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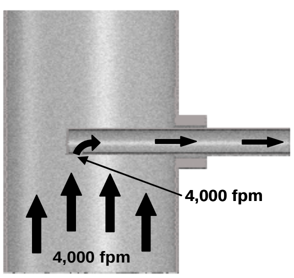
Pulverized Coal Fuel Line Testing and Balancing by the Storm Technologies, Inc. Technique.

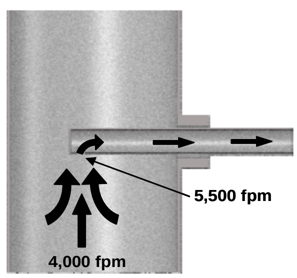
Using the STORM® Isokinetic Coal Sampler to Apply Essentials No. 3, 4 and 5

If you want Results, it has been our experience that it is worth the extra effort to complete isokinetic coal sampling, by the STORM® approach. When the isokinetic method is used, the coal sample is extracted from the pipe at relatively the same velocity, which is previously measured by the dirty air probe traverse before the sample is obtained from the pipe being tested.



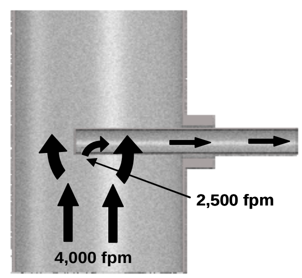
Iso-Kinetic Sampling

Notice how the particles are flowing into the sampler at the same rate as the coal is flowing through the pipe



Super Iso-Kinetic Sampling

Notice how the particles are being pulled into the sampler at an higher rate than the pipe velocity



Sub Iso-Kinetic Sampling

Notice how the particles are being pushed away from the sampler tip due to its obstruction

Along with extracting the sample at the same velocity, there are a number of other important measurements that are taken by the STORM® approach to air and fuel flow measurement. Other important measurements include pipe static pressure, pipe temperature, dirty air balance, fuel flow balance, individual pipe velocities, total pulverizer fuel flow and total airflow (primary airflow, including air in-leakage and seal air). All these measurements are crucial in maintaining plant equipment at the highest standards. Operating outside of the acceptable limits could be costing your plant valuable man hours, fuel cost (fuel flexibility), slagging, fouling, hot superheater tube metals, capacity and equipment reliability.

The STORM® Isokinetic coal sampling and dirty airflow test kit is commonly utilized to determine the following:

- Ascertain relative pipe-to-pipe fuel balance
- Quantify individual fuel line air to fuel ratios
- Quantify pulverizer air to fuel ratio
- Quantify individual fuel line velocity and airflow

- Ascertain pipe-to-pipe airflow balance
- Quantify fuel line temperature and static pressure
- Obtain representative fuel samples for coal fineness analysis
- Total fuel flow at different feeder speeds

In Figures 1 and 2 (below) a STORM® Dirty Air Probe and Isokinetic Coal Sampler is shown for reference.

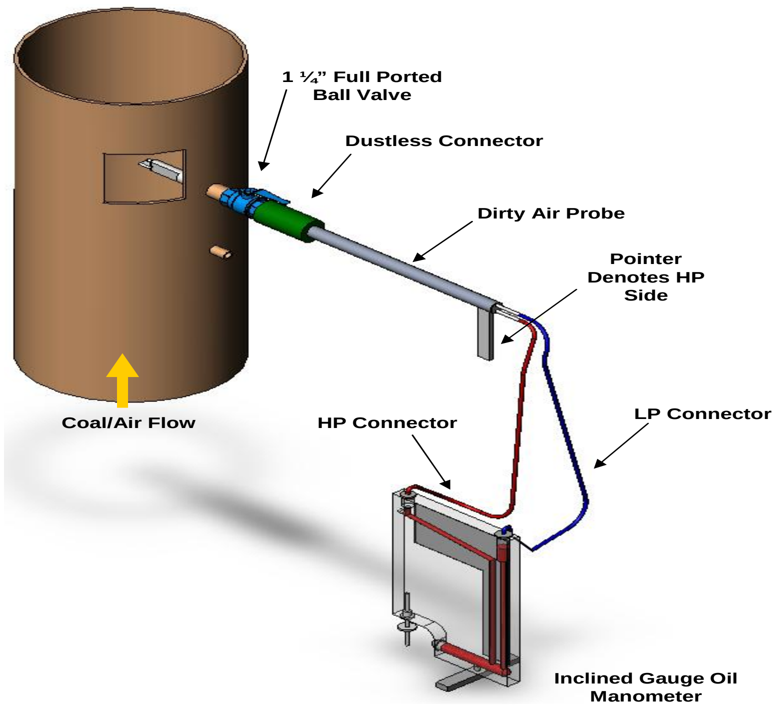


Figure No. 1 – STORM® Dirty Air Velocity testing equipment

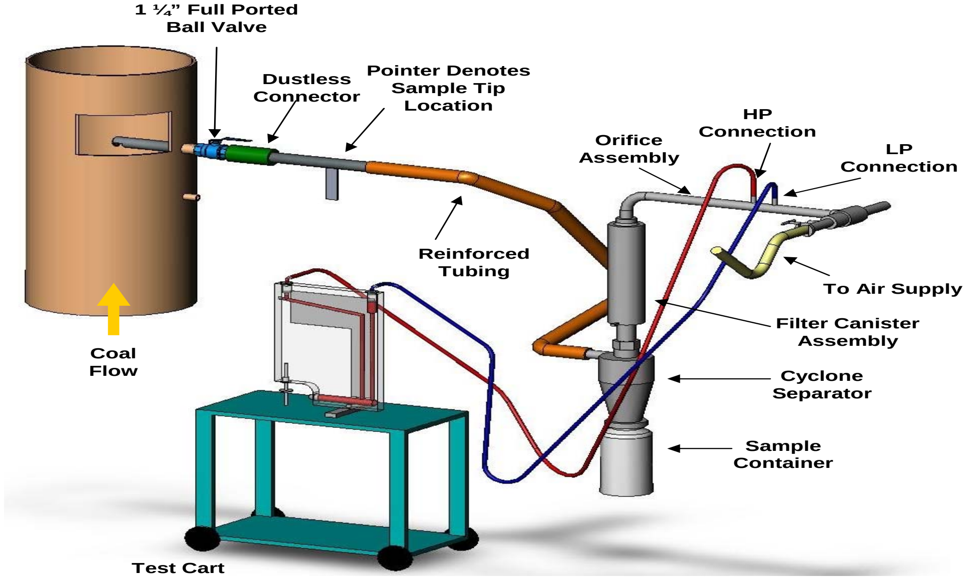
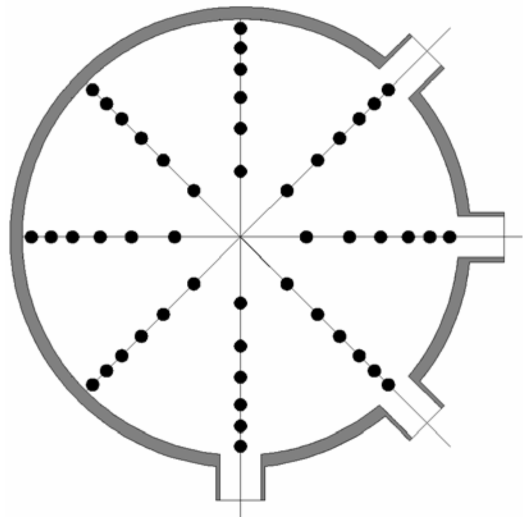


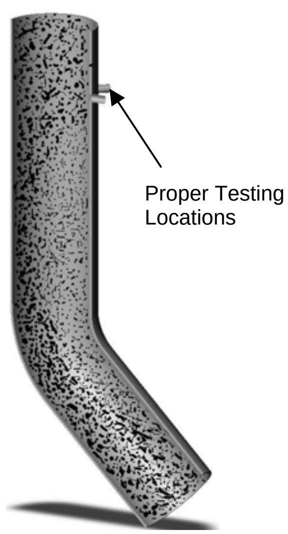
Figure No. 2 – STORM® Isokinetic Coal Sampling equipment

The Isokinetic coal sampling method is conducted to ascertain the true mill fineness and pulverizer performance. Considering that some methods of coal sampling do not include pipe to pipe primary airflow measurement/balance and fuel flow measurement/balance. This is another advantage of the STORM® method of coal sampling.

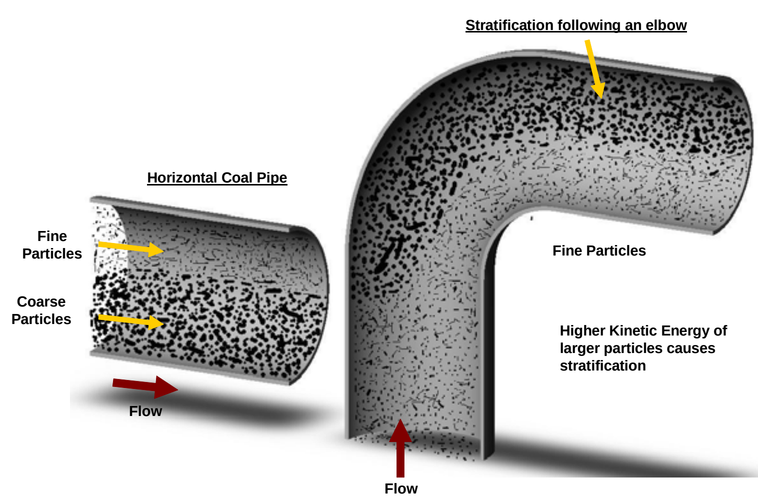
When using the STORM® Isokinetic Sampling method, the fuel lines being sampled are marked off for an equal area traverse. With the proper amount of test ports installed, and a favorable coal pipe sampling location, any roping of coal past the sampling location can be measured and recorded. The picture to the right shows the detailed view of a 48 point traverse and the axis being measured (if 10 diameters upstream from the bend or horizontal run aren't available). The first test that is run by a testing crew is the dirty air traverse. It also uses the same points when measuring the velocities in the pipes. By measuring the true velocity flowing through the pipe, the guess work of Isokinetic sampling is eliminated. The ASME sampling method implies that a representative aspirating air velocity can be adjusted without first measuring the velocity. This is not correct. After the dirty air velocity test the coal sampling extraction is completed. The sample is timed for accuracy by the person controlling the sampling probe, while the other person keeps the velocity through the probe constant for the pipe being sampled.



Through our experience, it is crucial to test pulverized coal fuel lines in the vertical rise only. The coal flowing through the pipe has a particular stratification in bends and on the horizontal runs. Coal flowing around a bend will flow heavy on the outside corner of the bend, and in a horizontal run it will be heavy on the bottom of the pipe. Coal sampling data collected in a bend or on a horizontal run will not be representative. The following figures display a bend in a fuel line and also the horizontal run of pipe's stratifications. The first picture depicts the proper location for coal sampling.



Proper Testing Locations



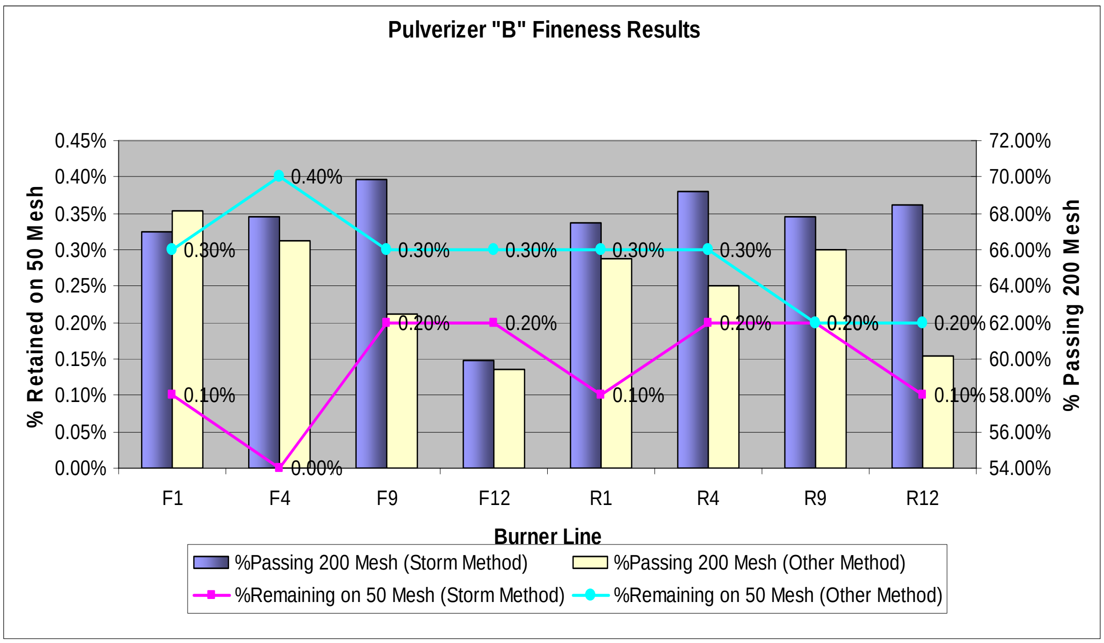
Improper Testing Locations

The STORM® method samples at the isokinetic velocity, meaning the sampler extracts the pulverized coal at the same velocity as flowing in the fuel line. The depiction of this is shown on the first page. Our sampler's have a specially designed tip. It is the same area opening as the ASME sampler, but the STORM®design tip has an internal deflector built into it. This eliminates the bouncing out or rebounding of large coal particles. Both large and small particles are captured once they enter the tip. You'll notice that the single tip is also much larger than those on a RotoProbe. Their tips are .2 inch diameter holes or roughly .031 square inches each. For comparison, the RotoProbe tip is technically smaller than a pencil eraser's diameter. With wet coal, these tips can often become plugged. Biased sampling suggests that mill is performing "as designed" when the fineness is truly below the required level needed. One other design feature of the STORM® sampler is that it can handle high capacity fuel flow rates of up to 50k/lbs hr per pipe. It is virtually un-pluggable. Our sampler was designed with an internal orifice to measure the amount of air moving through the sampler. With the pressure drop through the sampler, this orifice was designed to measure and control the velocity at the tip to be the same as the velocity of the flowing coal air stream. We also have a back-up filter above the cyclone to trap any small particles to increase recovery rate, reliability, and overall accuracy.

As seen above, this is a traditional sampler with a large cyclone. It has no control over flow; it cannot accurately measure fuel balance and has no provisions to measure dirty air velocity. The main problem with this type of sampler is that it is not capable of isokinetic sampling as previously described. This is not the preferred approach and most precise method of coal sampling, including the verification of the velocities and fuel flow within the pipe. The use of the STORM® Isokinetic sampler with trained personnel has served us well in measuring, adjusting and tuning for "Best" pulverized performance. Our experience has been that our sampler outperforms all other coal sampling techniques.

The following two examples represent typical past experiences in pulverized coal fired boiler inputs. Case studies 1 & 2 show why we use the Isokinetic Coal Sampling method and the other measurements that can be taken, as opposed to other sampling methods. It truly is the best way that we have found to quantify ***Results*** to improve overall plant performance and to guide cost effective and results oriented performance driven maintenance.

Example 1 – MPS-89 Pulverizer with 8 Coal Pipes. Flyash LOI (loss on ignition) was double digits and there was Repeated Slagging in the upper furnace at the finishing superheater pendants. Coal fineness, when sampled from one of 8 pipes always would show 70% + passing a 200 mesh sieve. Yet the flyash was poor, and fuel balance appeared poor. Later, by the STORM® approach, using the STORM® Isokinetic Coal Sampler, all eight pipes were sampled and the fineness samples, weighed and sieved for all eight pipes. The worst single pipe was about 60% passing 200 mesh. The “Best” pipe of 8, measured above 80% passing 200 mesh. On average – the pipes were about 70% passing 200 mesh. The average was at a widely accepted standard of 70% passing 200 mesh, Acceptable to some standards but not ours. We specify 75% minimum passing 200 mesh and on a mass weighted average basis. The actual data is shown in figure below.



The single pipe No. F9 above did in fact meet the 70’s standard that the boiler guarantees were based on, at the 70% passing 200 mesh. But, Fuel Fineness and Fuel Distribution overall were poor and it showed up in slagging, fouling and higher than desirable flyash Carbon losses.

The data shown above was derived by two methods of coal sampling. The blue bars and the pink line show the results of the STORM® Isokinetic coal sampling method. The white bars and green line show the measurements taken by another method. As you can see, both methods produced similar results. However the other method did not obtain relative pipe to pipe fuel balance, airflow balance, and air to fuel ratios. These measurements are important in identifying performance problems and pulverizer deterioration.

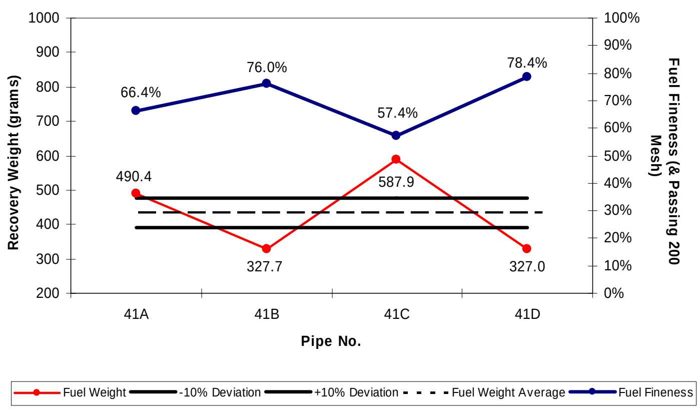
Example 2 – Raymond Shallow Bowl Mill Size #923. The fuel fineness by a single pipe ASME sampler came out to 76% to 78% passing 200 mesh (depending on the pipe chosen for the sample). However, there is more to balancing coal pipes that simply achieving 70+% passing 200 mesh in a single pipe! With other sampling methods applied, 70% is acceptable and is an indication of a properly functioning pulverizer, however, with the STORM® sampling method dirty air balance, fuel flow balance, and air to fuel ratios are also taken into consideration. When all the other factors are within acceptable limits and the fineness is acceptable to the STORM® standards, then the pulverizer is a properly tuned into a solid fuel injection system.

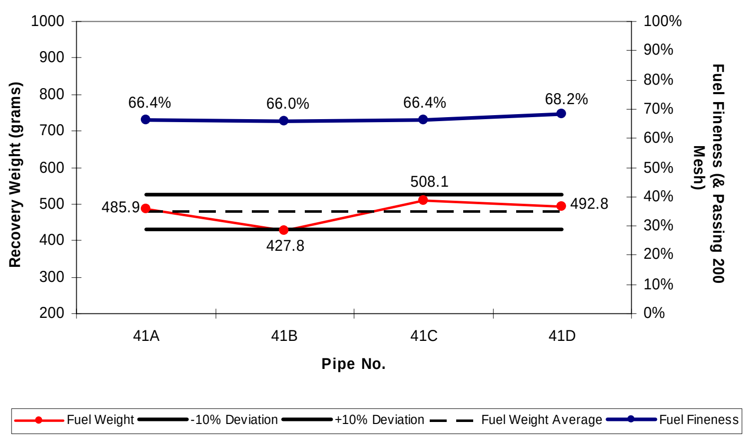
The data for the two graphs below was taken using the isokinetic method when the primary airflow was biased up; the fuel distribution was poor along with the imbalanced fineness results as shown on the first (top) graph.

The Importance of Essential No. 6
Accurate & Reliable Measurement and Control of the Primary Airflow

Poor Fuel Balance as a Result of High Primary Air Flow

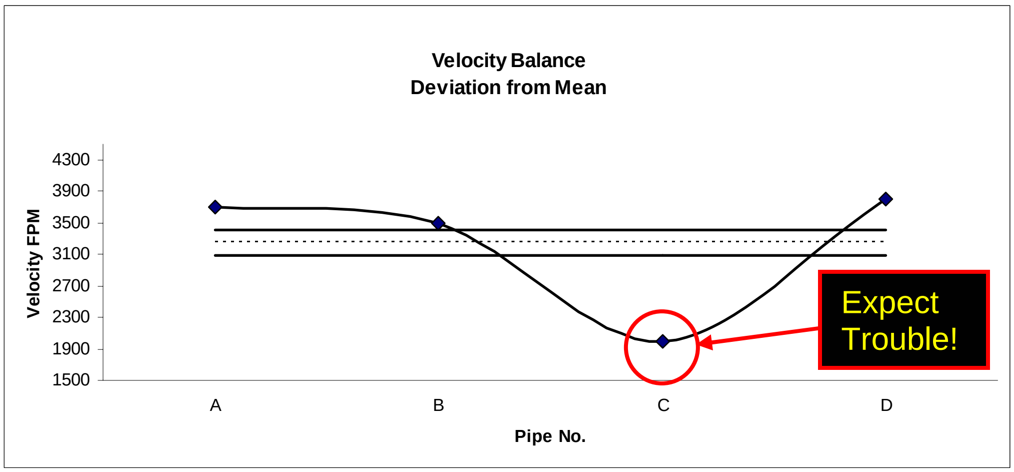
As you can see in the graph to the right, the blue line shows the fuel fineness as measured, and the red line displays fuel balance as measured by the STORM® Isokinetic Coal Sampler. High primary airflow caused the fuel balance to be imbalanced out of the recommended ±10% deviation, and the fineness scattered across the four pipes.



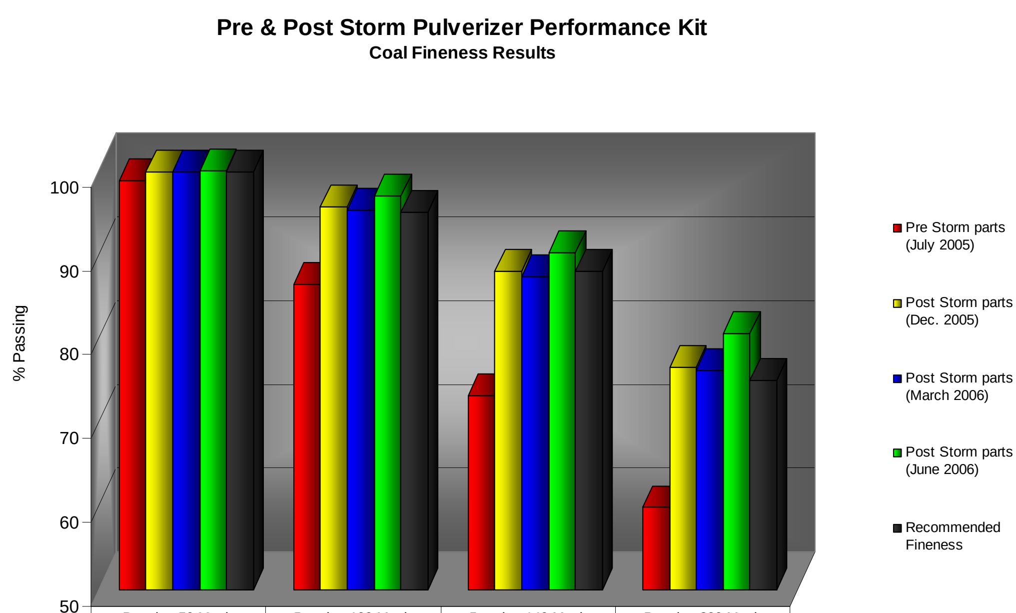


The graph to the left shows the same fuel line and fuel source after the STORM® retesting was completed on the same mill at reduced primary airflow. STORM® personnel balanced the primary airflows to maintain 1.8 lbs of air per lb of fuel ratio. The optimized P.A. flow to this mill caused the fuel flow balance to be within the recommended ±10% deviation. Along with the balanced fuel flows, the fineness across the mill has leveled out. The burners are firing the average fineness of coal; even through the fuel fineness is poor. This balance in the mill causes better combustion in the upper furnace. Balanced mills make for a more balanced furnace. A balanced furnace contributes to lower LOI's, slagging, fouling, and reduced spray flows. The next step on this mill is to increase the fineness to 75% passing a 200 mesh sieve.

As you can see in the graph shown below, individual pipe to pipe velocities can be measured with the use of the STORM® Isokinetic Coal Sampler. This velocity measurement is important in identifying burner issues, blockages, slow velocities that cause layout, and swing valve malfunctions. It is crucial to maintain velocities above 3,300 fpm to ensure a coal particle is entrained in the fuel air mixture. If velocities drop below, 3,000 fpm as depicted on the following graph, there could be a possibility of a fire or explosion. Other testing methods do not indicate the velocities in each fuel line leading from a pulverizer.

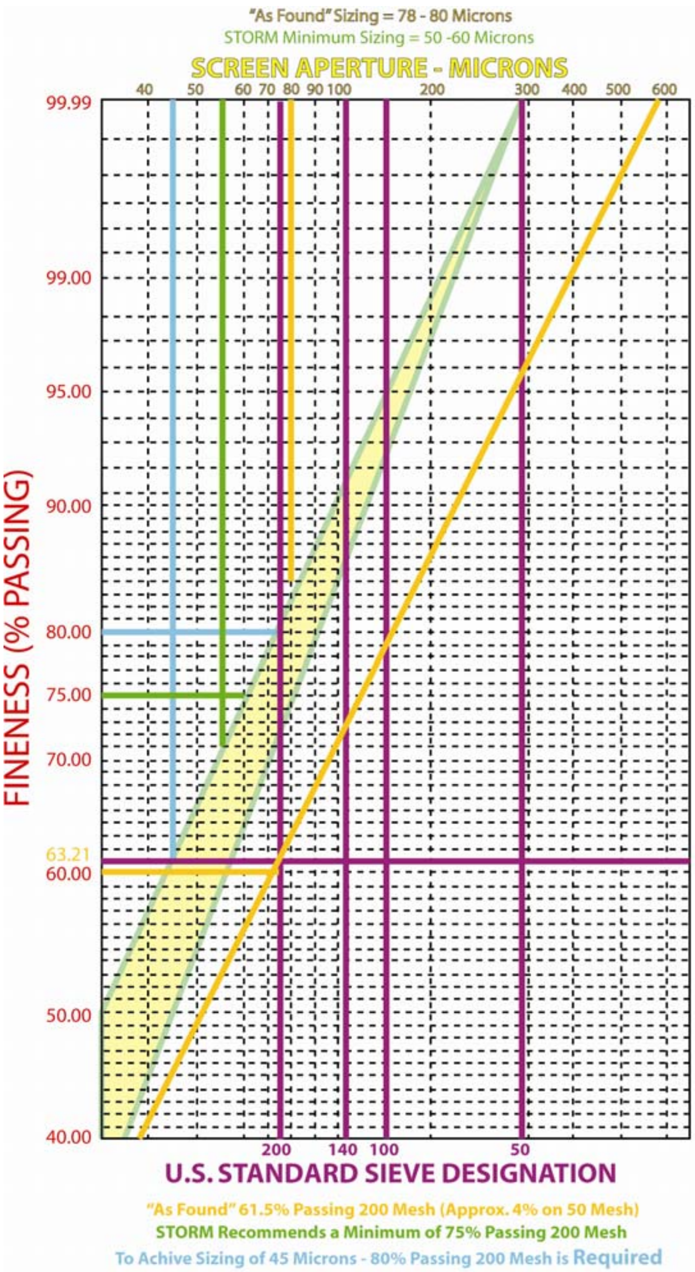


Even with the proper fineness achieved with STORM® pulverizer components, fuel balance is hard to achieve within ±10% by any standards. (Note: the testing on this mill was done over an 11 month period; different fuels can have an adverse affect on fuel balance).



	Passing 50 Mesh	Passing 100 Mesh	Passing 140 Mesh	Passing 200 Mesh
Pre Storm parts (July 2005)	98.86	86.51	73.18	59.84
Post Storm parts (Dec. 2005)	99.9	95.68	88.03	76.55
Post Storm parts (March 2006)	99.85	95.33	87.38	76.2
Post Storm parts (June 2006)	99.94	96.97	90.22	80.55
Recommended Fineness	99.9	95	88	75

Because of this, periodic testing using the STORM® Isokinetic Sampler is recommended. Fineness testing alone, by any method, is only part of the challenge of optimizing performance in the Burner Belt. Other methods will only represent a fineness sample in the respective pipe. Storm Technologies Inc. views the pulverizer as the heart of a pulverized coal firing system. Fuel lines need to be measured and fineness achieved across the entire load range and between pipe to pipe. With the isokinetic coal sampling method, air to fuel ratios, dirty air balance, fuel flow balance, and coal fineness can all be obtained in one single test technique in each pipe. This is important in saving time and money to employ a testing team that does not do the work as efficiently when using another sampling method as opposed to the STORM® Isokinetic Sampling method. Most important is obtaining accurate and reliable fineness and fuel distribution data.

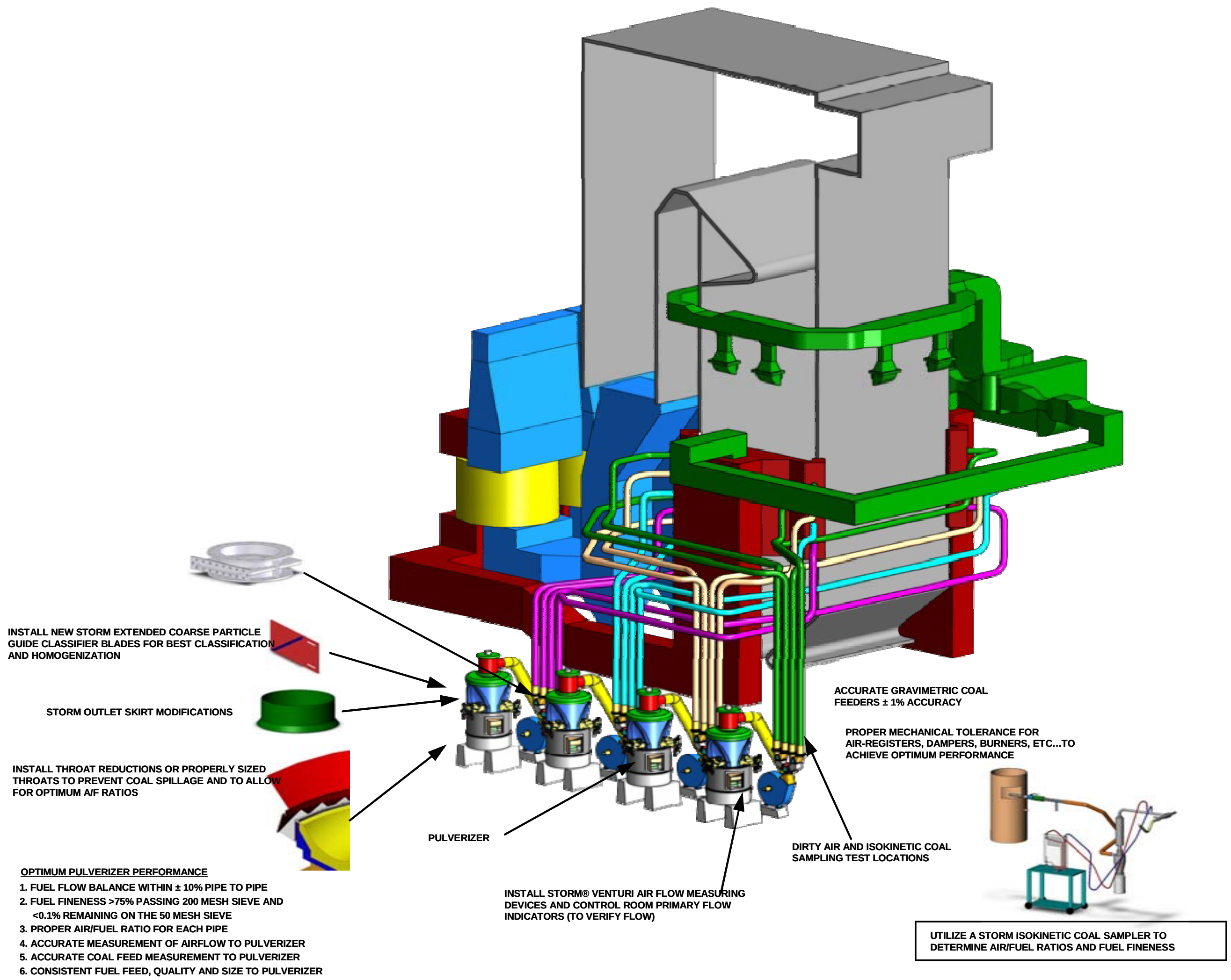


Dirty air Testing

Coal Sample being extracted

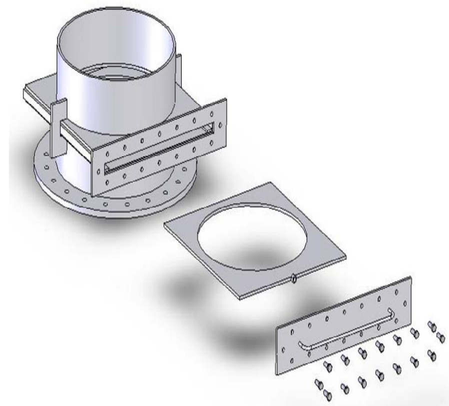
Regulating the Velocity

The following picture shows the areas of improvement that were discussed in this newsletter.



So, Let's Review the Six Steps to Fuel Line Balancing

1. Clean Air Balancing within ± 2%



Balance the fuel line system resistances by clean air testing, using the STORM® Two Team, Dual Traverse Method, to achieve resistance within ±2% for all pipes. The most expeditious way to achieve ±2% balance is to install orifice housings. This is the first important step in balancing fuel flows. By itself, it will not balance the two phase mixture of pulverized coal and primary airflow, but it is the essential first step.

2. Measured Primary air Hot "K" Factor calibrations ± 3%

The density of cold air is different from hot air. This can sometimes lead to a significant variance in given velocity while having a similar mass flow rate. Hence, the K-factor will vary. Because of this, we prefer to conduct Hot "K" airflow calibrations that use typical operational air or gas density when developing an average K-factor/Curve.

This information is useful in developing a Pulverizer Primary Airflow "Ramp" and in measurement of all combustion airflows, including primary air, secondary air, overfire air, and underfire air.

3. Dirty air velocity measurements at optimum primary air/fuel ratio with a balance of ± 5%

The average velocity for each burner line is determined while the mill is "in service". This velocity is then used for collecting an isokinetic coal sample from each line. Dirty airflow measurements are also useful in determining the level of mill performance (mill air in-leakage values (on suction mills), mill heat balance calculations, airflow balance, etc.).

4. Fuel line fineness and distribution testing by air/fuel ratio sampling & ensuring that an optimum fineness level is achieved.

Accurate weighing and sieving of the coal samples through 4 sieves is also important. Why four sieves? With near 0% remaining on the 50 mesh sieve, at least three points are needed on the Rosin-Rammler Chart to plot the fineness Results. Four sieves of 50, 100, 140 and 200 mesh are recommended for fineness sampling. Fuel line fineness should be 75% or more passing a 200 mesh screen and a maximum of 0.1% remaining on the 50 mesh screen.

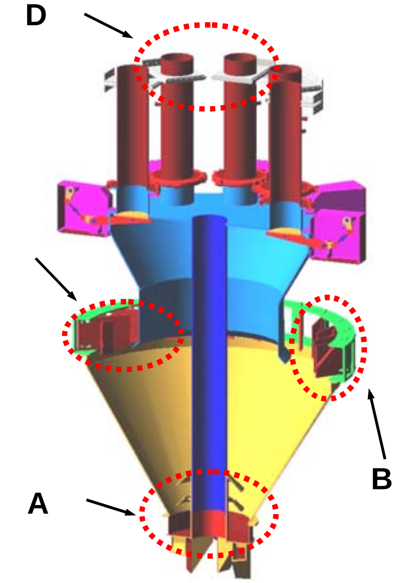
5. Fuel line balancing through classifier changes or fuel line distribution modifications to achieve ± 10%

Pulverizer Classifiers Provide Two Functions:

- Return coarse particles from the upper classifier zone to the grinding zone to be reground for re-circulation to desired fineness.

- To homogenize the two phase mixture of primary air & pulverized coal:

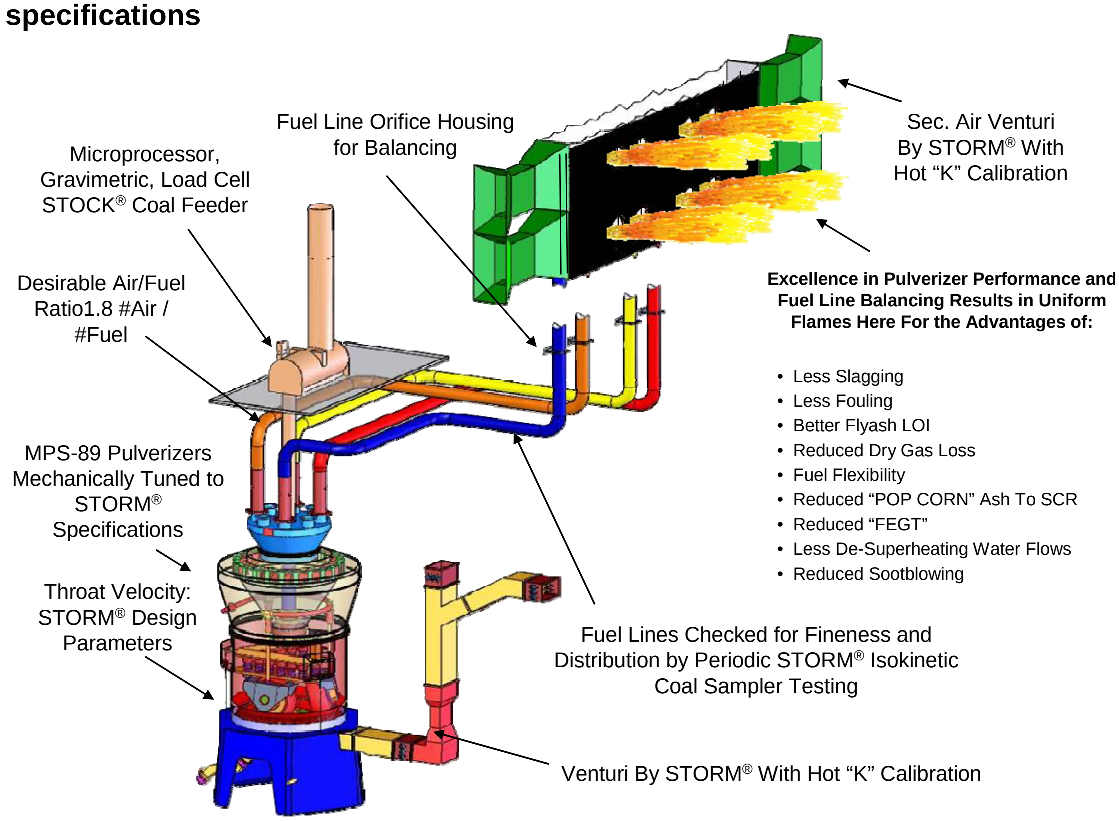
Unless there is sufficient fineness (such as recommended by STORM® at >75% passing 200 mesh); there is little reason to expect uniform solid fuel flows out of each of the fuel pipes.



<u>STORM® Recommended Classifier Modifications</u>

A. Install STORM® designed inverted cones/conical baffles, and set clearances and tolerances per STORM® specifications.
B. Install new STORM® Extended Coarse Particle Guide Classifier Blades for best classification and homogenization.
C. STORM® designed outlet skirt with mechanical tuning tolerances.
D. Clean air system resistance balanced with square edge orifice plates.

6. Pulverizer "blue printing" to <u>STORM®</u> specifications



This newsletter was prepared by Jake Stover taking the lead and with contributions from the staff of Storm Technologies, Inc. Dick Storm, editor.