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Fuel Sampling Standard

1.0 Isokinetic Coal Sampling

Isokinetic coal sampling is performed to accomplish the following:

1. Ascertain relative pipe to pipe fuel balance.
2. Quantify individual fuel line air to fuel ratios.
3. Quantify pulverizer air to fuel ratio.
4. Quantify individual fuel line velocity and air flow.
5. Ascertain pipe to pipe air flow balance.
6. Quantify fuel line temperature and static pressure.
7. Obtain representative fuel samples for coal fineness analysis.

Quantification of these parameters are required to ascertain pulverizer performance which is paramount in achieving optimum unit performance. Optimum pulverizer performance would require the following parameters to be achieved without compromise:

- Pipe to Pipe fuel balance within ±10% of the mean fuel flow.
- Pipe to Pipe dirty air flow balance within ±5% of the mean air flow.
- Optimized pulverizer Air to fuel ratio.

Pulverizer Type	*Lbs. Air per Lb. Coal*
MPS and EL Mills	1.5 to 1.8
Raymond Bowl Mills	1.8 to 2.0
Ball Tube Mills	1.1 to 1.4
Attrita Mills	1.2 to 1.6

- Minimum fineness level $\geq$75% passing 200 Mesh and $\leq$0.3% remaining on 50 Mesh.
- Pulverizer to pulverizer mass air and fuel balance within ±5% of the mean.
- Pulverizer outlet temperature $\geq$155°F.
- Minimum fuel line velocity of 3250 Fpm.

Isokinetic coal sampling requires both the Dirty Air Probe and the Isokinetic Coal Sampler.

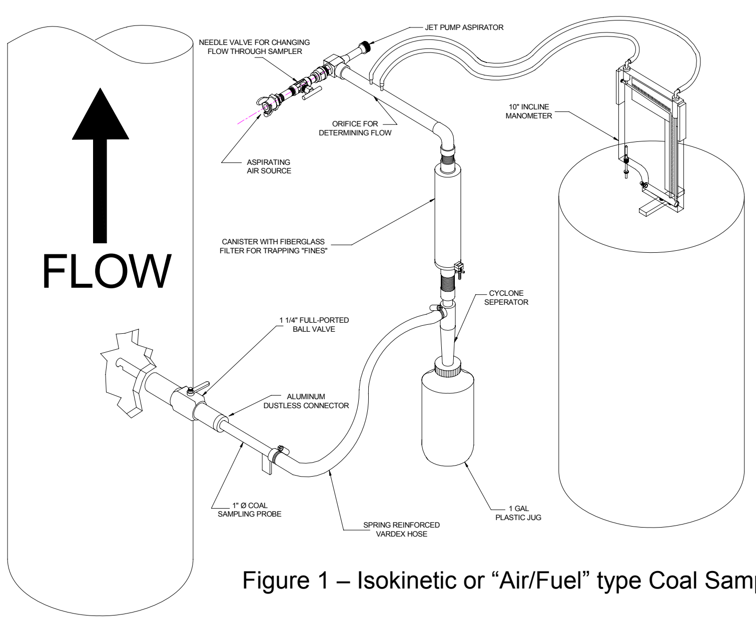


Figure 1 – Isokinetic or "Air/Fuel" type Coal Sampler

1.0 Isokinetic Coal Sampling

1.1 Performing a Dirty Air Test

Dirty air velocities must be measured in each fuel line to establish proper sampling rate for the Isokinetic Sampler and to determine air flow in each fuel line. The dirty air probe is a field proven device which allows the measurement of air flow in a dust-laden environment with a minimum of probe stoppage. The dirty air probe is illustrated by Figure 3. Dirty air velocity and fuel sampling measurements will be on a minimum of two axes 90° apart on a vertical run of pipe. An increased number of traverse planes will be utilized when taps are close to elbows or other flow disturbances. Test taps in horizontal runs are to be avoided. Figure 4 illustrates the physical effects of elbows and horizontal pipe runs on coal particles.

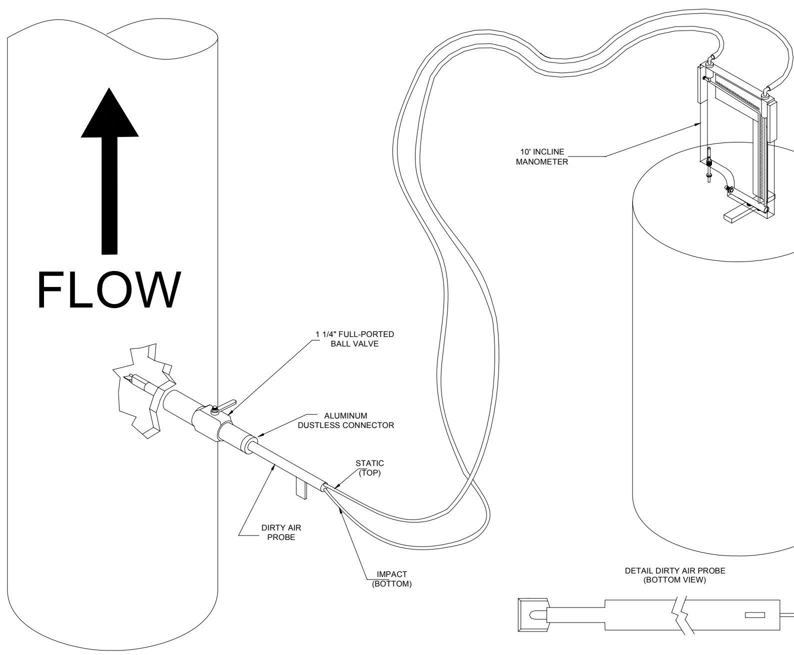


Figure 3 – Dirty Air Probe

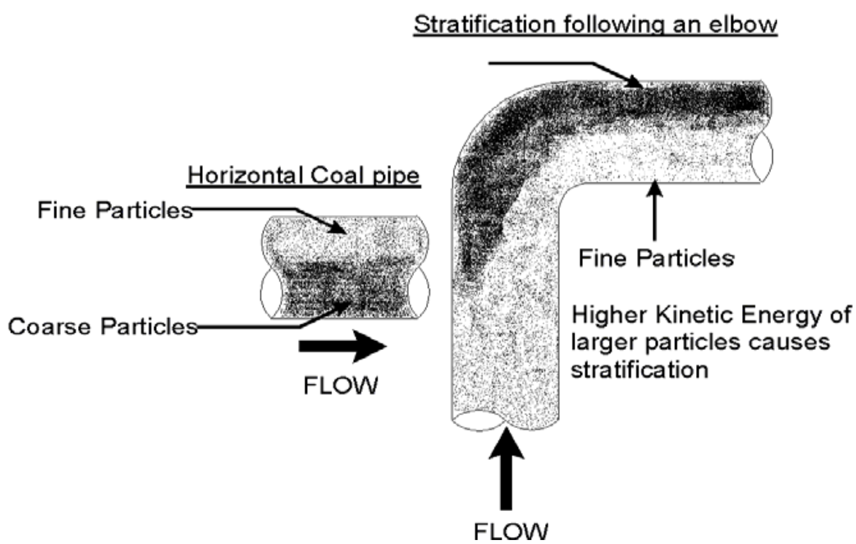
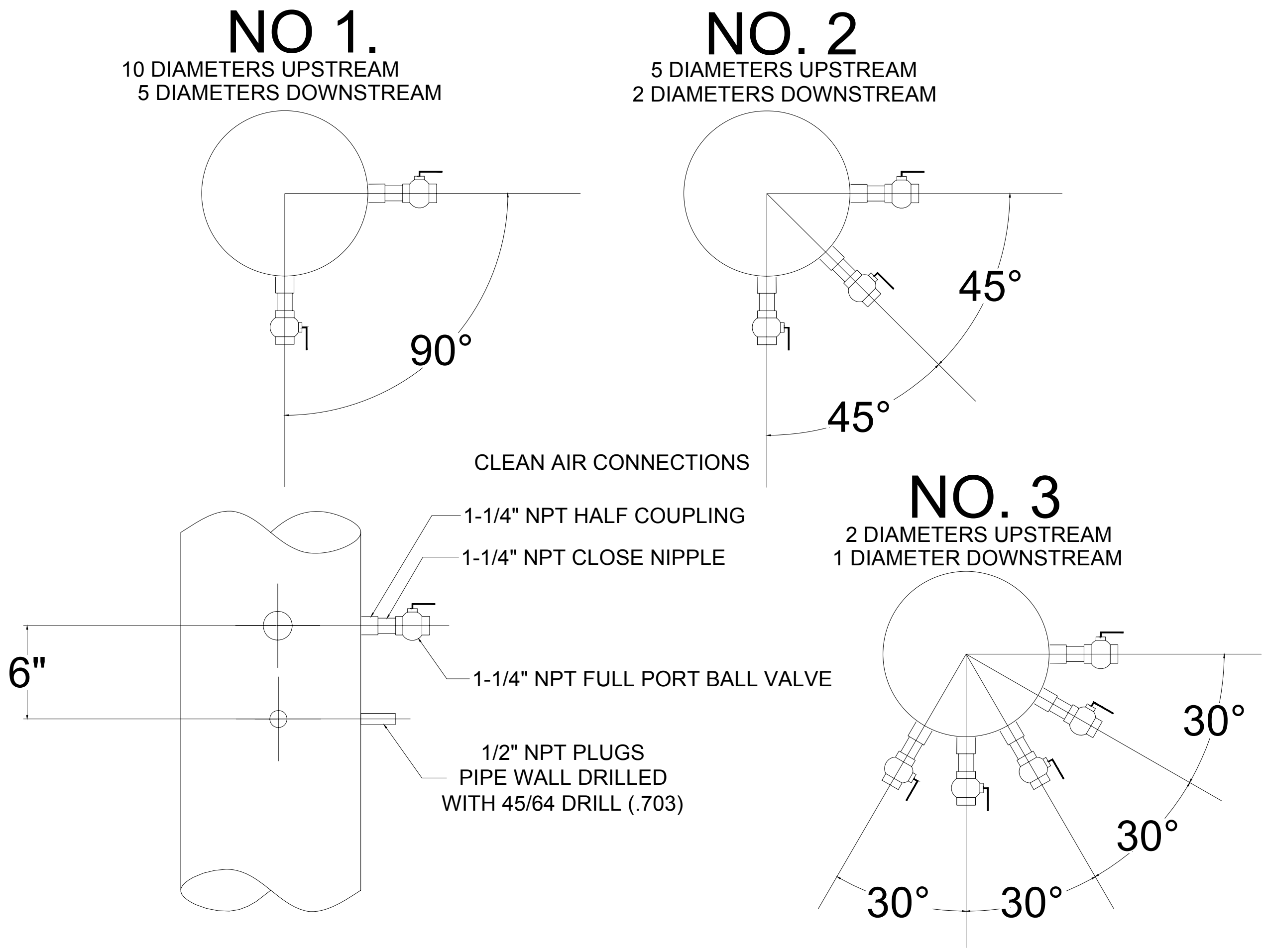


Figure 4 – Physical Effects of Elbow and Horizontal Pipe Runs

1.0 Isokinetic Coal Sampling

1.1 Performing a Dirty Air Test

Coal line test taps, which facilitate insertion of dirty air probes, require 1¼" full-ported ball valves. Use of a Rotorprobe™ will require installation of 2" full-ported ball valves. A minimum of two ports at 90° apart will be required. Figure 5 specifies the number of test ports required, depending on the proximity to elbows or other flow disturbances.



NOTES:

1 -- THE 1 1/4" NPT CONNECTIONS MUST FIT A 1.050 SAMPLE PROBE

2 -- THE COCK OR BALL VALVE SHOULD BE (+/-)1/8" OF THE SAME LENGTH FOR MAX. PRODUCTIVITY OF TEST TEAM (TO AVOID DIFFERENCE IN PROBE MARKING)

Figure 5 -- Coal Sampling Test Tap Installation Standard

1.0 Isokinetic Coal Sampling

1.1 Performing a Dirty Air Test

Coal samples, to obtain fineness, have been commonly extracted at the exhauster outlet on units equipped with CE Raymond Bowl pulverizers. Although this practice has been widely advocated, representative coal samples are not obtained. The kinetic energy of rotation imparts centrifugal forces on larger coal particles which have higher mass. The resulting propagation of a majority of the coarse coal particles to the outside of the exhauster scroll in a very small zone facilitates occupation of the highest percentage of the traverse plane by fine coal particles. With a high percentage of the traverse plane biased towards collection of fine particles, fineness results are much higher than actual. Figure 6 illustrates the non-representative sampling of pulverizer coal at the exhauster outlet. Due to the error associated with sampling at the exhauster, we are adamant in recommending that all coal samples be taken from the fuel lines.

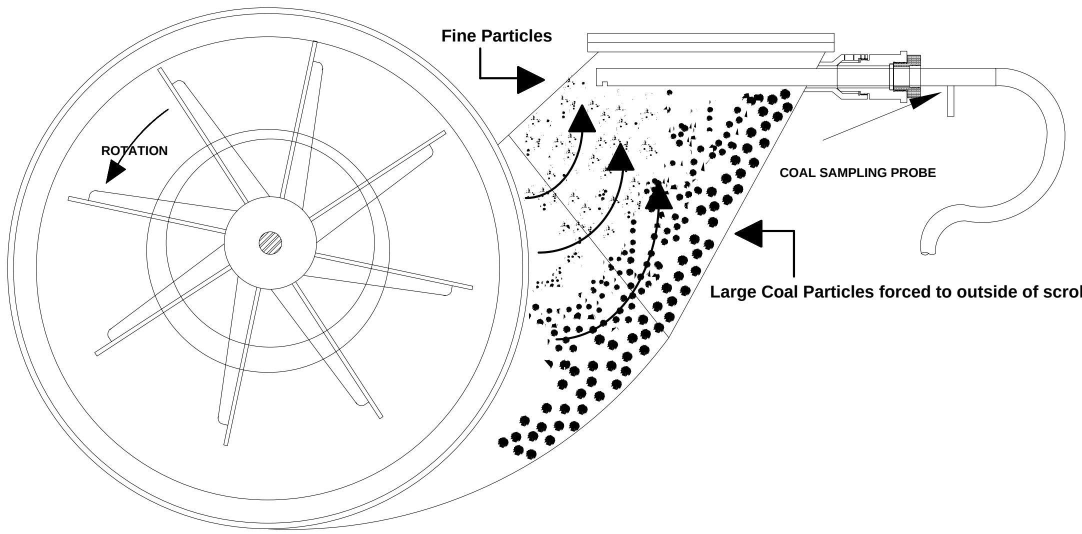


Figure 6 -- Coal Particle Distribution at the Exhauster Outlet

1.0 Isokinetic Coal Sampling

1.1 Performing a Dirty Air Test

2. Traverse points on the dirty air probe are marked on an equal area grid in accordance with the ASME Performance Test Code for traversing circular ducts. When marking the dirty air probe, be sure to offset the first mark to accommodate for the length of the test port nipple, pipe wall and dustless connector. This ASME standard, for pipes with 10" or larger diameters, is illustrated by the Figure 7.

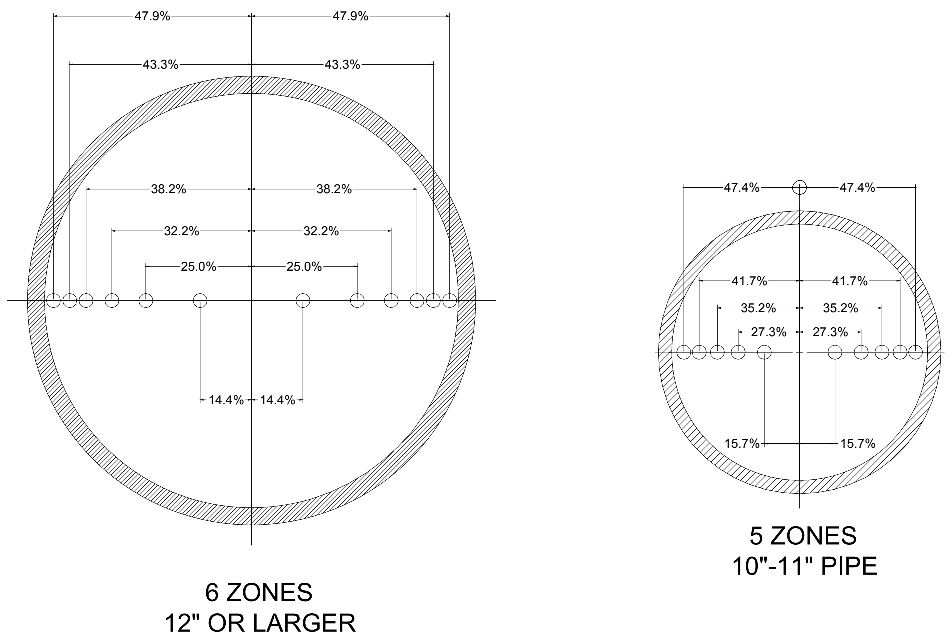


Figure 7 -- Equal Area Traverse Grid per ASME Performance Test Code
***Dimensions are "Percent of Pipe Diameter"

3. Two equal length "Tygon"™ tubing sections are cut to desired length. The tubing is then taped or bound together and one tube is marked on both ends to identify it as the “high–pressure” (impact) line. The remaining tube, which is unmarked, is identified as the “low–pressure” (static) line.

4. A 10" inclined-vertical manometer is set up on a level and stable location. Open the low and high pressure valves for the manometer, ensure the manometer is level using the integral leveling bubble and “Zero” the manometer. “Tygon”™ tubing is then attached to the correct sensing lines on the dirty air probe and the manometer.

5. The following data should be recorded for each individual pipe dirty air test:
   - Coal pipe designation
   - Individual velocity heads for each traverse point (typically 24 points - (12) per port)
   - Temperature and static pressure for each pipe

6. Prior to inserting the dirty air probe, ensure the manometer is level and “zeroed”.

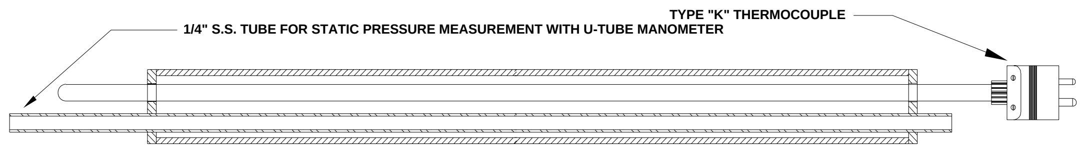
7. Insert the dirty air probe into the dustless connector; open the full-ported ball valve and insert the dirty air probe to the first mark with the probe’s pointer directed into the flow. The dirty air probe will seal the port. Allow the incline manometer indication to stabilize, record and move to the next point. Repeat this process for all (12) traverse points.

8. Between ports, disconnect the “Tygon”™ tubing from the probe; blow out the dirty air probe’s sensing lines with the quick disconnect adapter on the coal sampler and repeat the traverse on the remaining port(s).

1.0 <u>Isokinetic Coal Sampling</u>

1.1 <u>Performing a Dirty Air Test</u>

9. Insert the static and temperature probe into one of the ports in the same manner that the dirty air probe was inserted. When inserting the static-temperature probe, the U-tube should be disconnected. The tight seal between the dustless connector and probe will compress the air in the dustless connector and may blow out the U-tube fluid. Connecting the “Tygon”™ tubing to the U-tube manometer after the ball valve is open and the probe inserted prevents loss of U-tube fluid. Record static pressure indicated by a U-tube manometer and temperature indicated by a digital thermometer. The static and temperature probe is illustrated by the figure shown below.



An example data sheet for recording dirty air traverse data is illustrated below.

Innovative Combustion Technologies,	***Coal Pipe I.D.***
Tennessee Valley	***Coal Pipe Area Ft²***
Colbert Steam Plant Unit No. 3	***Barometric***
Test No. ***Date:***	***Pulverizer***

Pipe:

Point	Port 1	Port 2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

K Factor		
Sqrt Vh		"w.c.
ΔP		"w.c.
Temp.		°F
Static		"w.c.
Density		Lbs./Ft³
Velocity		Fpm
Airflow		Lbs./Hr.
Grams		Grams
Fuel Flow		Lbs./Hr.

Pipe:

Point	Port 1	Port 2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

K Factor		
Sqrt Vh		"w.c.
ΔP		"w.c.
Temp.		°F
Static		"w.c.
Density		Lbs./Ft³
Velocity		Fpm
Airflow		Lbs./Hr.
Grams		Grams
Fuel Flow		Lbs./Hr.

Pipe:

Point		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

K Factor		
Sqrt Vh		"w.c.
ΔP		"w.c.
Temp.		°F
Static		"w.c.
Density		Lbs./Ft³
Velocity		Fpm
Airflow		Lbs./Hr.
Grams		Grams
Fuel Flow		Lbs./Hr.

Total Dirty Airflow		Lbs./Hr.
Total Fuel Flow		Lbs./Hr.
Air to Fuel Ratio		-
Average Velocity		Fpm

Pipe No.	***Air*** % Dev.	***Fuel*** %Dev.
Mean		

1.0 Isokinetic Coal Sampling

1.1 Performing a Dirty Air Test

10. Calculating dirty air data is similar to reducing clean air data. The following equations are utilized to reduce dirty air flow traverse data:

$$\text{Density } (\rho) = \frac{460\,°F + 70\,°F}{460\,°F + °F} \times \frac{Bp\,''\,Hg + \frac{Sp\,''\,wc}{13.6}}{29.92\,''\,Hg} \times 0.075 \text{ lbs/ft}^3$$

$$\text{Velocity} = 1096\,\frac{Avg\sqrt{vh}}{\sqrt{\rho}} \times \text{Probe K} \qquad A\,vg\sqrt{vh} = \frac{\sum_{vh=1}^{n}\sqrt{vh}}{n}$$

$$\%\ \text{Deviation/ mean} = \frac{\text{Velocity - Average Velocity}}{\text{Average Velocity}} \times 100$$

$$\text{Volumetric Flow (Q)} = \text{Velocity(F PM)} \times \text{Pipe Cross Sectional Area (ft}^2\text{)}$$

$$\text{Mass Flow (W)} = \text{Q (CFM)} \times 60 \text{ min/hr} \times \text{Density (lb/ft}^3\text{)}$$

$$Bp = \text{Barometric Pressure ('' Hg)}$$

$$Sp = \text{Static Pressure ('' wc)}$$

11. After determination of the dirty air velocity in a given fuel line, isokinetic coal samples are extracted. The coal sampling probe is marked identically to the dirty air probe. The figure below illustrates the isokinetic coal sampler.

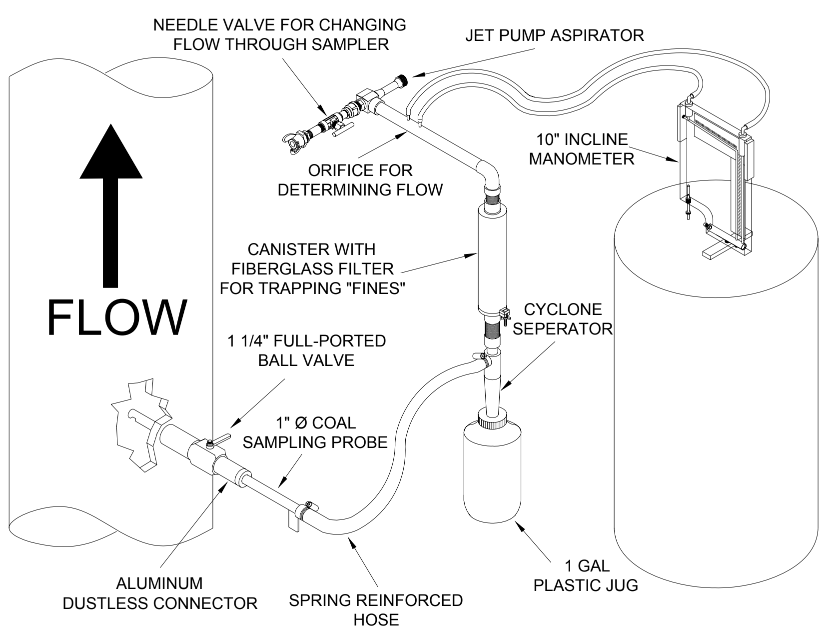


Figure 8 – Isokinetic or “Air/Fuel” type Coal Sampler

1.0 Isokinetic Coal Sampling

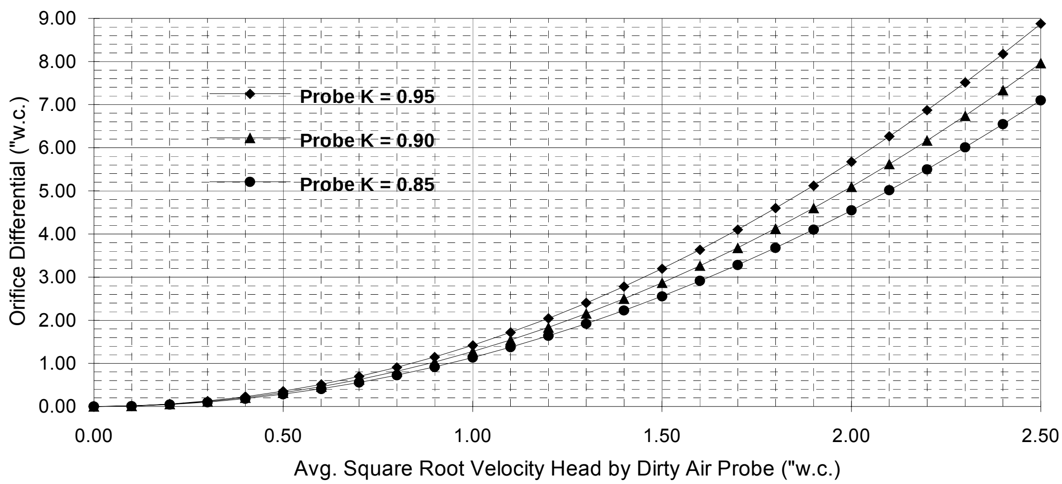
1.1 Performing a Dirty Air Test

12. Calculate the sampler orifice differential pressure based on the dirty air velocity traverse. Sampler differential is monitored by a standardized orifice and an inclined manometer. The average square root velocity head observed by the dirty air probe is entered into the following formula: $\Delta P = 1.573 \times (\text{avg. } \sqrt{Vh})^2 \times (\text{Probe K Factor})^2$.

    The simplified formula above indicates an orifice ΔP which will yield an average velocity through the sampling tip equivalent to the average velocity of the coal and mixture passing through the fuel line. This is referred to as isokinetic sampling.

    The graph below illustrates sampler orifice differential at varying dirty air probe "K" factors.

Relationship of Vh and Coal Sampler Orifice Differential



13. Connect the “Tygon”™ tubing to the incline manometer and the orifice sensing lines. The orifice sensing line upstream of the orifice (closest to the filter canister) should be connected to the high pressure side of the incline. The orifice sensing line downstream of the orifice is connected to the low pressure side of the incline.

    The desired differential pressure will be monitored and maintained at all times while the probe is in the fuel line. A needle valve is placed on the air supply line to manipulate the differential pressure. Prior to insertion of the sampling probe, place your hand over the aspirator discharge to minimize collection of coal during insertion. Insert the sampling probe (with the pointer 180° from the direction of flow) onto the first mark, rotate the probe pointer into the direction of flow and simultaneously start the stop watch and establish proper orifice differential by turning on the air and adjusting the needle valve.

14. The sample probe, which is marked in the same manner as the dirty air probe, will remain at each traverse point for an equal and <u>precise</u> time. Sampling time is very critical and great care should be taken to ensure the correct sampling time is obtained for each individual point. The sample time (t) is determined by the number of sampling points that is determined by the number of test ports. The following sampling times are typical:

(2) ports	(24) traverse points	(10) seconds/point	(4) minutes total sample time
(3) ports	(36) traverse points	(7) seconds/point	(4.2) minutes total sample time

1.0 Isokinetic Coal Sampling

1.1 Performing a Dirty Air Test

15. After traversing each port, turn off the air supply and remove probe from pipe.

16. Once all ports have been traversed, disconnect “Tygon”™ from orifice sensing lines and turn on air. Shake sample transport hose and tap cyclone to insure all coal sampled is evacuated.

17. Empty the sample collected in the sample jar and filter canister into a sample bag labeled with the pipe designation, test number and date. Take care to ensure that the entire sample is emptied into the sample bag. Sample weight will be utilized to calculate fuel flow.

18. Replace filter, sample jar and repeat process on the remaining fuel lines. In some cases, especially while sampling high moisture coal, the sampler should be thoroughly cleared prior to re-assembly of any residual coal dust or scum by blowing high pressure air through the sampler components.

19. Determine sample weight in each of sample bags, record on data sheet and perform fineness sieve analysis on all coal samples.

20. Formulas to reduce all Dirty Air and Isokinetic coal sampling data are as follows:

$$\text{Density}\,(\rho) = \frac{460°\text{F} + 70°\text{F}}{460°\text{F} + °\text{F}} \times \frac{\text{Bp}''\,\text{Hg} + \dfrac{\text{Sp}\,''\text{Hg}}{13.6''\,\text{wc}/''\text{Hg}}}{29.92''\,\text{Hg}} \times 0.075\ \text{lbs/ft}^3$$

$$\text{Velocity} = 1096\,\frac{\text{Avg}\sqrt{\text{vh}}}{\sqrt{\rho}} \times \text{Probe K} \qquad \text{Avg}\sqrt{\text{vh}} = \frac{\sum_{\text{vh}=1}^{n}\sqrt{\text{vh}}}{n}$$

$$\%\ \text{Deviation/mean} = \frac{\text{Velocity - Average Velocity}}{\text{Average Velocity}} \times 100$$

$$\text{Volumetric Flow (Q)} = \text{Velocity(FPM)} \times \text{Pipe Cross Sectional Area (ft}^2)$$

$$\text{Mass Flow (W)} = \text{Q(CFM)} \times 60\text{min/hr} \times \text{Density (lb/ft}^3)$$

$$\text{Bp} = \text{Barometric Pressure ("Hg)}$$

$$\text{Sp} = \text{Static Pressure ("wc)}$$

$$\Delta\text{P (Sampler Orifice during Sampling)} = 1.573 \times (\text{Avg}\sqrt{\text{vh}})^2 \times (\text{Probe Factor})^2$$

$$\text{Coal Flow} = \frac{\text{Sample Weight (grams)}}{453.6\ \text{grams/pound}} \times \frac{60\ \text{Minutes/Hour}}{\text{Total Sample Time (min)}} \times \frac{\text{Pipe Area(ft}^2)}{\text{Sample Tip Area (ft}^2)}$$

$$\text{Sample Tip Area} = 0.0021\,\text{ft}^2$$

$$\text{Air to Fuel Ratio} = \frac{\text{Air Flow in Pouds per Hour}}{\text{Coal Flow in Pounds per Hour}}$$