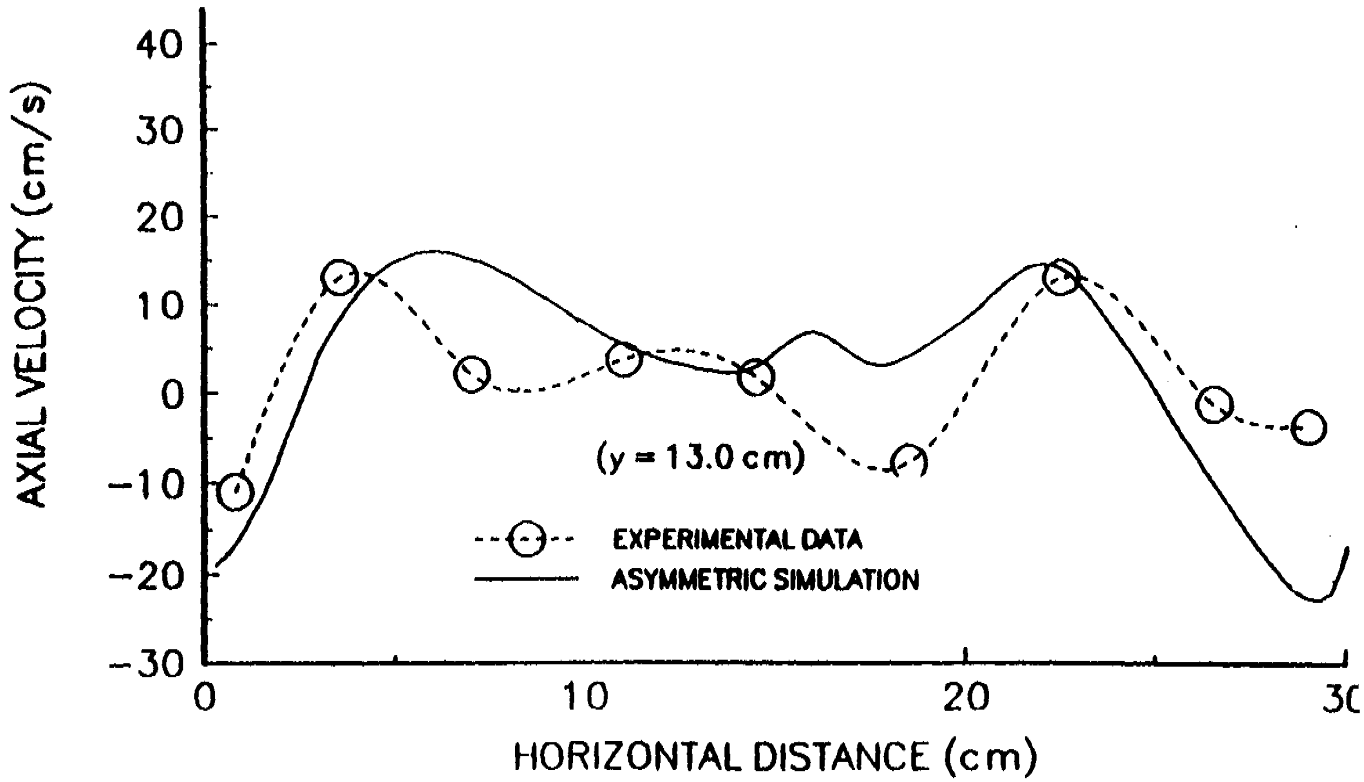


FIGURE 19. Comparison of Computational and Experimental Solids Velocity Profiles at Axial Position of 13.0 cm in Bubbly Coalesced Regime for Asymmetric Mode Simulation.

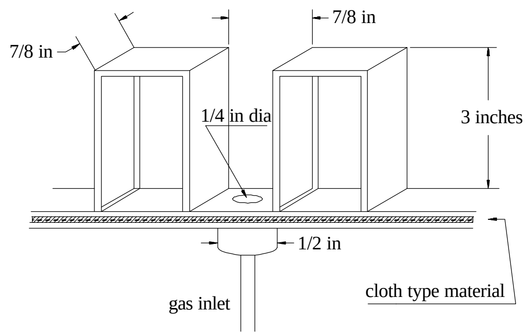


Figure 20 - Jet Details

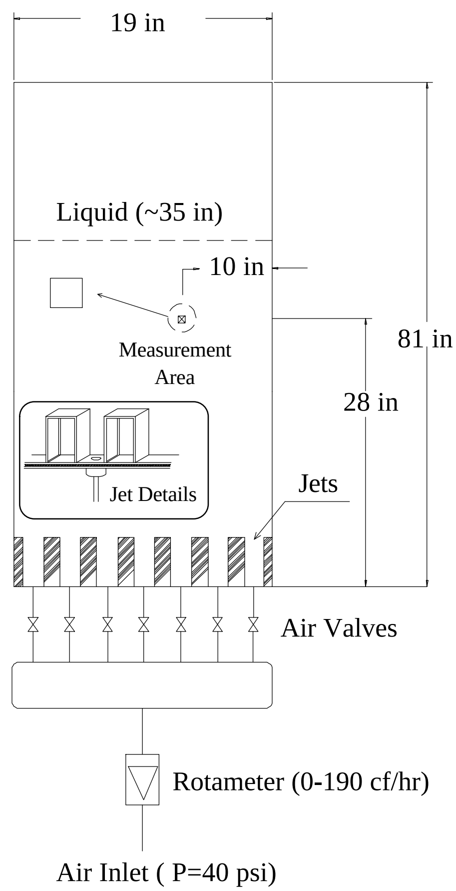


Figure 21- Sketch of Three-Phase Fluidized Bed for Measurement of Granular Temperature (Turbulence) Approaching Air Products Methanol Synthesis Reactor with no Liquid Flow

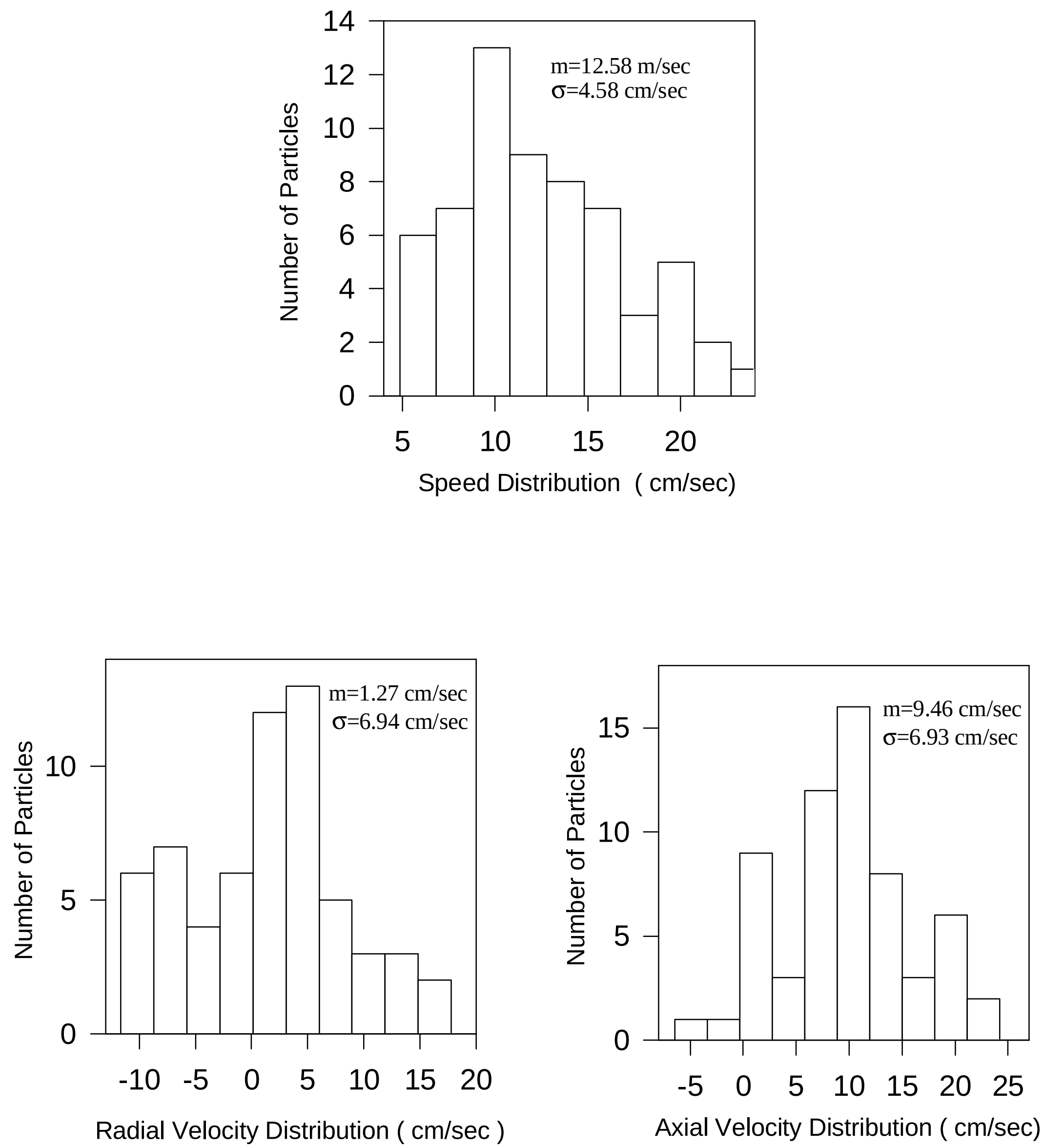


Fig 22 - Particles Speed, Radial and Axial Velocity Distribution at ε_S =0.07

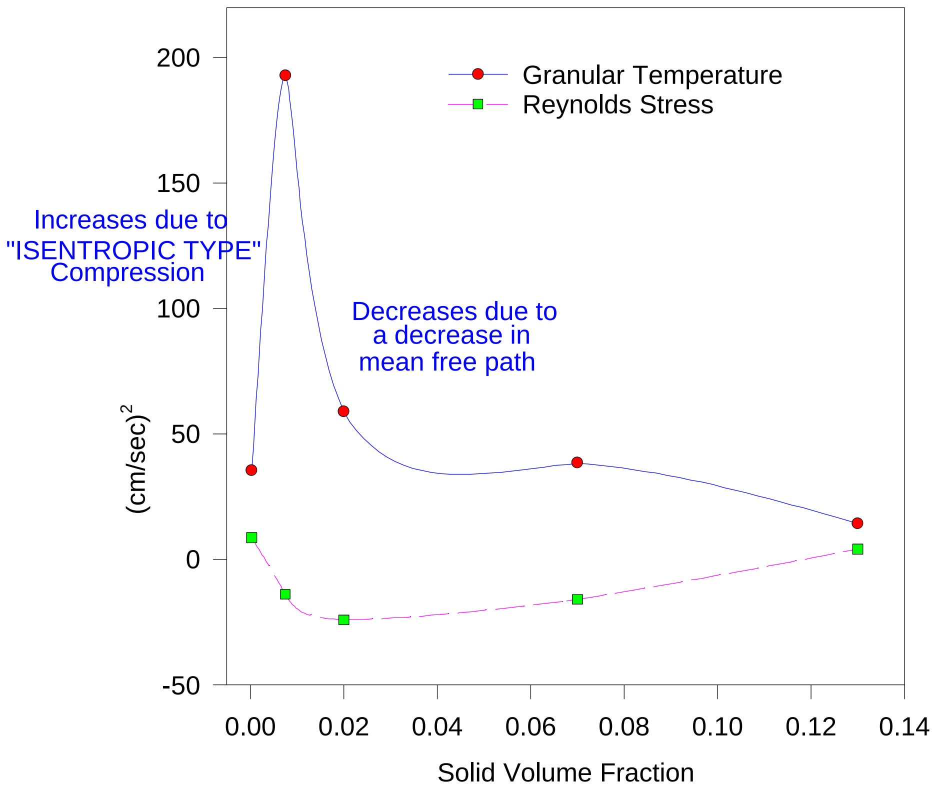
(m = mean , σ = standard deviation)

$$-P_{xy}\frac{\partial u_s}{\partial y} = 12\, e_s^{2} \rho_s g_o \left(1-e^2\right)\left(\frac{\theta}{d_p}\right)\left(\frac{\theta}{\pi}\right)^{\frac{1}{2}}$$

production of particle oscillations by shear P_{xy}

dissipation due to particle oscillations with an effective restitution coefficient , e

$$\frac{\text{Reynolds Stress}}{\text{Granular Temperature}} = \frac{\overline{u'_s v'_s}}{\theta} = \left(\frac{5}{8}\right)^{\frac{1}{2}}\left(1-e^2\right)^{\frac{1}{2}}$$ (for dilute limit)



Reynolds Stress and Granular Temperature Comparison

Figure 23 - Granular Temperature and Particle Reynolds Stress for a Three-Phase Bed with U_g = 2.8 cm/s

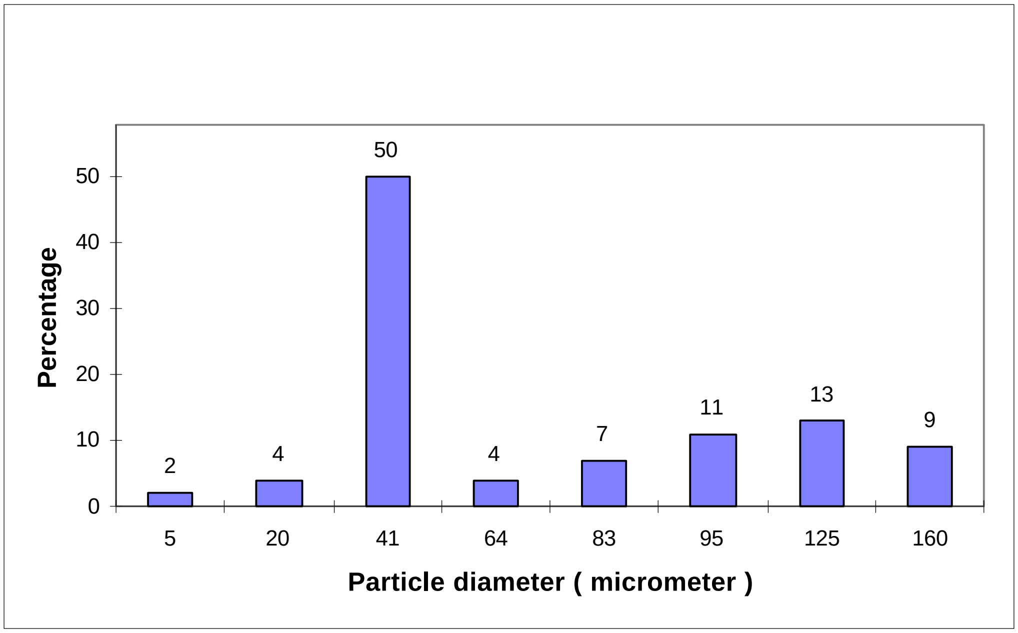


Figure 24 - Fresh Catalyst Size Distribution

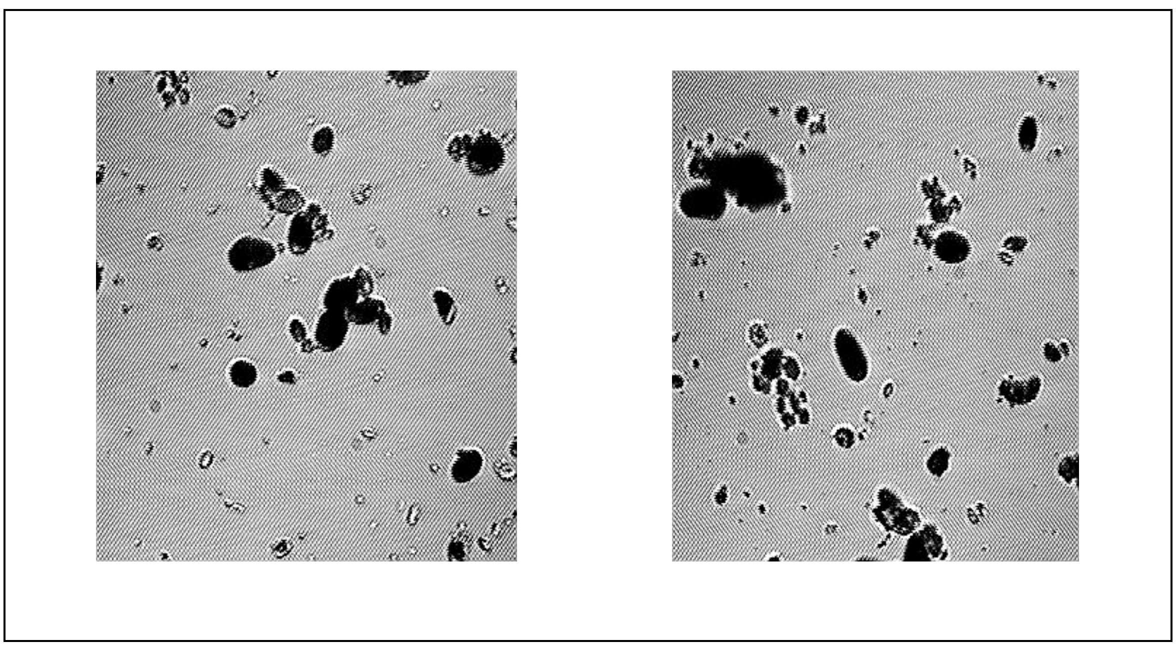


Figure 25 - Used Catalyst Particles Pictures Captured by Microscope

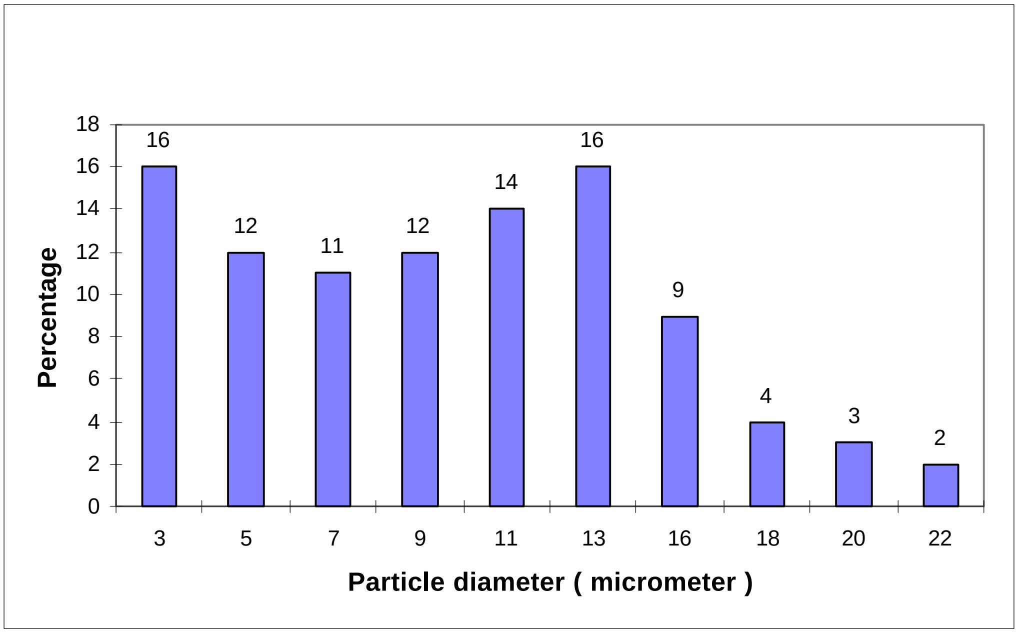


Figure 26 - Size Distribution of Used Catalyst

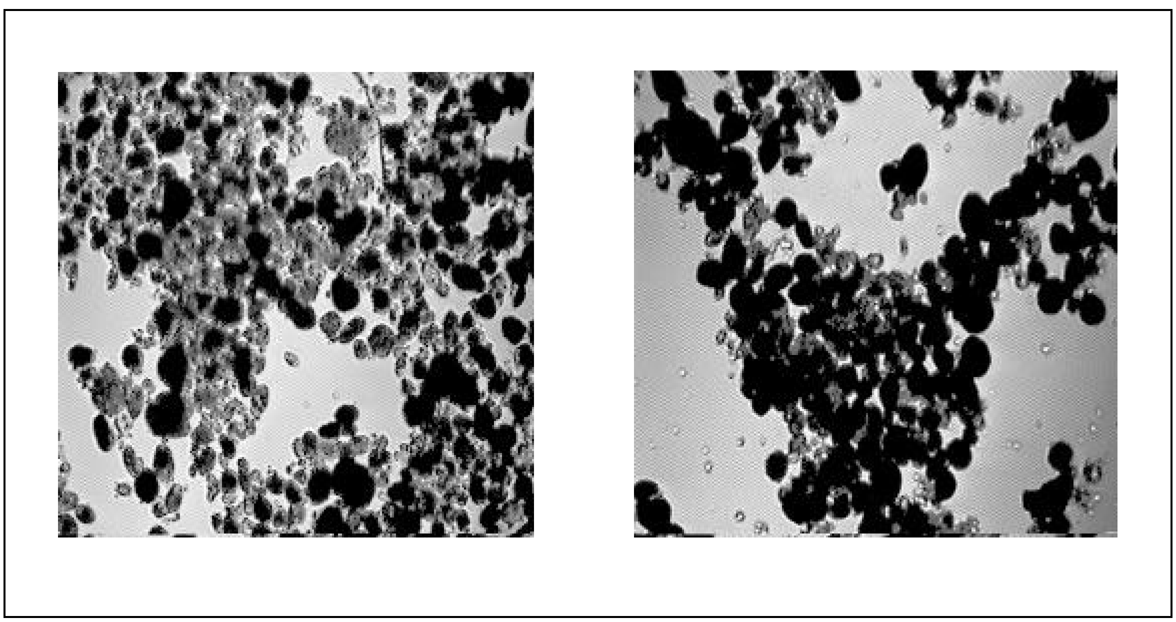


Figure 27 - Cluster Formation from Small Particles