PROCESS METRIX
Instrumentation for Process Control

Mass Balance Flow Facility (MBFF)

Figures A1 and A2 show overall views of the MBFF at PMC and the figure captions describe the overall layout, (not repeated here). The basic seeded flow is 120 cfm (58,000 cm^3/s, ±3%), and the mass flow rate can be varied by a factor of 20 from 0.5 to 10 gm/min (±10%) from the AccuRate™ auger feeder. The auger feeder provides quasi-steady mass feed-rates that are measured about every third size distribution result by collecting and weighing approximately 2-4 gms of sample at the auger exit for a period of 4-8 minutes. Specific mass feed-rates could be accurately determined with accuracy better than 5%, although short term fluctuations (1 sec rate averages) from the auger gave factors of 2 variation in the particle count-rate. Typical distribution measurement times were 2 minutes, averaging out these short term fluctuations. This gives mass feed concentrations on the order of 150 mg/m^3 for the lower range of measurements, approximately 200 times higher than measured levels in filtered Syn Gas. The new PPC software allows both short term and long term continuous integrations on a rolling time basis which will allow operators to observe both short term (1 second) count-rate fluctuations, and longer term average size distribution and absolute particle concentration variations .

The MBFF method is simpler, and we believe more accurate than sampling and weighing milligram level samples of powder in the flow (e.g. Method 5). Repeatability on total mass of better than 5% can be achieved over the short term. Significantly, this approach allowed us to carry out several hundred measurements efficiently and accurately over a period of 2 months, investigating a wide range of potential interface and operating conditions. The only assumptions necessary for this approach are to determine uniformity of powder dispersion across the flow pipe (3" dia), and to validate that particle transport in the seeded system is essentially 100% (negligible losses). Both these requirements were verified and are discussed further below.

A.1 Dust Dispersion

Figure A3 shows a detailed view of the mass feed system. The vibrating ramp helps to damp out some of the short term auger feed-rate variations. The eductor provides an injection mechanism for the powder, and more importantly disperses the agglomerated powder. We performed tests with both heated (i.e. dried) powders and unheated powders and found little variation in the measured size distribution for sufficiently high eductor motive air. However, at lower dispersion flow rates, we measured larger particle sizes, which gave lower particle count rates, as shown in Figure A4. Above motive air flow rates of 150 SCFH, there was no discernable variation in size distributions or count rates. All measurements are obtained at motive air flow rates in the range of 180-200 SCFH.

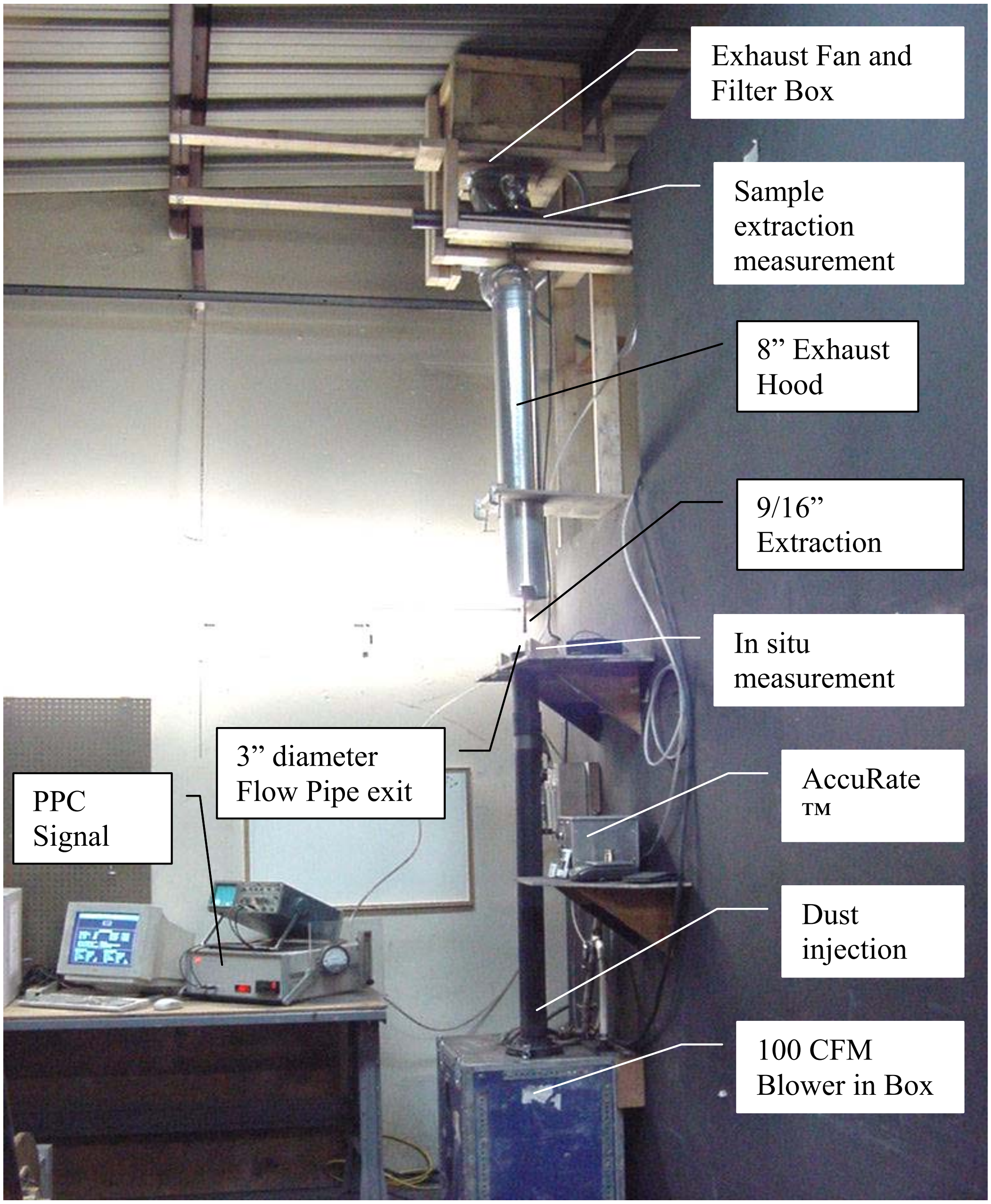

Figure A1. Overview photo of vertical Mass Balance Flow Facility (MBFF) at PMC. Signal Processor is shown on the left. The box at the bottom houses a nominal 100 cfm centrifugal blower. An AccuRate ™ feeder meters dust flow rates ranging from 0.5 – 10 gm/min into an vibrating ramp and venturi eductor (shown in further detail in Figure 6). The main flow pipe is 3 inches diameter, and has a length of 4 feet (16 diameters) to the free exit. In situ measurements are performed in the free jet at this exit. This photo shows the 9/16” diameter extraction probe (5 ft. in length) in center of exhaust hood, with PPC located at sample extraction point. The dust-seeded flow passes through a fan and filter box through the roof.

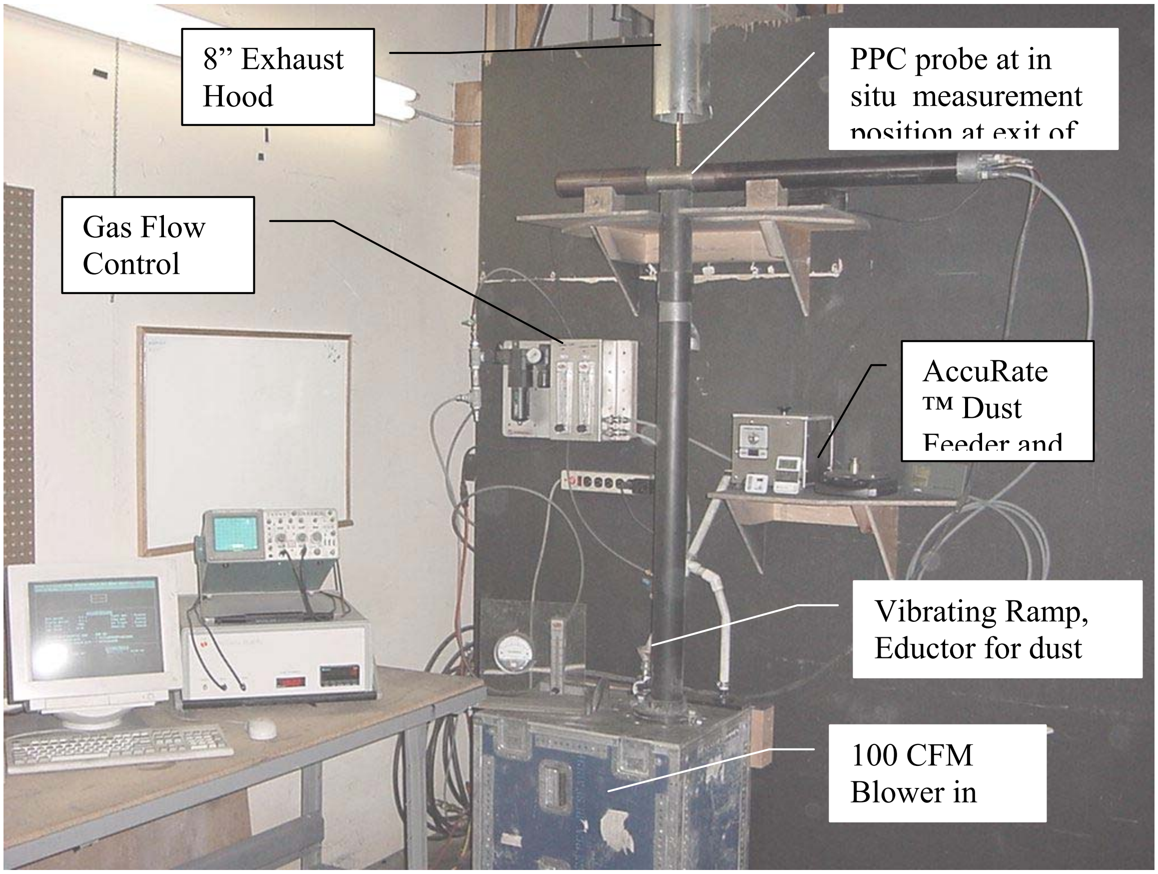

Figure A2. View of lower half of MBFF with mass feeder, vibrating ramp, and eductor for dispersion of dust feed into 3” primary flow of 110 cfm. PPC is shown located at in situ measurement position in free jet exit of primary flow.

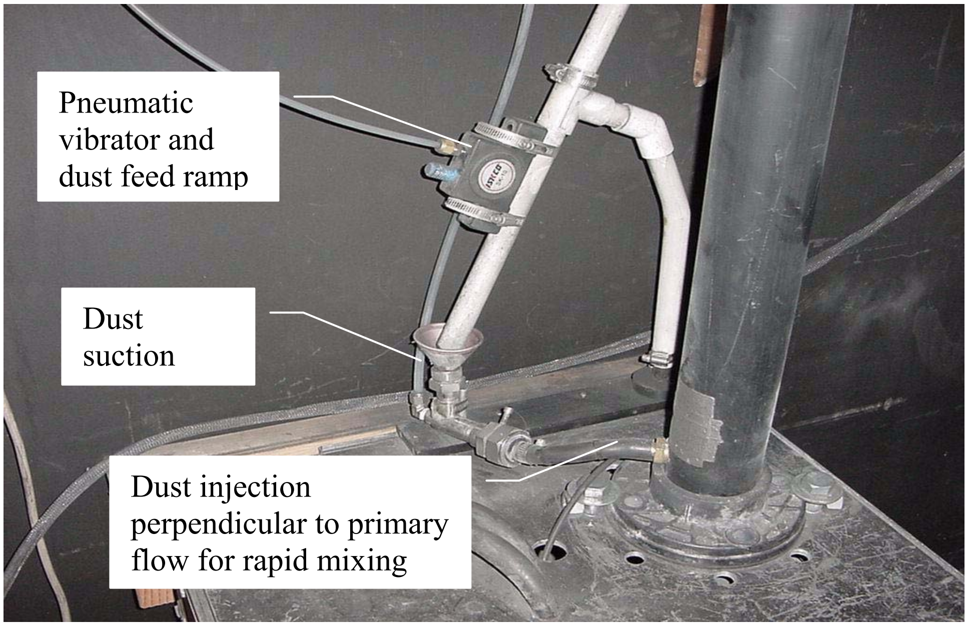

Figure A3. Vibrating ramp and suction eductor injection of dust feed into primary flow of MBFF.

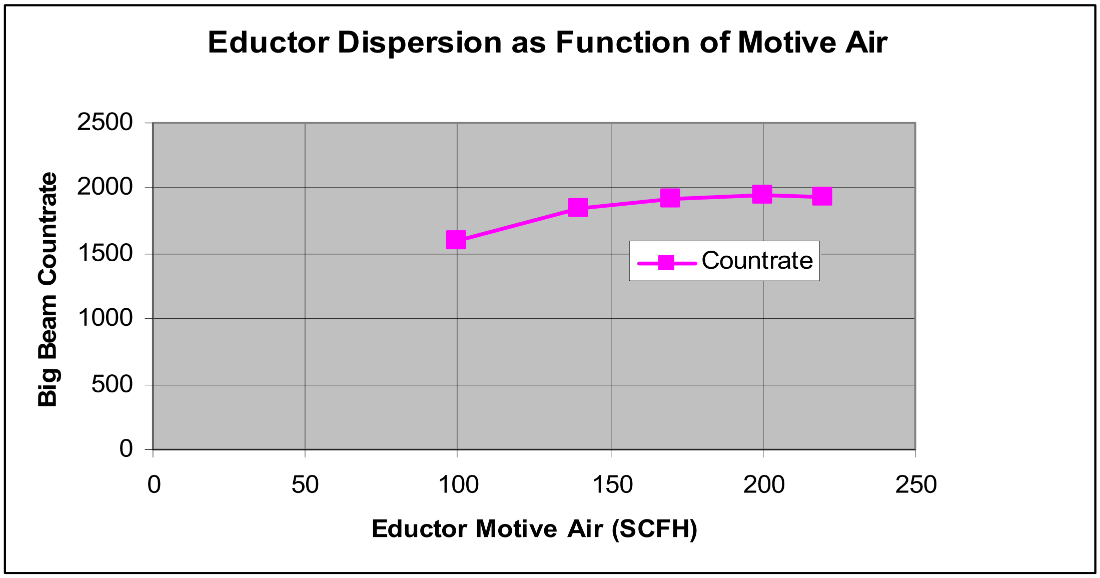

Figure A4. Variation of feed particle dispersion as a function of eductor motive air for a given mass flow rate. Decreased count-rate indicates particle agglomeration. From these results we learned that the minimum eductor flow rate is 150 SCFH.

At the dust suction intake the volume of air (and feed material) is approximately equal to the motive air flow rate, which gives an injected dispersed powder flow rate of approximately 6 cfm and a flow velocity of 35 m/s perpendicular to the primary flow of 110 cfm, with centerline peak velocity of approximately 14 m/s. This orthogonal injection provides rapid mixing of the dispersed powder in the primary flow. We also checked to see if co-axial injection at the centerline would improve the uniformity of the flow pipe exit mixing or change particle loss at the walls, but again found no discernable change in the size distribution or absolute concentration, as shown in Figure A5. These measurements were obtained at the free jet centerline and within ½” of the pipe walls, and are within the standard deviation of all results.

We also measured the variation in results with the in situ PPC flow placed immediately at the pipe exit and 2.5” downstream of the exit, and again found no variation at the centerline, confirming theoretical characteristics of the core of a free jet in the near exit region. Finally, we observed negligible deposits or build-up of dust on the flow pipe walls for this turbulent flow (Re = 71,000). Thus, **we conclude that centerline measurements of size and concentration in the near field of the free jet exhaust provide an accurate representation of the measured mass feed-rate dispersed uniformly throughout the known volumetric flow.**

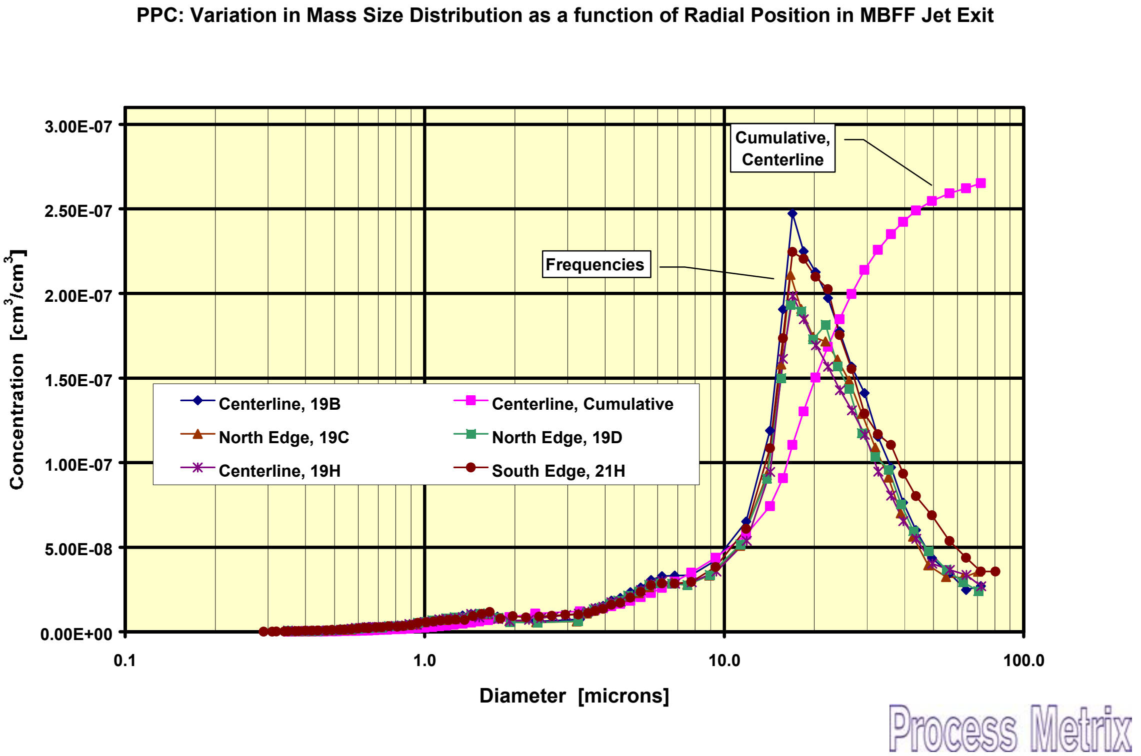

Figure A5. Radial Variation of in situ size distributions at jet exit of 3” MBFF. North and South measurements are approximately ½” from pipe wall. Total mass flow variation is ±10%, within range of uncertainty of all size distribution measurements.