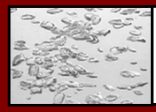
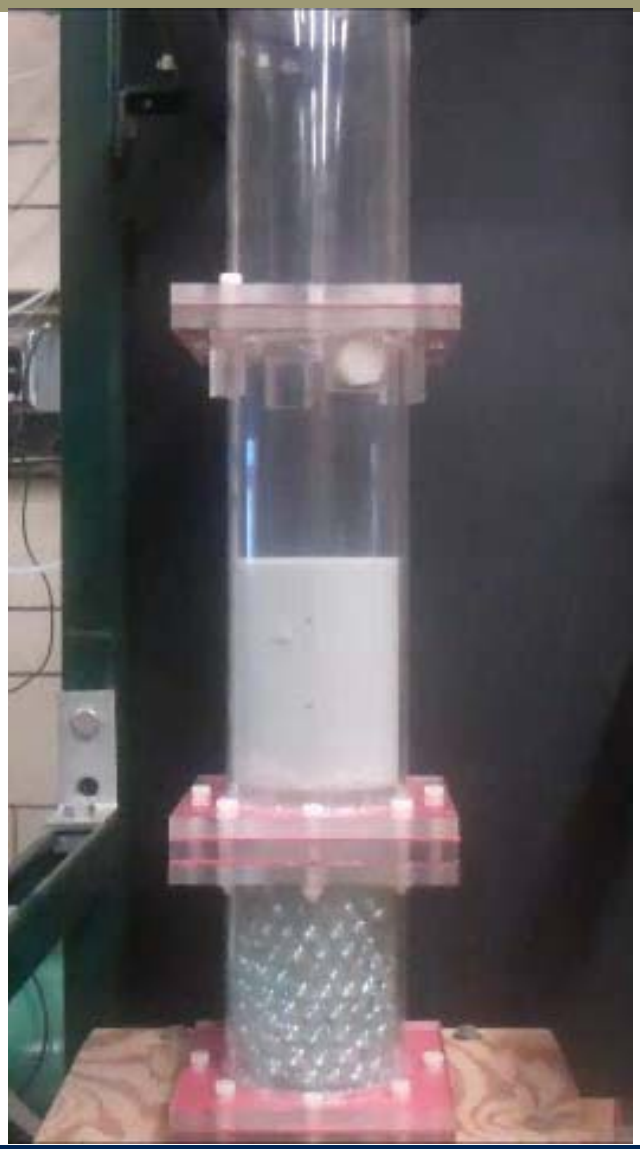


Probe Effects on the Local Gas Holdup Conditions in a Fluidized Bed

Emily Whitemarsh
Department of Mechanical Engineering
Iowa State University

April 14, 2015

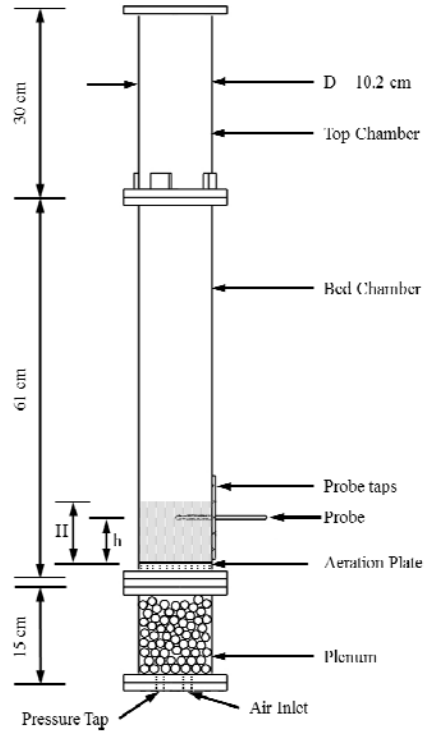
What is a Fluidized Bed?

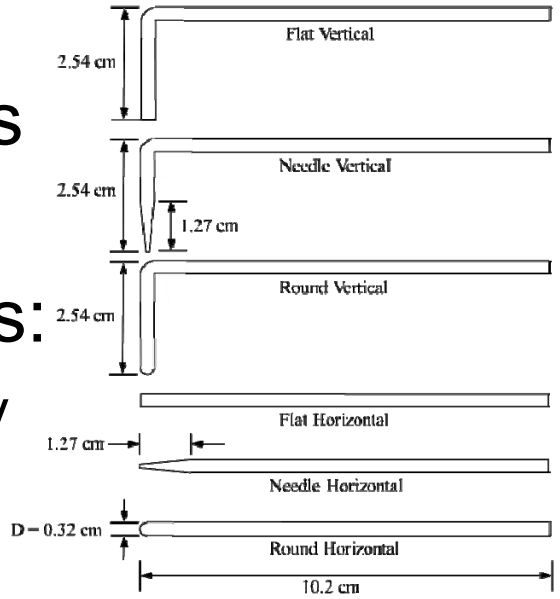


Fluidized Beds

- Used commonly in industry because they provide:
  - High levels of intermixing of the particles
  - High heat transfer rates
  - High relative velocities between fluid and particles
- Hydrodynamic behavior is very complex
- Characteristic Parameters:
  - Minimum Fluidization Velocity (U_{mf})
  - Gas Holdup (ε_g)

Fluidized Bed Diagram





Probe Geometries

Characteristic Parameters: U_{mf} + ε_g

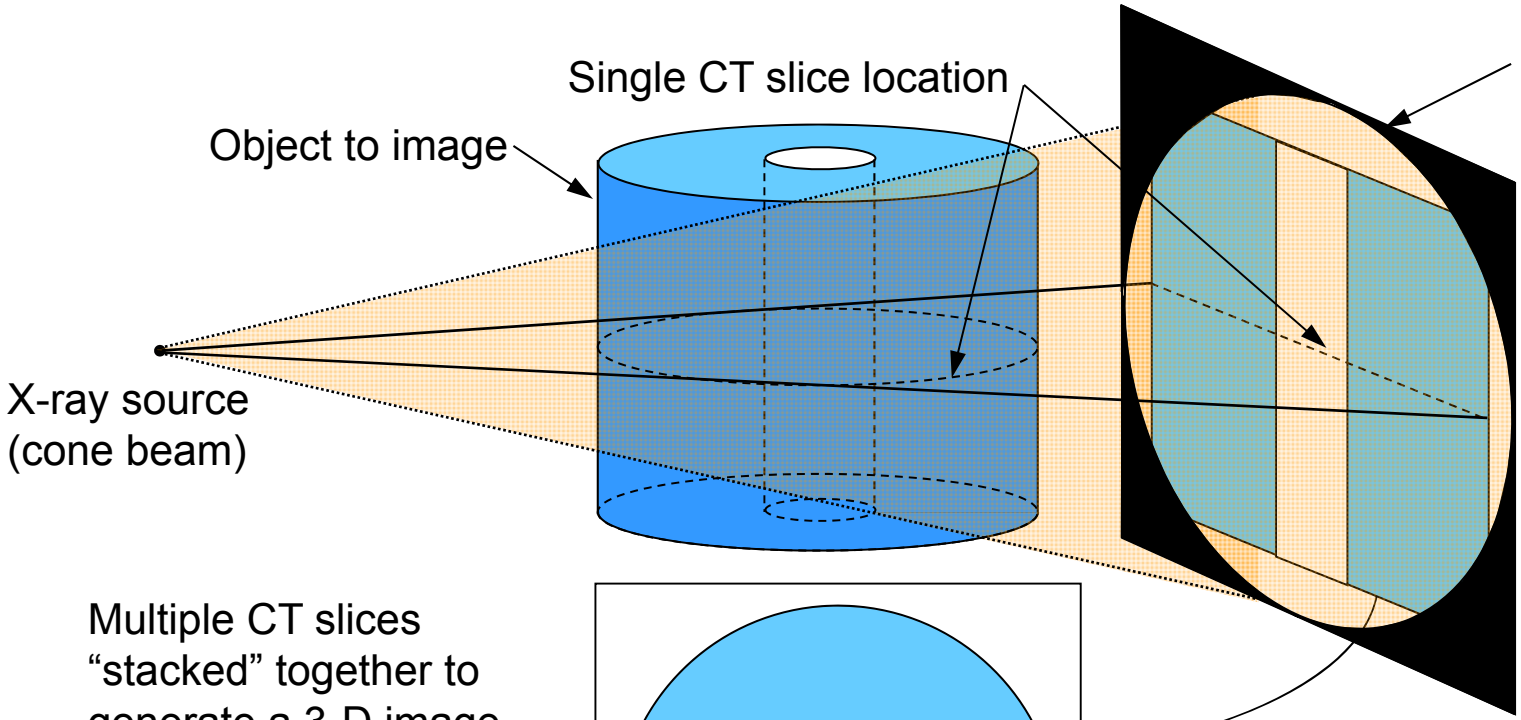
U_{mf}

- Defined as the minimum superficial gas velocity fluidize the bed.
- Sets the lower boundary for fluidization
- Determined by measuring pressure drop across the bed
- Two superficial velocities used in this study:
  - $1.5U_{mf}$
  - $3U_{mf}$

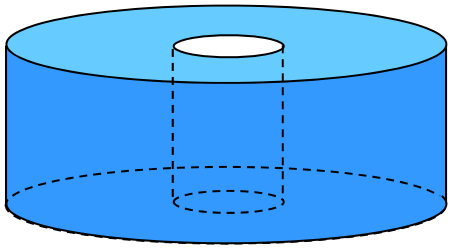
ε_g

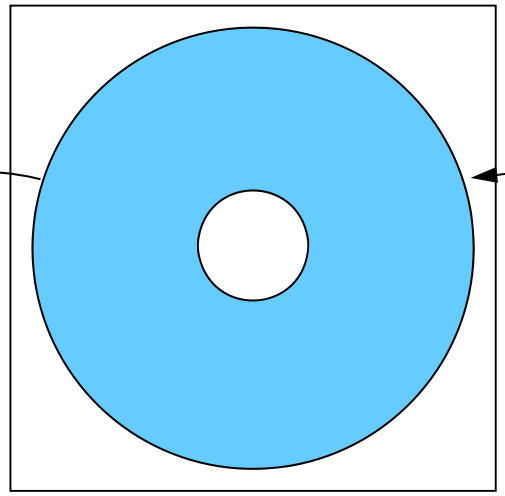
- Defined as volumetric fraction of gas present within the fluidized bed.
- Fluidization quality and mixing quality can be characterized
- Used X-ray computed tomography to determine local gas holdup.

X-ray computed tomography (CT)



Multiple CT slices "stacked" together to generate a 3-D image





Rotate source/detector pair or object
Multiple radiographs from different projections are reconstructed to show internal details of object cross-section

CT slice (2D; time averaged)

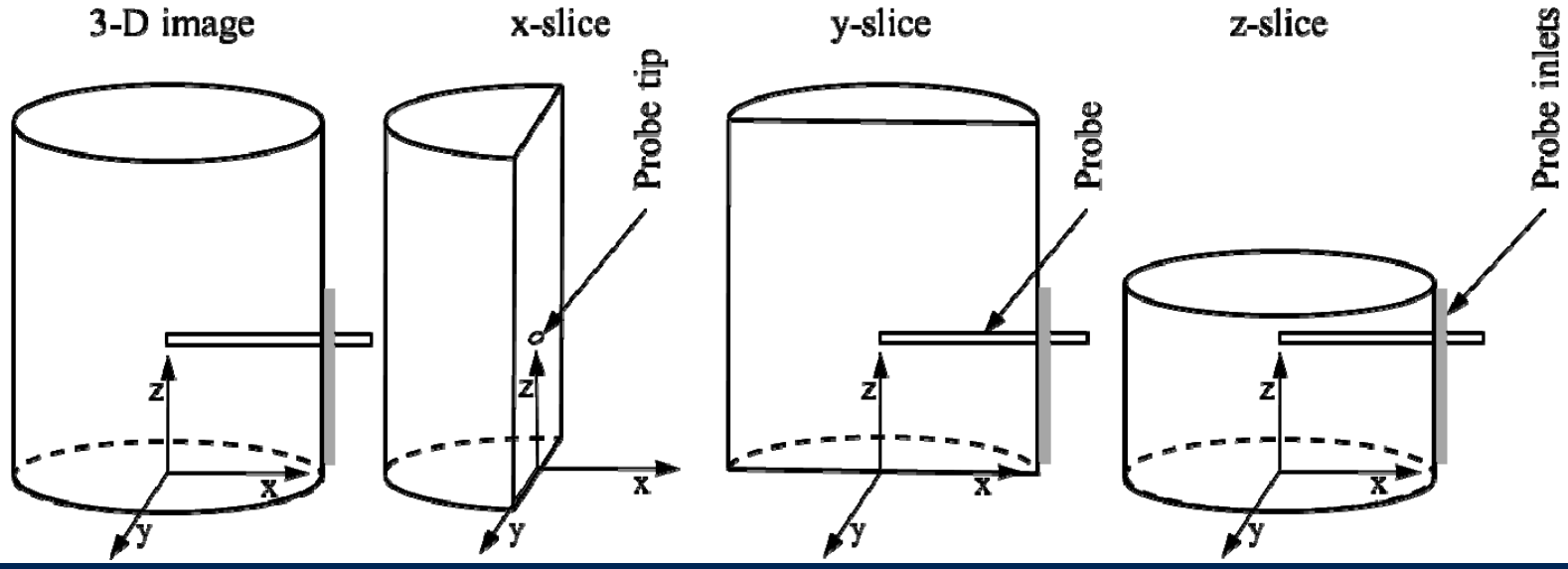
Local Gas Holdup

- Three different types of images were taken to calculate the time-average gas holdup of the bed:
  - A bulk file (I_b)
  - An air file (I_g)
  - A flow file (I_f)

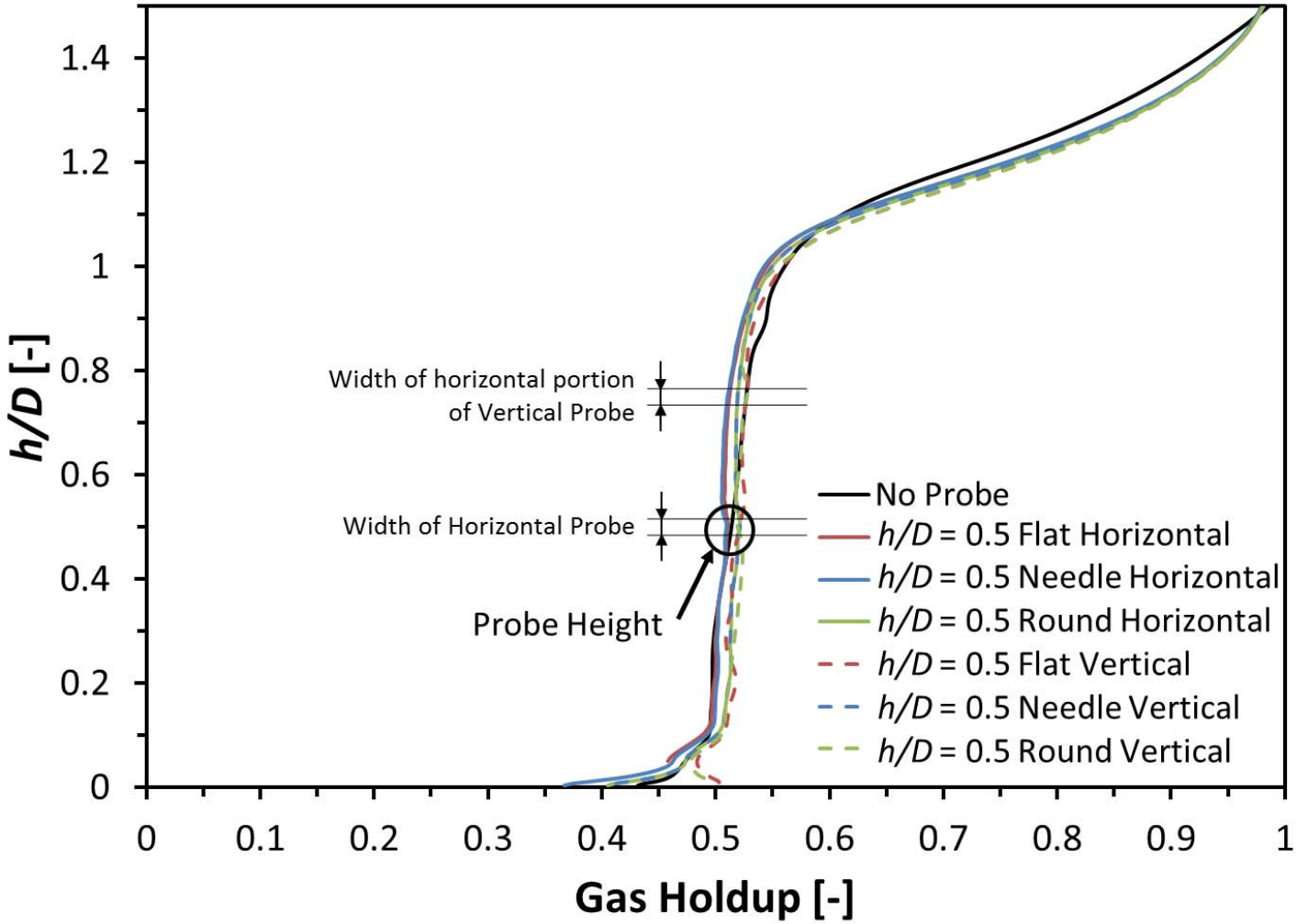
$$\varepsilon_g = \frac{I_f - I_b + (I_g - I_f)(\varepsilon_{g,b})}{I_g - I_b}$$

$$\varepsilon_{g,b} = 1 - \frac{\rho_b}{\rho_p}$$

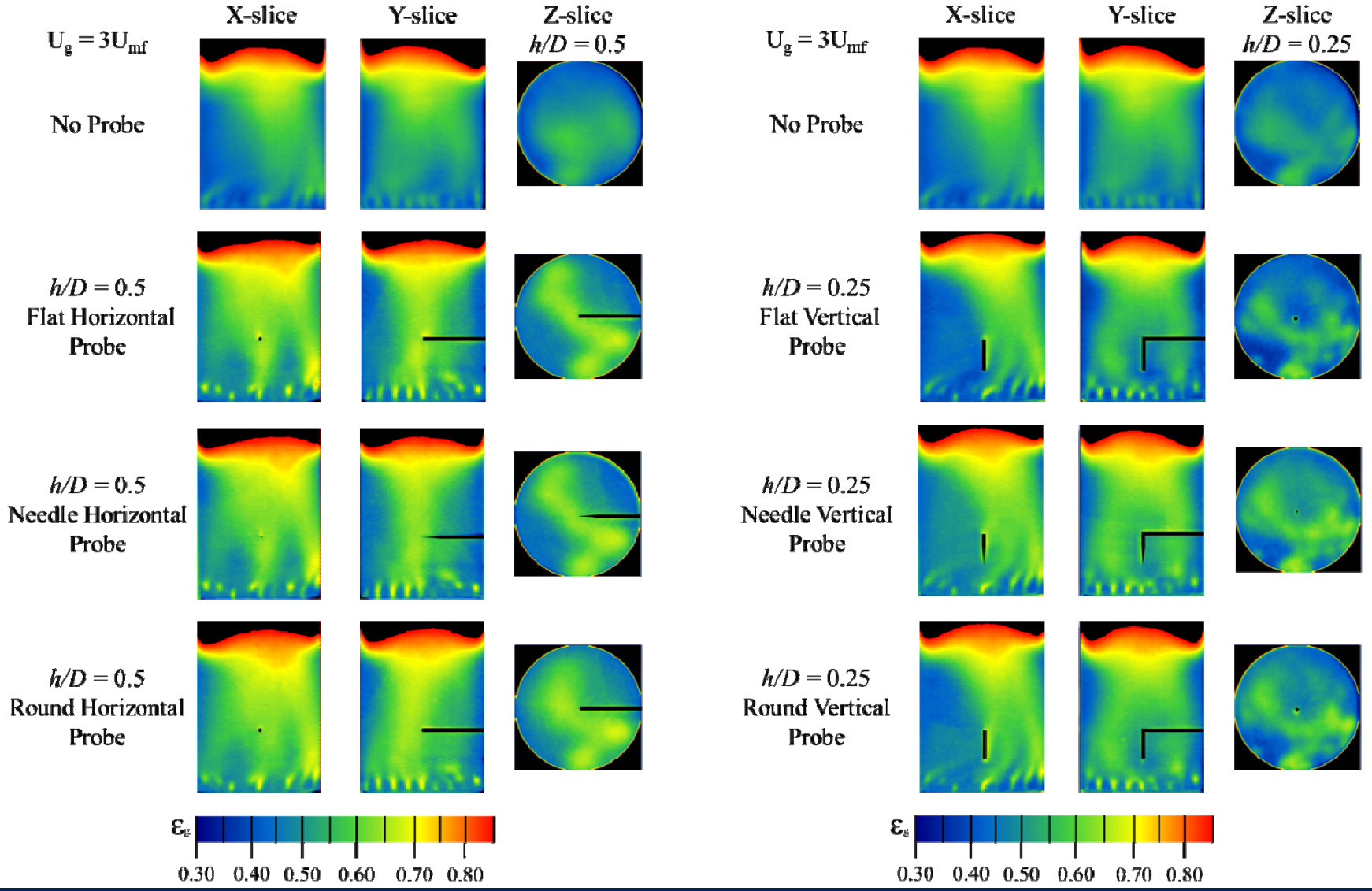
where ρ_b is the bulk density and ρ_p is the particle density.



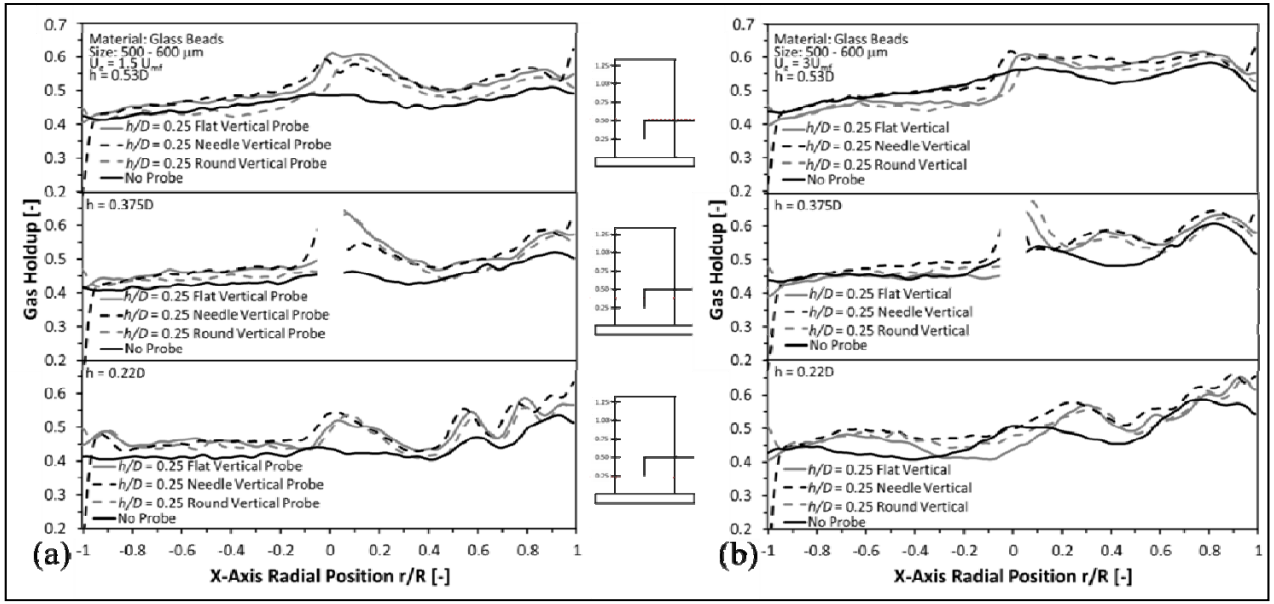
Average Gas Holdup



Gas Holdup Maps



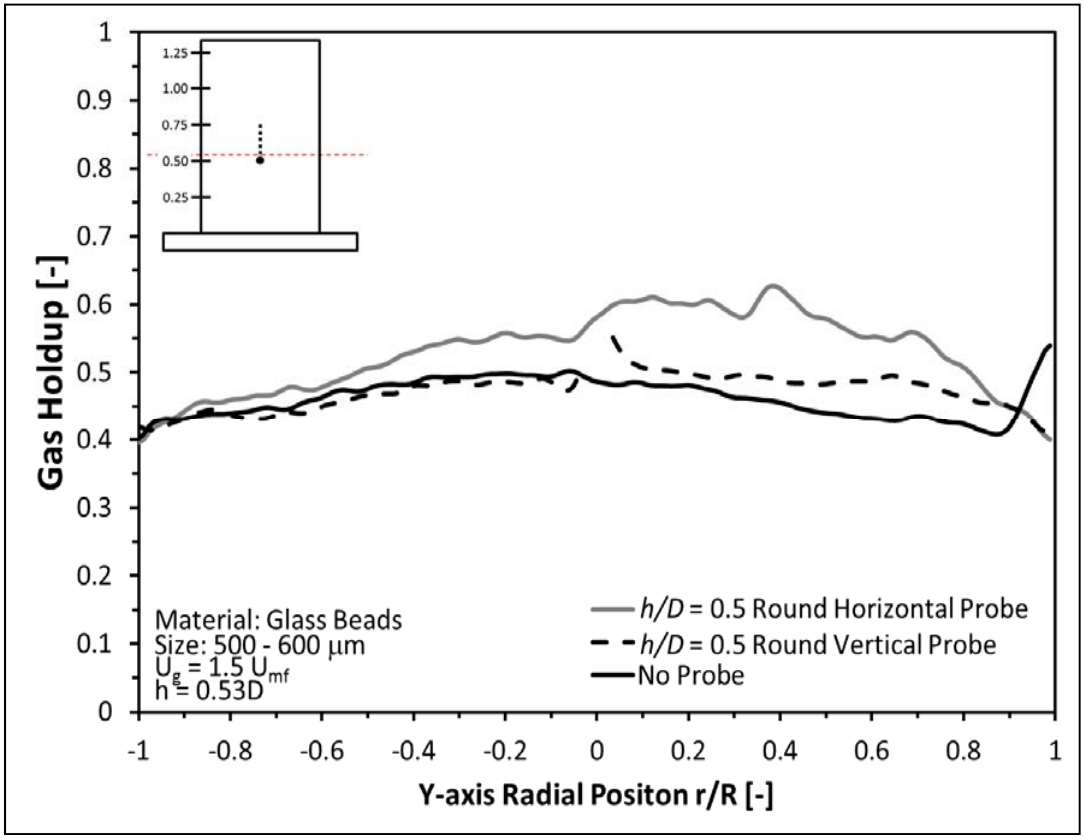
Effect of Flow Rate



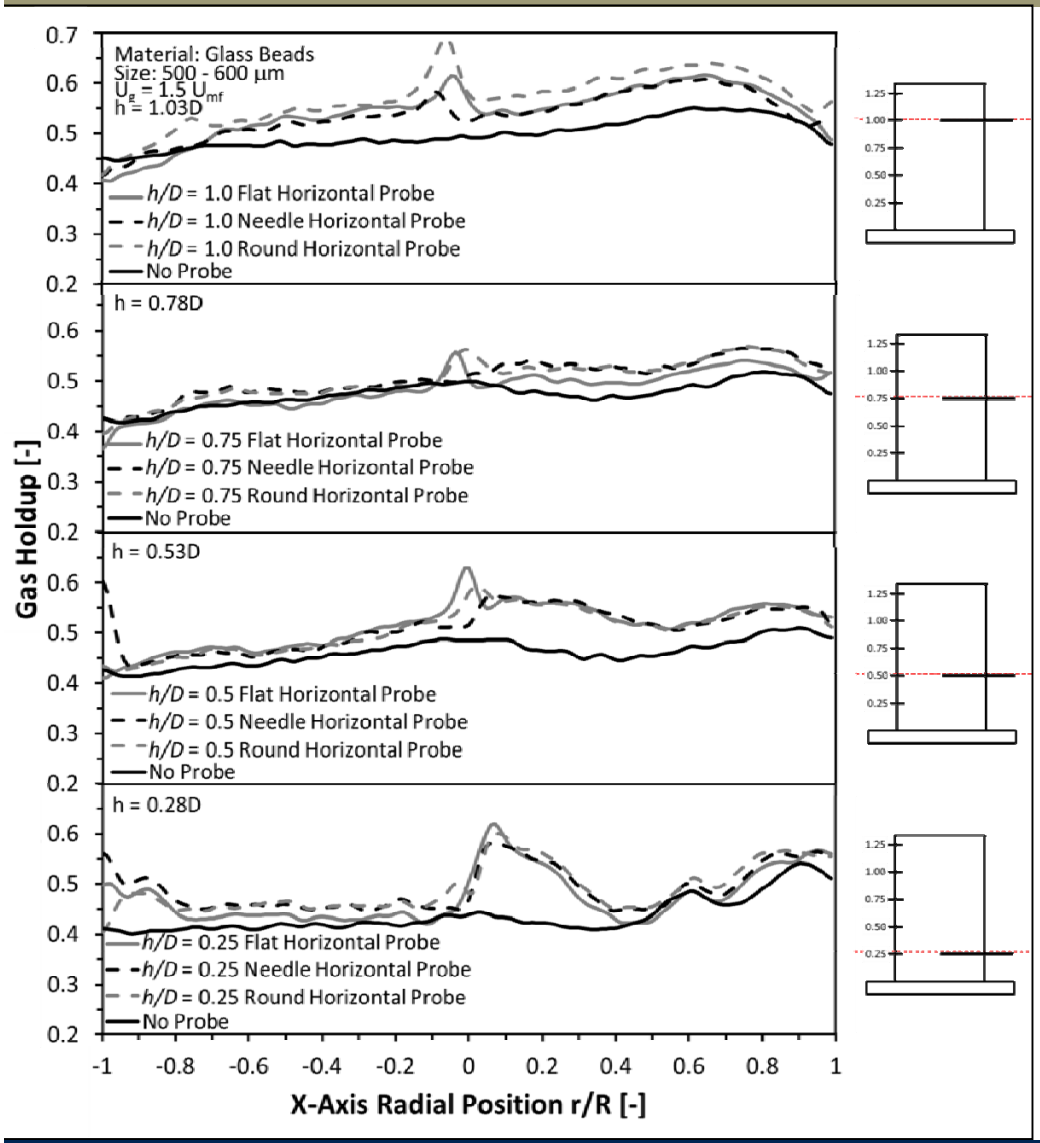
- The effect of the vertical probes is limited at the probe tip
- Gas holdup values are higher along the length of the probe, which infers that a spout of air traversing up the length of the probe
- Trends between flow rate are inconsistent

Effect of Probe Orientation

- The horizontal probes have a distributed effect on the local gas holdup
- The vertical probe orientation has a more localized increase right at the probe tip



Effect of Probe Axial Location



- The lower the probes are inserted, the larger the local variations around the probes.
- 3 different tip geometries showed no differences

Conclusions

- Measurement probes have minimal impact on the *overall* gas holdup, but there are significant *local* variations
- Effects were more prevalent the closer the probe was placed to the aeration plate
- Flow rate impacted the scale of the probe effects, although the trends were inconsistent
- Probe orientation (horizontal, vertical) differed in altering the gas holdup values; neither orientation exhibiting an obvious improvement
- Probe tip type was not a factor in the observed localized effect in the gas holdup values.

Acknowledgements

- Dr. Ted Heindel
- Dr. David Escudero
- Everyone at the Experimental Multiphase Flow Lab

Questions?