NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL 2010 Workshop On Multiphase Flow Science

An Experimental Determination of Jet Penetration Into A CFB Riser

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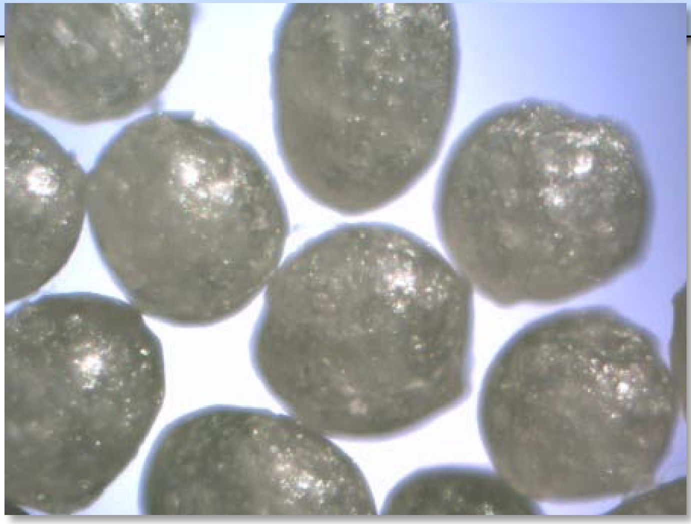
Outline

- Motivation – “Why Bother?”
- The Experiment – “How Are We Going To Do This?”
- The Jet – “What We’d Like to Control”
- The Raw Data – “What Do We Get?”
- The Reduced Data – “What Does This Mean?”
- Summary – “So What?”

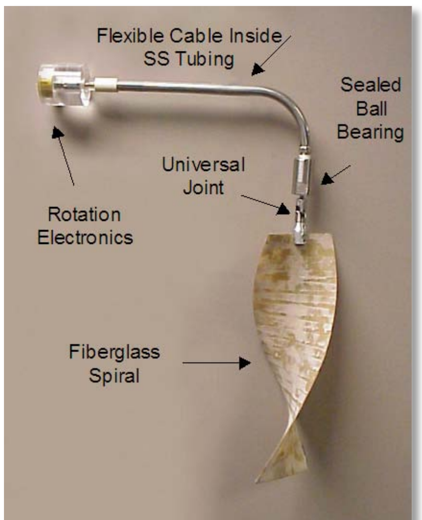


Motivation

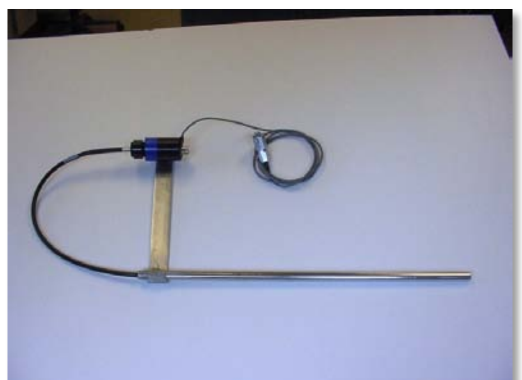
- Many transport reactor and CFB designs require solids feed at locations other than bottom
- Solids mixing and residence time distribution depends on how far the solids penetrate into the flow
- Supply experimental data for model validation

“Three” Measurement Techniques Used

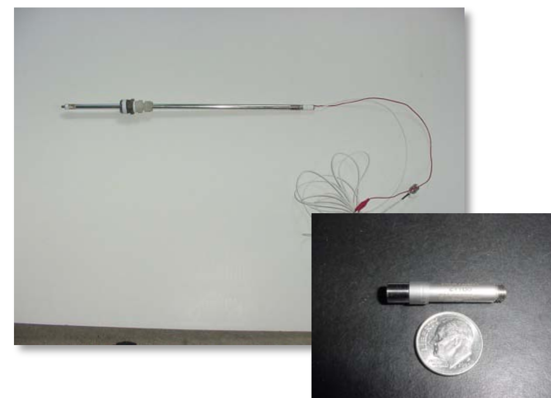
- **Solids mass flow in the jet measured using a 12 cm wide “Spiral” in feed line**



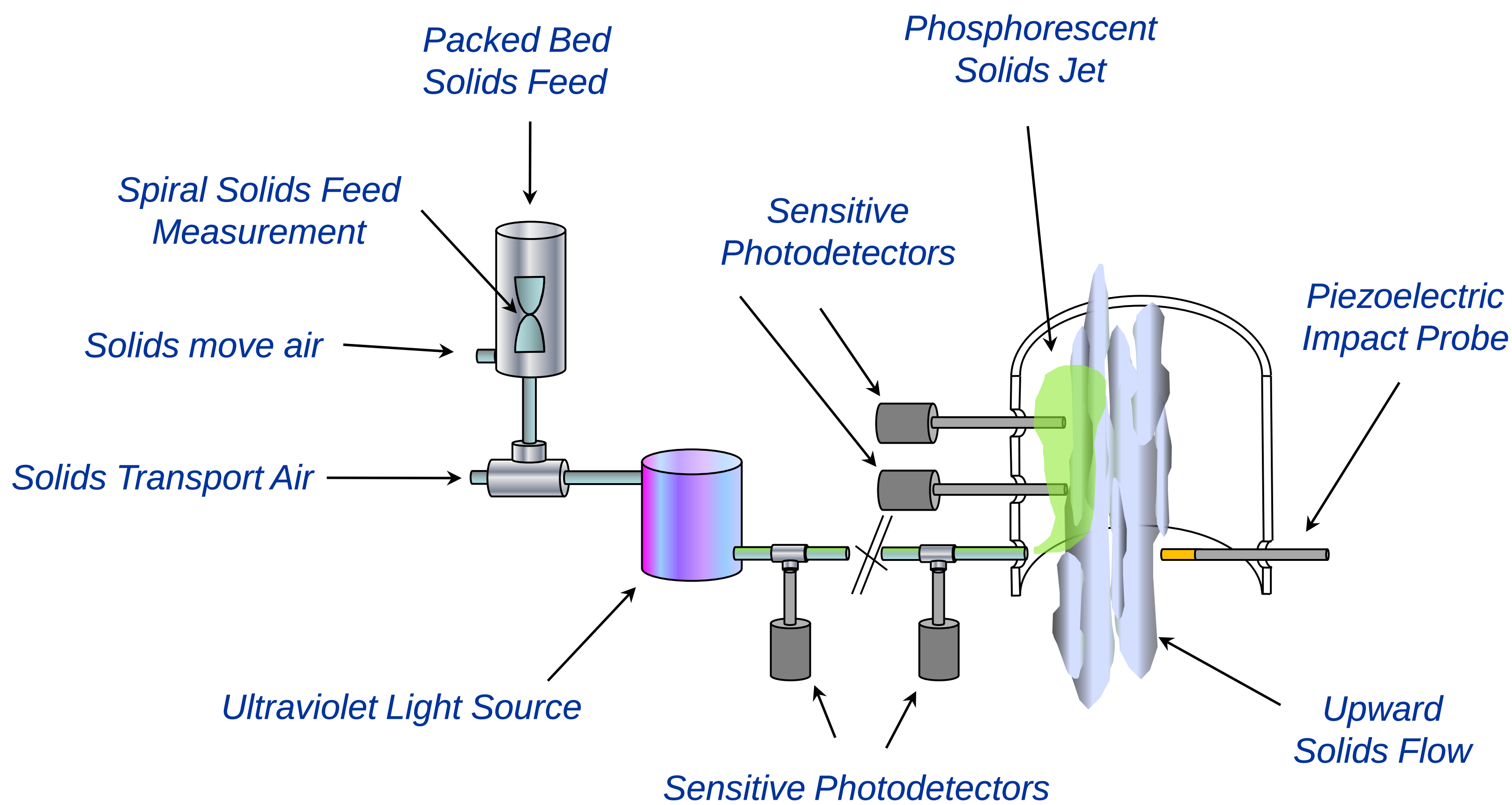
- **Particle tracking of phosphorescent jet within the riser uses sensitive photodetectors**
  - Two axial positions (15 cm and 30 cm above jet entrance)
  - 11 radial positions



- **Detection of radial component of jet particle velocity uses a small piezoelectric pressure transducer.**



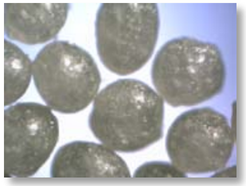
Experimental Setup

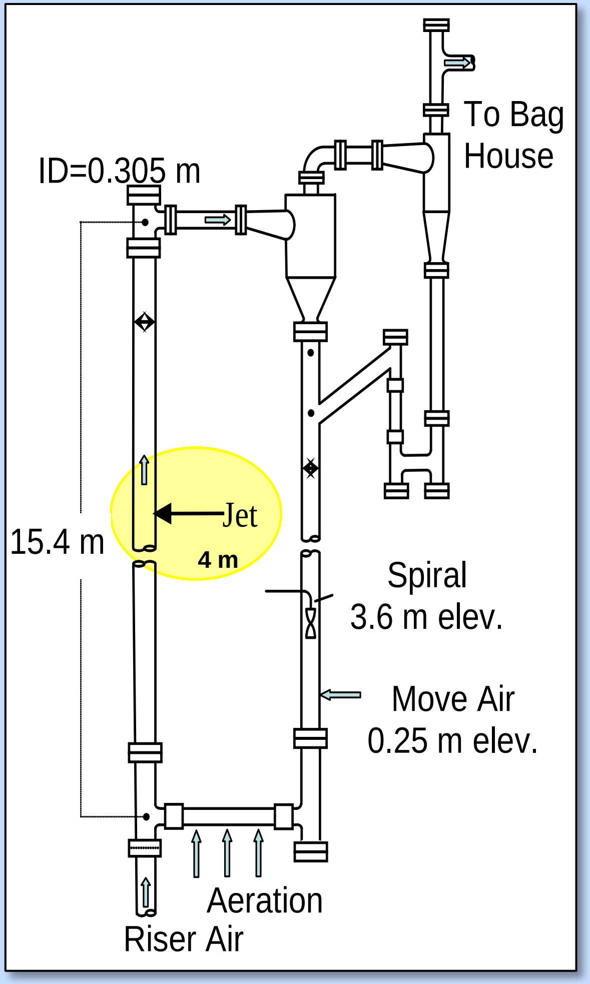


Experimental Conditions

	Jet conditions		Riser conditions	
Std No.	*Void fraction*	*U_{jet} m/s*	*Riser Air m/s*	*Circ rate kg/s*
SN0	*0.97*	*16.64*	*7.62*	*11.34*
SN1	*0.97*	*8.53*	*7.62*	*11.34*
SN2	*0.97*	*37.18*	*7.62*	*11.34*
SN3	*0.95*	*16.64*	*7.62*	*11.34*
SN4	*0.99*	*16.64*	*7.62*	*11.34*
SN5	*0.99*	*36.83*	*7.62*	*11.34*
SN6	*0.97*	*16.64*	*7.62*	*2.83*
SN7	*0.97*	*16.64*	*5.49*	*1.42*

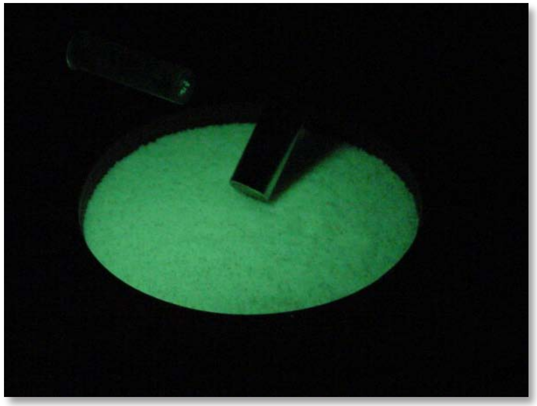
Particle Diameter (um)	**750**
Particle Density (gr/cc)	**0.867**

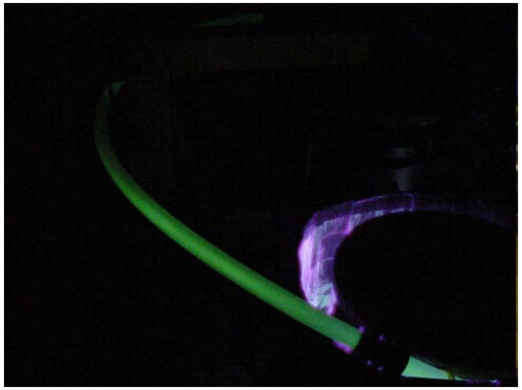




The Jet

- **Want to independently set…**
  - Average solids mass flow in jet
    - Solids mass flow set by…
      - adjusting solids transport air
      - solids move air
      - pressure drop across solids feed system
    - Measured using Spiral
  - Average solids fraction in jet
    - Depends on solids velocity in transport line
      - function of transport air flow
      - move aeration air flow
      - solids feed pressure drop

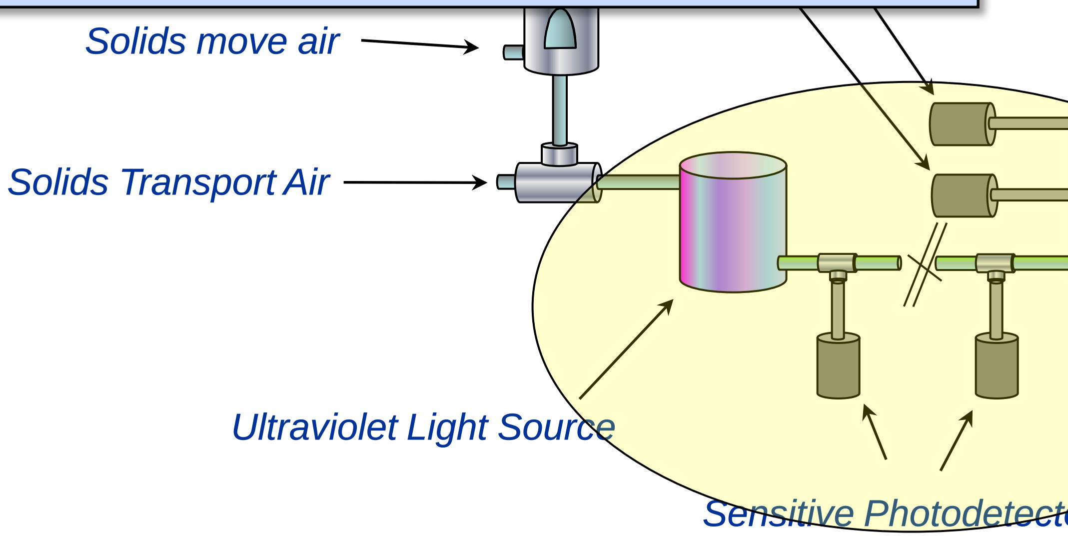


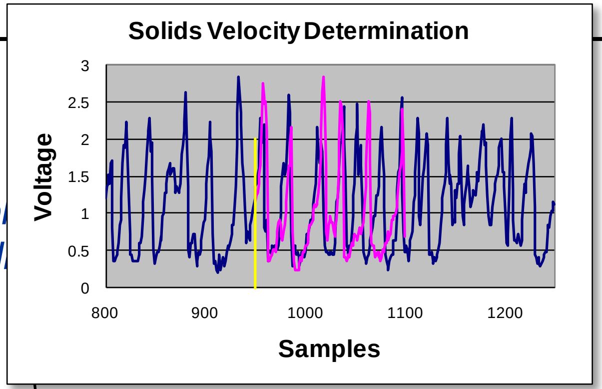


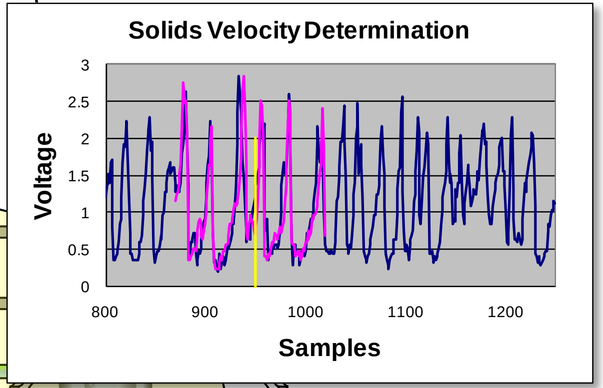
- $$Solids\ Fraction = \frac{(Mass\ Flow)}{(Solids\ Velocity)*(Flow\ Area)*(\rho_{particle})}$$

Jet Solids Velocity

- *Two photo receivers, one at beginning and one at the end of the transport line*
- *Actual solids velocity determined by cross correlating two signals*
- *Solids Fraction calculated from actual solids velocity and measured mass flow (feed spiral)*





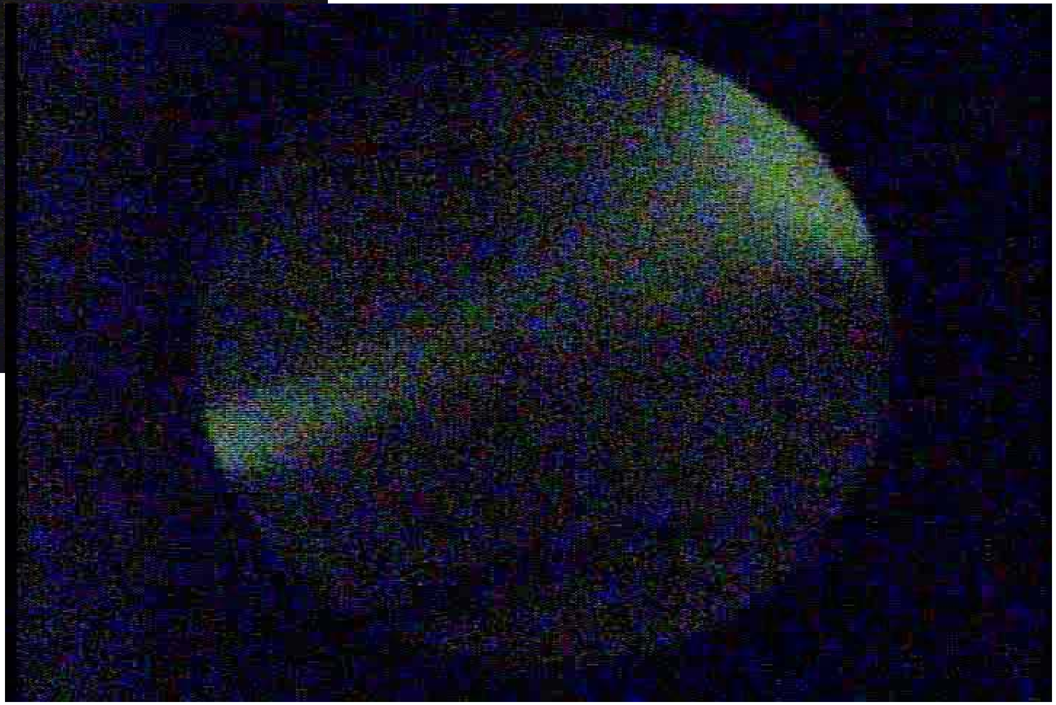


Video clips of Jet in Riser

G_s=0 kg/m^2-s, U_g=7.6 m/s

Front View

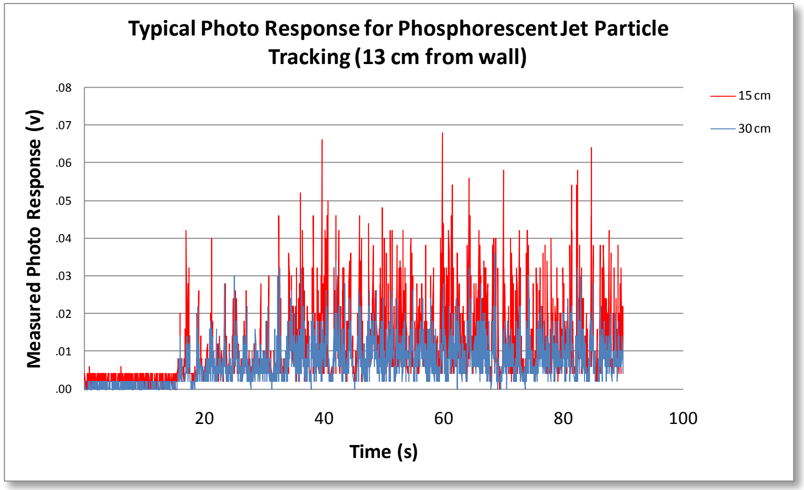
Side View

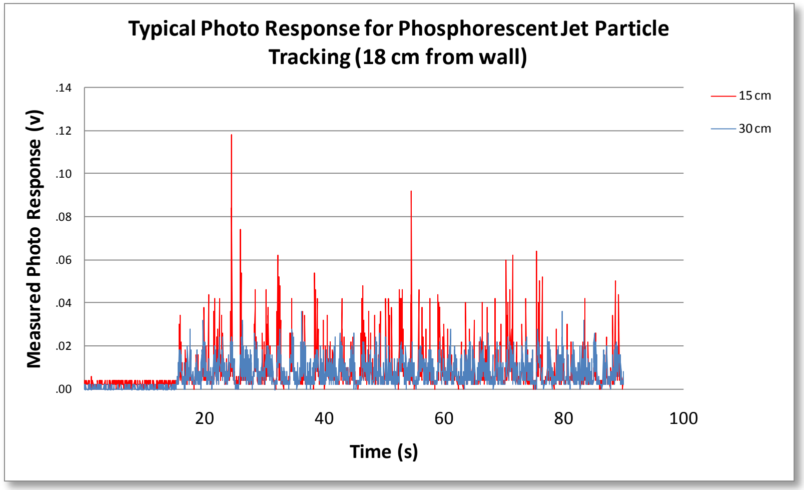


Raw Data
Particle Tracking

Phosphorescent Particle Tracking

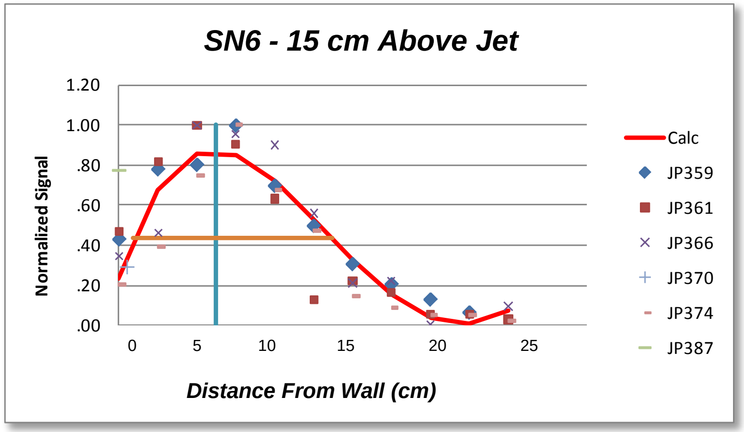
•Net response calculated by subtracting average dark response from average lit response
•Net photo response measured 15 cm and 30 cm above jet entrance and at 11 different radial positions
•Photo response for each radial profile normalized by dividing each net response by maximum net response for that experiment

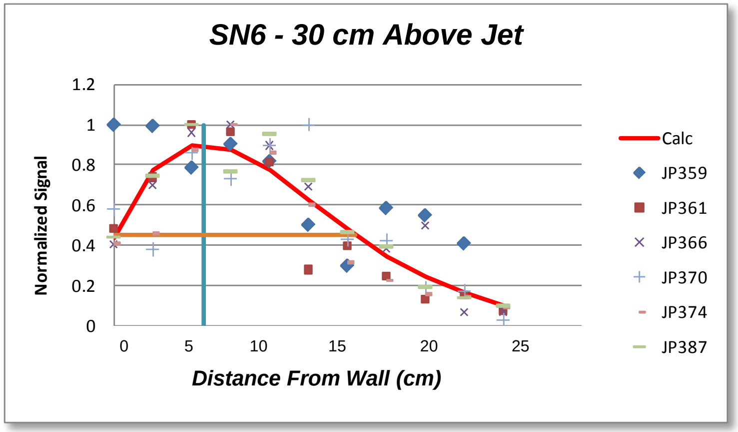




Reduced Data
Particle Tracking

- *Normalized response graphed as a function of radial position*
- *Resultant data fit with 4th order polynomial*
- *Location of peak calculated*
- *Width of curve determined at one half maximum peak value*

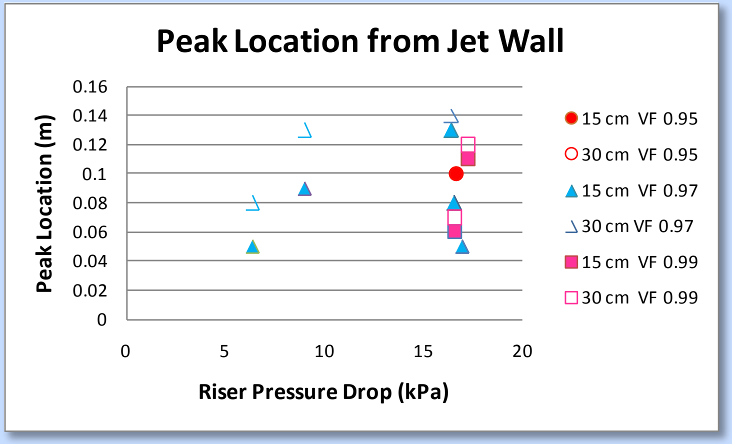


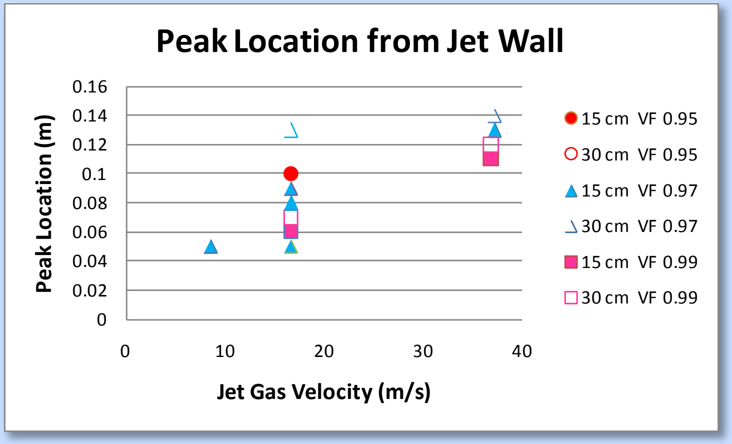


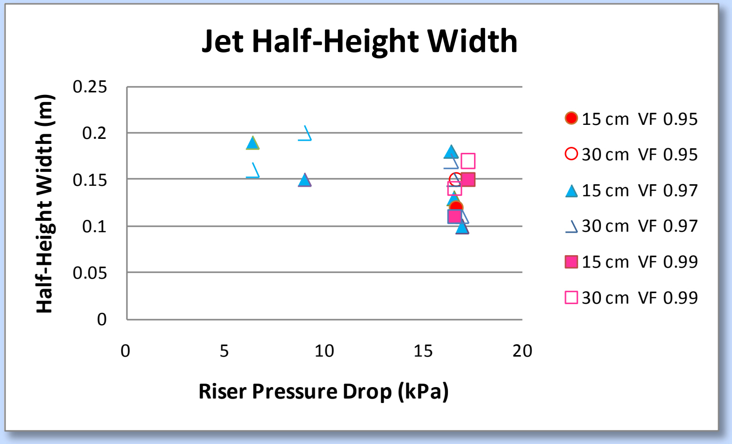
Summarized Experimental Results

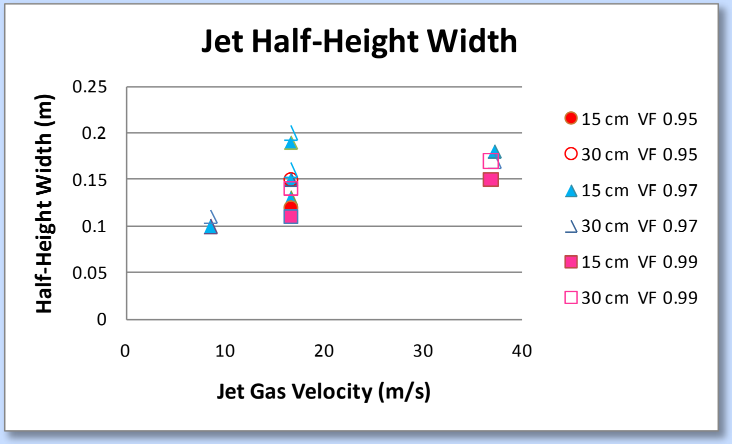
	Riser Conditions			Jet Conditions		0.15m Above Jet		0.30 m Above Jet	
	Riser Air (m/s)	Circ. Rate (kg/s)	Riser Pressure Drop (kPa)	Void Fraction	U_{jet} (m/s)	Radial Peak Location (m)	Half-Height Width (m)	Radial Peak Location (m)	Half-Height Width (m)
SN0	7.62	11.34	16.53	0.97	16.64	0.08	0.13	0.08	0.15
SN1	7.62	11.34	16.94	0.97	8.53	0.05	0.1	0.05	0.11
SN2	7.62	11.34	16.39	0.97	37.18	0.13	0.18	0.14	0.17
SN3	7.62	11.34	16.65	0.95	16.64	0.1	0.12	0.1	0.15
SN4	7.62	11.34	16.56	0.99	16.64	0.06	0.11	0.07	0.14
SN5	7.62	11.34	17.25	0.99	36.83	0.11	0.15	0.12	0.17
SN6	7.62	2.83	6.36	0.97	16.64	0.05	0.19	0.08	0.16
SN7	5.49	1.42	8.97	0.97	16.64	0.09	0.15	0.13	0.2

Summarized Experimental Results





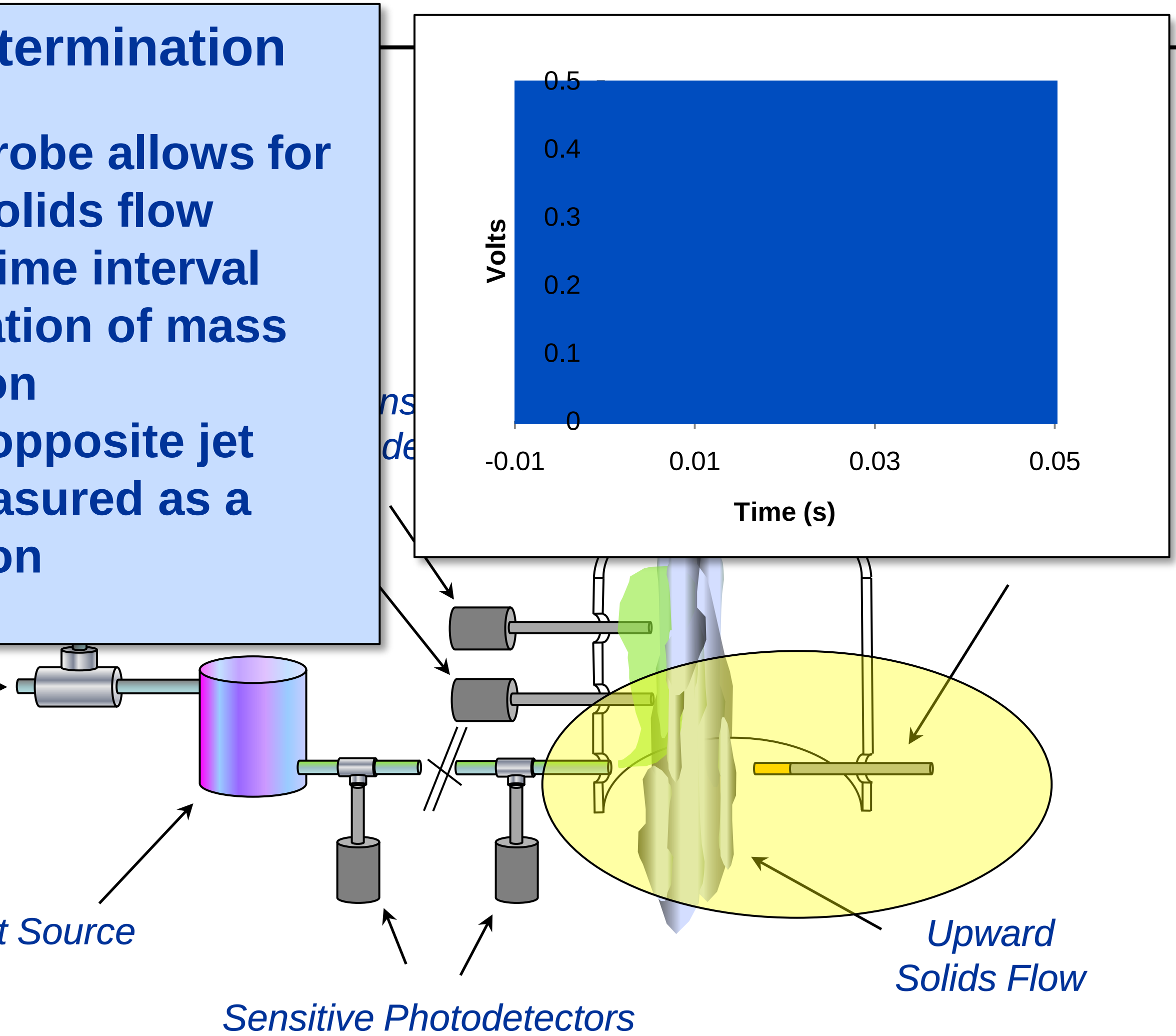




Jet Penetration – Particle Impact

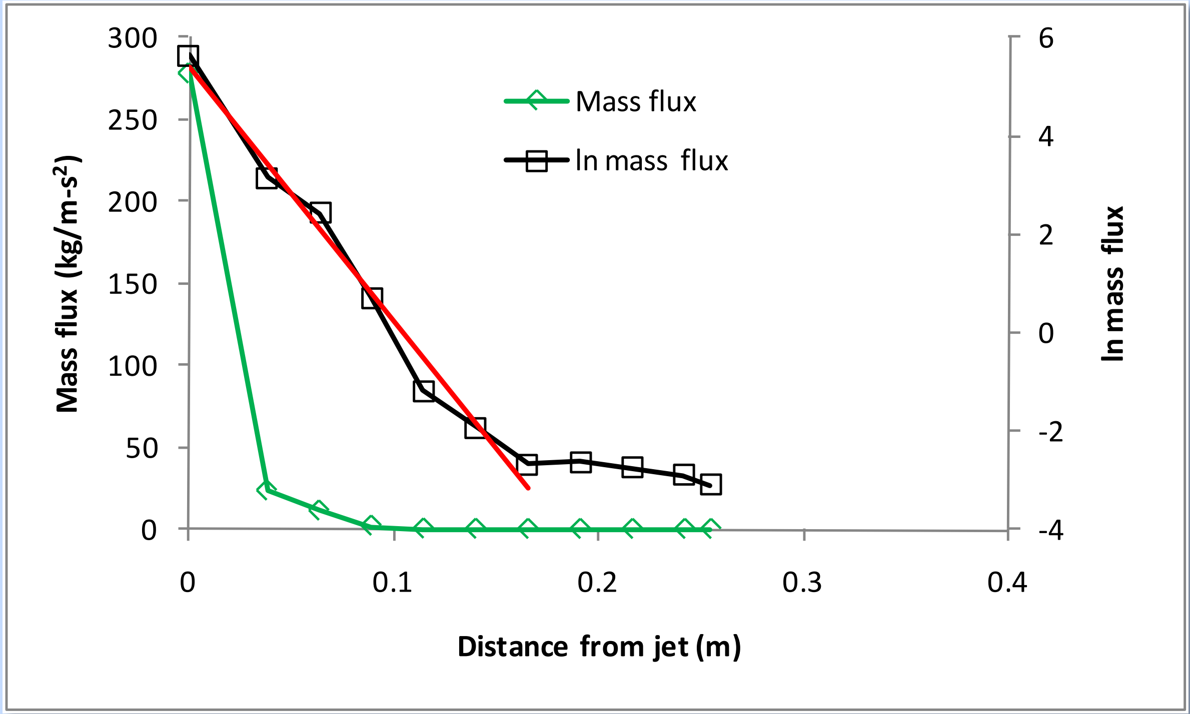
Radial Solids Flux Determination

- Horizontally oriented probe allows for the detection of radial solids flow
- Number of strikes per time interval allows for the determination of mass flux in the radial direction
- Probe located directly opposite jet
- Number of impacts measured as a function of radial position



Reduced Data - Particle Impact

- Radial mass flux calculated from number of particle impacts
- Natural log of flux plotted versus distance from jet
- Slope of linear portion used to characterize jet penetration

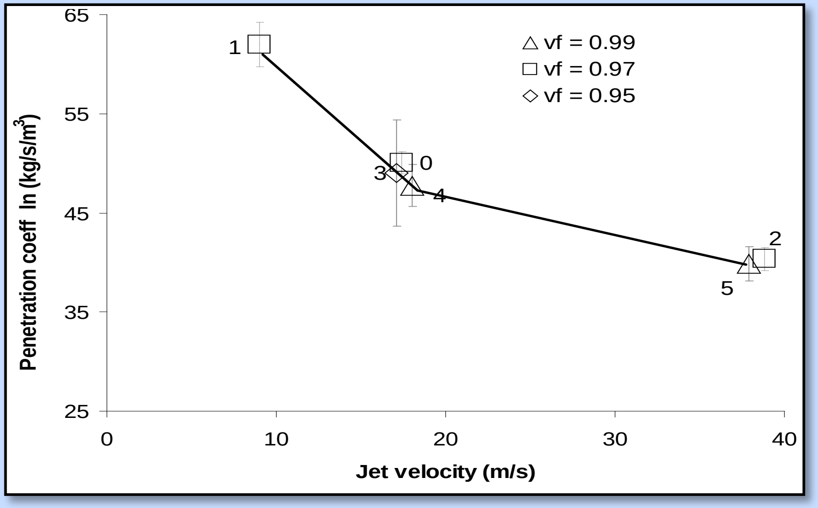


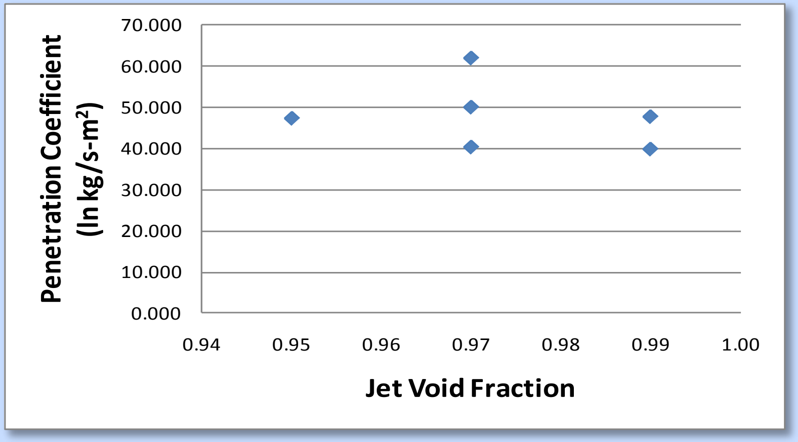
$$Solids\ Flux = \frac{\left(\frac{Number\ of\ Strikes}{Second}\right) * (Single\ Particle\ Weight)}{(Detector\ Area)}$$

Particle Impact Decay Rate Measured In-line With Jet

- Jet penetrates farther as jet gas velocity increases (penetration coefficient smaller)

- Can't tell if penetration of jet is a function of jet void fraction





Summary

- Phosphorescent bed material was used to track jet material inside the riser
- Jet spreads as material is carried up riser
- Higher jet gas velocity carries material into riser further (seen in tracer and impact data)
- Higher gas velocity results in slightly broader jet distribution
- Jet void fraction has little effect on penetration