8.6 MILL DIRTY AIR FLOW TEST

8.6.1 Intoduction

The factors affecting pulveriser performance include grindability of coal, moisture content of coal, size of input coal, wear condition of grinding elements and classifier, fineness of pulverized coal, primary air quantity and temperature. On a day-to-day basis, mill performance is monitored by tracking mill power consumption, regular PF fineness measurements, mill DPs, coal spillage etc.

This procedure provides guidelines for conducting performance checks on Pulverisers using a Dirty Pitot probe for identification of pulveriser system deficiencies. The procedure also provides guidelines for both isokinetic and non-isokinetic collection of pulverized coal sample from mill discharge pipes for checking the fineness fractions. This methodology is suitable for sampling from vertical circular pipes only.

In a Dirty airflow test, the temperature, static pressure and DP across the pipe cross-section are measured to calculate coal / air mixture velocity and flow in each PF pipe. The velocity and flow measurements of 'dirty air' (coal air mixture) are done under defined operating conditions and close to nominal mill loading to ensure tests' repeatability. An essential pre-requisite to balancing of fuel and air to the burners is calibration of Primary Airflow through the pulverisers. If adequate straight lengths are available in the ducts, the flows should be checked by a calibrated pitot traverse.

Also, a balanced 'clean air flow' distribution does not necessarily result in a balanced 'dirty air' or 'coal flow' distribution amongst the discharge pipes of a mill. The focus needs to be on dirty airflow and coal flow balance measurements.

The relative flow distribution between burner pipes is assessed by calculating the deviation of the flow through individual pipe expressed as a percentage difference relative to the mean flow of all the pipes. Permissible variations for imbalances in coal / air mixture and coal flows amongst the four discharge pipes are +/-5% and +/-10% from the average.

8.6.2 OBJECTIVE

The objective of this procedure is to establish a standard method for the following performance tests related to pulveriser system

1) **Dirty air balancing** between coal transport pipes

2) **PF sample collection** of pulverized coal for fineness fractions

8.6.3 Test Procedure - Dirty air balancing using Dirty Pitot kit

1) Tests ports are installed on coal pipes to facilitate clean and dirty air traversing using pitot tubes and dirty air probes. Optimum location for these taps should be between five diameters downstream and ten diameters upstream of the nearest elbow or change of direction. A minimum of two test ports per coal pipe, 90 degree apart, is required for testing.

2) The numbers of sampling ports are determined based on the available straight lengths of coal pipes, upstream or downstream of the nearest bends. The guidelines for locating testing cross sections are described in ASME PTC 4.2.

3) Traverse points on the pitot tube are marked on an equal area grid in accordance with ASME Performance test Code 4.2 for traversing circular ducts or pipes.

4) Two equal lengths 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 as the 'high pressure' line or 'impact' line. The second tube is used as the 'low pressure' line or 'static' line.

5) A 5" to 10" vertically inclined manometer is set up on a level and stable work area. The tygon tubing is connected to the high and low side taps on the manometer as indicated below. A digital manometer may be used in lieu of the inclined manometer, if available.

6) The following data should be recorded for each test.
   - Coal pipe designation
   - Individual velocity head for each traverse point (2 ports - 24 points)
   - Temperature and static pressure for each coal transport pipe

7) Prior to inserting the pitot tube into the flow, ensure the manometer is level and has been "zeroed".

8) Install a dustless connector at the ball valve outlet to ensure coal containment in coal transport pipe during traverse.

9) Insert the dirty air probe through the dustless connector. Open the ball valve fully while inserting the dirty air probe and place the probe on the first measurement point.

10) Allow the manometer reading to stabilize, record the data and move to the next measurement point. Repeat this process for all 12-test points on the particular port.

11) Prior to moving to next test port, disconnect the tubing from the probe, blow the sensing lines and repeat the traverse on the remaining ports. Typical log sheets for recording data in Control Room and test locations are attached as Format 8.6.2 & Format 8.6.3.

12) Measure and record static pressure and temperature reading for each coal transport pipe using the static pressure probe. Before inserting the probe in the coal pipe, static pressure sensing line is connected to one side of the manometer. The tube on the other end is pinched to prevent blowout of manometer fluid during insertion of the probe. The thermocouple is attached to a temperature Readout.

13) Calculate velocity in each fuel line and ascertain dirty air balance. The dirty air balance should be expressed as a deviation from the mean velocity of all the pulverisers individual coal transport pipes (a maximum deviation of +/-5% indicates a satisfactory clean air balance). The following equations are utilized to process dirty air traverse data.

$$\text{Density } (\delta) = \frac{460 + 70\ ^{\circ}F}{460 + T\ ^{\circ}F} \times \frac{Bp + \frac{Sp}{13.6}}{29.92\text{" Hg C}} \times 0.075\ \text{Lbs./ft}^3$$

$$\text{Velocity} = \frac{1095 (Vh)^{1/2}}{(\delta)^{1/2}} \times K\ ;\ (Vh)^{1/2} = \frac{(Vh_1)^{1/2} + (Vh_2)^{1/2} + (Vh_3)^{1/2} + \ldots}{\text{no. of traverse points}}$$

$$\%\ \text{Deviation} = \frac{\text{Avg. Velocity} - \text{Velocity}}{\text{Avg. Velocity}} \times 100\%$$

Volumetric Flow (Q)= Velocity x Pipe Cross-sect. Area
Mass Flow (W) = Q x 60 min/hour x Density
Bp = Barometric Pressure ("Hg); Sp = Static Pressure ("WC)
K – Calibration Coefficient of the Pitot

Say Mill Out Temp – 88C/190.4 F, Bp – 28.7 "Hg,
Sp – 1.6 "WC

$$\textit{Density (d)} = \frac{530}{650.4} \times \frac{(28.7 + 1.6/13.6)}{29.92} \times 0.075 \text{ Lbs./ft}^3$$

$$= 0.05886 \text{ Lbs./ft}^3 * 16.01847 = 0.9429 \text{ kg/m}^3$$

Say $(Vh)^{1/2} = 1.4576$ ***"WC***

$$\textit{Velocity} = 0.93 * \frac{1095 * 1.4576}{(0.05886)^{1/2}} * 0.00508$$

$$= 31.1 \text{ m / s}$$

$$\textit{Dirty Air Flow} = 31.1 * 0.14522 * 0.9429 * 3600 / 1000$$

$$= 15.33 \text{ T/hr}$$

8.6.4 PF sample collection of pulverized coal for fineness fractions

8.6.4.1 Iso kinetic Sampling

After determination of the dirty air velocities in their associated coal transport pipes, iso kinetic coal samples are extracted. The coal-sampling probe is marked identical to the dirty air test probe and following steps are followed for isokinetic sampling.

i. Calculate the sampler orifice differential pressure based on the dirty air velocity traverse data. The sampler differential i.e. the differential to be maintained during sampling, is determined by entering the average square root velocity head observed by the probe for a single port into the following equation.
   Sampler $\Delta P = 1.573 \times (\text{avg. Vh})^2 \times (\text{probe K factor})^2$

ii. This formula will yield a sampler differential pressure which will result in a velocity through the sampler tip that is equal to the velocity of the coal and air mixture through the coal transport pipe (i.e. isokinetic sampling).

iii. Connect the tygon tubing to the inclined manometer and the orifice sensing lines on the sampler (the sensing line closest to the filter canister is the "high" side. Prepare to enter the test port with the sampling probe and maintain the desired differential pressure for that port.

iv. Insert the sample probe into the port to the first sampling point. The desired differential pressure will be monitored and maintained at all times while the probe is in the sample port. A needle valve on the sampling apparatus is utilized to maintain the sampler differential (it is a good idea to establish the approximate sampler differential just prior to inserting the probe into the port). The sampler probe will remain in the coal transport pipe for 4 minutes (2 ports, 12 points per port, 10 seconds per point) for a standard two-port arrangement. The sampling time is very critical and great care should be taken to ensure the correct sampling time is obtained for each single point.

v. Upon completion of sampling from all ports on a single fuel pipe, turn off the aspirator air supply and remove sampler from the coal transport pipe. Disconnect manometer from apparatus, turn aspirator air back on and shake sample transport hose and filter assembly to ensure all coal sampled has been evacuated from the sampler.

vi. Empty the sample collected in the collection jar into a sample bag and establish the weight of the sample (in grams). Assign this weight with a pipe designation, test number and date.

vii. Repeat the same procedure for completing the isokinetic coal sampling from the remaining coal transport pipes of the same mill. A new filter needs to be used for testing of each coal pipe.

viii. After completing the testing of all the coal transport pipes of a mill, calculations can be done as per the following formulae.

Sampler $\Delta P = 1.573 \times (\text{avg. Vh})^2 \times (\text{probe K factor})^2$

Coal Flow

$$= \frac{\text{Sample Weight (gms)}}{453.6 \text{ gms / lb.}} \times \frac{60 \text{ min / hr}}{4 \text{ min}} \times \frac{\text{Pipe area} - \text{ft}^2}{\text{Sample tip Area ft}^2}$$

Sample Tip Area = 0.0021 ft^2 (Typical)

$$\text{Air to Fuel ratio} = \frac{\text{Air Flow per Hour}}{\text{Coal Flow per Hour}}$$

Gross Coal sample can be collected from feeder inlet chute for determination of coal characteristics namely size of raw coal, moisture, HGI for applying corrections to the measured test data. The power consumed by the mill during the test can be computed by connecting energy meters.

Sampling as per ISO 9931 using a rotary PF sampler requires a minimum straight length of 5 diameters upstream and 1 diameter downstream in the fuel pipes and is preferred for measuring relative coal flow distribution between burner pipes. The rotary sampler is inserted through one port in the pipe and samples across the pipe cross-section at 64 different points to draw a representative PF sample. Under steady flow conditions, the ISO 9931 method is said to be capable of reproducibility of +/- 2% (or better) in mass flow. The specifications of Rotary Sampler are enclosed as Annexure 1.

8.6.4.2 Non Iso kinetic Sampling

Non iso-kinetic sampling is done using a Cyclone sampler on routine basis for collecting a PF sample from mill discharge pipes to monitor pulveriser performance. Feedback on PF fineness levels along with unburnt loss in bottom ash and fly ash is circulated to concerned groups to focus their attention on the need to initiate corrective action. The following points relate to non-isokinetic sampling.

- Mill fineness sample collection is always done under stable and defined conditions. Mills are set for normal operation and no change over are scheduled.

- Coal lab staff collecting fineness sample is immediately informed in event of any disturbance in normal operation.

- Appropriate ball valves are provided at sampling location so that a dust guard can be mounted on it for collecting a PF sample in dust free environment.

- The sample is obtained by traversing the pipe across its entire diameter with uniform rate of movement for 2 minutes. Samples in both directions at 90 degrees must be taken for the same period of time.

- All the coal pipes are sampled for collecting a composite sample for a pulveriser.

- Mill fineness sample is checked for four typical screens and the results can be plotted on Rosin - Rammler chart to validate the data.

As far as practical, Mill are set for nominal parameters which can be defined for a station jointly by Operation, Mill maintenance and

Efficiency group. Mill testing during part load operation (say below 80% of rated capacity) is to be avoided, except for the mills that are already showing degradation.

A typical format for reporting fineness fractions is given here.

Mill	Mill air Flow T\hr.	Mill Output T\hr.	Mill out Temp. C	Mill DP mmWC	+50	+70	+100 % retained	-200
Mill 2A								
Mill 2B								
Mill 2C								
Mill 2D								
Mill 2E								
Mill 2F								

Format-8.6.1

8.6.4.3 Coal fineness Analysis

(This analysis is best performed directly after sample extraction to prevent coagulation of sample due to moisture absorption especially for samples drawn from the mills handling high moisture coal)

i. Roll the sample bag to provide a proportionate sample. Remove 50 grams of coal from the sample.

ii. Shake this 50 grams of sample through a series of 50, 100, 140 and 200 mesh U.S. Standard screens.

iii. Record the weight of coal residue on each of the four screens and the bottom catch pan. A scale capable of accuracy to 0.001 grams is required. Calculate the percentage of sample passing through each mesh using the following equations.

Weight of Test Sample	50 g	50.0
Weight of Residue on 50 Mesh	R_1 g	______
Weight of Residue on 100 Mesh	R_2 g	______
Weight of Residue on 140 Mesh	R_3 g	______
Weight of Residue on 200 Mesh	R_4 g	______
Weight of Sample in Pan (Passing 200 Mesh)	R_5 g	______

% Passing 50 Mesh $$\frac{(50.00 - R_1)}{50} \times 100\ \%$$

% Passing 100 Mesh $$\frac{(50.00 - (R_1+R_2))}{50} \times 100\%$$

% Passing 140 Mesh $$\frac{(50.0 - (R_1 + R_2+R_3))}{50} \times 100\%$$

% Passing 200 Mesh $$\frac{(50.00 - (R_1+R_2+R_3+R_4))}{50} \times 100\%$$

% Recovery $$\frac{(50.00 - (R_1+R_2+R_3+R_4+R_5))}{50} \times 100\%.$$

iv. Plot the results of the four-sieve analysis on Rosin & Rammler graph to check the veracity of sampling and sieving. Sieve analysis of sample collected from each corner should be plotted on this log scale and the points should fall on a straight line.

8.6.5 REFERENCES

ASME Performance Test Code 4.2 – 1969,
Coal Pulverisers DS/ISO 9931 Sampling of pulverized coal conveyed by gases in direct-fired coal system

Annexure I

8.6.7 Rotary Sampler - Specifications

Rotary probe Pulverised coal sampling system including the following accessories

a) Sampling lance and associated system for sampling, Portable box with heater, venturi nozzle, pressure gauge, pneumatic valves, power supply cable as required for iso-kinetic PF sampling as per ISO 9931
b) Cyclone collector
c) Reinforced compressed air hose as per requirement
d) Sample bottles – 4 nos.
e) Dustless connection – 8 nos
f) O&M manual

Spares for Rotary Sampler

Sampling lance	1No. For fuel pipe Internal dia:400-700mm (To be specified)
Sampling tips	4 nos.
Air filters	1 set

Station : **Format-8.6.2**
Date:

Dirty Air / Fuel Ratio Test

Unit		**Mill**	**DATE:**	
		Start Time	**Barometric Prsr.**	
		End Time	**Probe 'K' Factor**	

Corner 1		
POINT	**PORT 1**	**PORT 2**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

TEMPERATURE **C**
STATIC PRESS **"w.c.**

Corner 2		
POINT	**PORT 1**	**PORT 2**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

TEMPERATURE **C**
STATIC PRESS **"w.c.**

Corner 3		
POINT	**PORT 1**	**PORT 2**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

TEMPERATURE **C**
STATIC PRESS **"w.c.**

Corner 4		
POINT	**PORT 1**	**PORT 2**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

TEMPERATURE **C**
STATIC PRESS **"w.c.**

Table 2

Dirty Pitot Survey - Unit ___

Mill _____ **Date __/ __/ _____** **Readings taken by _________________**

		______hrs	______hrs	______hrs	______hrs	______hrs	______hrs	______hrs
Unit Load	MW							
PA Flow	t/hr							
Coal Flow	T/hr							
Mill Outlet Temp	C							
Mill DP	mmWC							
Mill Amps	Amp							
Hot Air Damper	% open							
Cold Air Damper	% open							
PA Hdr.Prsr.	mmWC							
Inlet PA Temp	C							
Frequency	Hz							
Time - 20 disc. rev.	sec							

Note: Please ensure stable conditions for the mill being tested. In case of unavoidable variations, please inform the test crew at firing floor.

Format-8.6.3