

MEASUREMENT AND PREDICTION OF COAL FLOW RATES IN PULVERISED FUEL PIPES

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Declaration

I declare that this dissertation is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

A handwritten signature in dark ink, appearing to be 'D. M. M.', is written over a horizontal dotted line.

(Signature of Candidate)

20 day of December, 2021

Abstract

Burners at coal fired Power Plants require a controlled ratio of air fuel mixture to realise lower NO_x emissions and to optimise combustion efficiency in coal fired power plants. Another contributing factor for lower NO_x emissions is the coal particle size distribution.

Iso-kinetic sampling is utilised for the monitoring of PF size and mass distribution to the burners at Power Utilities. The accuracy of these sampling methods is questionable.

The primary aim of the project was to establish the degree of accuracy of the manual and automated sampling equipment used in Eskom and their methods of application. Based on international and local standards and procedures a testing program was setup and the sampling equipment were evaluated on an industrial scale at one of Eskom's Power Plants. Flow correlation calculations and CFD modelling were also carried out to complement the site evaluation of the PF Sampling methods.

The Rotoprobe and 3 Axis traverse produce favourable results with respect to accuracy and repeatability. The target plate and 1 Axis traverse produced questionable results.

Dedicated to my loving, supportive and inspiration wife,

Prema

&

my awesome kids

Ashaylen, Tristan & Sihanna

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Nomenclature

List of Symbols

A	cross sectional area of pipe, m^2
DAP	Dirt Air Probe
d_n	Sampling nozzle inner diameter, mm
d_p	Particle diameter, mm
D	Pipe diameter, mm
EPRI	Electric Power Research Institute
f_r	Friction factor
Fr_{min}	Froude number at minimum transport velocity
g	Gravitational acceleration, m/s^2
G_s	Solid mass flow rate per unit area, $kg s^{-1} m^{-2}$
i	particular sampling point of interest
IPP	Independent Power Producers
LC-4	Manual PF Sampler
li	Sampling point location, mm
LNB	Low NOx Burners
m^*	Mass flow ratio of solids to gas
M_p	Mass flow solids, kg/s
M_a	Mass flow gas, kg/s
M_d	Total mass of pulverised fuel (after drying), kg
MF_d	Mass flow of pulverised fuel (dry), kg/s
MRC_d	Mass flow of raw coal (dry), kg/s
MRC_w	Mass flow of raw coal (wet), kg/s
n	Number of sampling points
n_r	Number of sampling points on each radius
%Mc	Percentage of moisture in raw coal, %

PF	Pulverised fuel
PU	Power Utility
RTS	Return to Service
S_{Δ}	Particle size distribution parameter
T	Sampling time per point, s
$U_{\min}$	Minimum transport velocity, m/s
U_s	Saltation velocity, m/s
U_{s0}	Single particle saltation velocity, m/s
U_t	Single particle terminal velocity, m/s

Greek Letters

B	Model constant
ρ_f	Density air, kg/m ³
ρ_p	Density of Solid, kg/m ³
η	Viscosity of air, Pas
θ	angle
θ_r	Angle of response

Chapter 1 Introduction

1.1 Research Background/Context

South Africa's State-owned Power Utility Eskom has been in operation for over 90 years and relies primarily on the combustion of coal for its base load electricity supply. South Africa has an abundant coal reserve and coal is still the cheapest energy source for producing electricity. Even though Independent Power Producers (IPPs) with the focus on renewable energy technologies have recently entered the South African market, Eskom will remain a giant player with respect to the supply of electricity to South and Southern Africa for many years to come.

Eskom generates electricity from diverse sources including coal fired plants, nuclear, gas turbines, hydro and a small percentage of renewable sources, but as mentioned above relies primarily on coal for South Africa's electricity needs, from 15 coal fired power plants. 37149MW from a total installed capacity of 52104MW is produced at these coal fired power stations (Dpe.gov.za., 2021). To meet this demand these Power Plants consumed approximately 113,7 million tons of coal in 2017 (South African Market Insights, 2018).

Legislation found in the Air Quality Management (AQM) Act 39, of 2004, stipulates stringent limits for particulate and gaseous emissions into the environment. Amongst other limits the AQM act states that Nitrogen Oxide (NO_x) emissions should not exceed 750mg/Nm³ (ref dry basis, 10% O₂). In response to the AQM act, the PU sought out technologies to reduce gaseous and particulate emissions.

Low NO_x burners (LNB) were selected as the most economical technology to aid in reducing its NO_x emissions, which ranges from 900 kt to 1000 kt per annum for the PU fleet.

The two new plants under construction will both be built incorporating LNB technology. A previously mothballed plant which was recently returned to service (RTS) was retrofitted with low NO_x burners and there are plans to roll out the technology at other plants.

To realise lower NO_x emissions and ensure that these burners operate effectively, pulverised coal must be delivered, controlled and evenly distributed between the (pulverised fuel) PF pipes and to the burners. The burners require a controlled ratio of air (primary, secondary and tertiary air) fuel mixture with a relatively even particle size distribution. The requirements for acceptable particle size and mass distribution as stated in the Eskom Standard 240-7640331 Zwiegelaar, (2015) are listed below.

After PF sampling the sample is graded (separation by size utilising sieving) and weighed to determine the particle size distribution. The conventional burner requirements are:-

- Passing through 75µm: 65% to 75%
- Passing through 106µm: 77% to 86%
- Passing through 150µm: 88% to 94%
- Passing through 300µm: 98.8 to 99.8%

The standard also requires that the PF distribution between the pipes should not deviate by more than 20% from the mean on a mass basis and that PA distribution between pipes should not deviate by more than 5% from the mean on a mass basis.

For LNB with no over fire (as in the case of RTS plant) air the requirements are:-

- Passing through 75µm: 71% to 80%
- Passing through 90µm: 80% to 90%
- Passing through 200µm: 99.4% to 99.95%
- Passing through 300µm: 98.8 to 100%

The standard also requires that the PF distribution between the pipes should not deviate by more than 15% from the mean on a mass basis and that PA distribution between pipes should not deviate by more than 5% from the mean on a mass basis. The requirements for LNBs are more stringent compared to conventional burners.

Unevenly distributed flow in PF pipes can yield any or a combination of the following undesirable results:

- Hot or cold spots in the boiler,
- Slagging and fouling,
- Load losses,
- Lower NO_x emissions not realised,
- Increased unburned carbon,
- Erosion of boiler components such as boiler tubes, PF piping and burners,
- Blockage of PF pipes,
- Instability in the combustion process,
- Increased explosion risk in the boiler
- Ununiformed wear of PF piping and burners,
- Poor turn down ratios, i.e. being able to operate at lower loads without having to rely on fuel oil support.

Two important issues must be highlighted. Firstly, during the design phase of pneumatic conveying systems, important parameters such as operating velocity, pressure drop, etc. in PF pipes are currently predicted by empirical correlations. Various correlations like Rizk, Weber, Matsumoto, etc. can be utilised to calculate the same design and operating parameters.

Each correlation will yield a different value for the saltation velocity. The saltation velocity will be used to calculate operating velocity, therefore the choice of correlation and accuracy of the design and operating parameters calculated is questionable.

Secondly if flow in the PF pipes is not adequately monitored and measured, attempting to control and balance the flow with respect to mass flow and size distribution could prove to be a futile exercise.

In order to balance and control the flow of PF, the logical starting point is to know what conditions are prevailing. In this regard both of the abovementioned points are important. The most suitable correlation must be utilised to provide the best operating parameters, once this is optimised the most accurate, reliable and

repeatable technology must be applied to measure and monitor PF and air flow (particle velocity, particle mass flow, particle size and air flow) in order to optimise combustion.

1.2 Purpose of the Study

The purpose of the study was to evaluate current pulverised fuel measurement technology, standards and practices and recommend a best practice for PF measurements in Power Utilities. Evaluation of the PF sampling technology required the accuracy and repeatability of the methods to be established.

1.3 Research Motivation

Benefits of optimised combustion resulting from identifying the best practice for measurement of PF mass flow and distribution would include:

- Balancing of fuel flows will contribute to combustion stability from burners continuously operating at design air/fuel ratios.
- Allow functionality (staged combustion) of Low-NO_x burner technology and realise lower NO_x emissions.
- Balanced PF distribution would result in uniform wear and a reduction in wear failures on PF transport lines and burners.
- Complete combustion of PF, i.e. improved combustion and a reduction in unburned carbon.
- Improve turn down ratio.

1.4 Problem Statement

Phenomena such as PF settling, choking and roping can result in localised areas in the pipe with high PF concentrations cause disturbances in the pneumatic transport lines and lead to velocity and mass flow imbalances between various burners.

Occurrence of these flow phenomena is highly unpredictable and as mentioned above is currently evaluated by means of correlations. The most suitable

correlations must be identified and utilised for the calculation of operating parameters such as conveying velocity.

Iso-kinetic sampling is utilised for the monitoring of PF size and mass distribution to the burners and for the monitoring of mill performance at the Power Plants. Many inaccuracies can creep in during the sampling process resulting from operator error, plant conditions, moisture, leaks on the equipment, etc.

Current standards and practices in Eskom were evaluated in this study in order to optimise PF sampling measurements. Information gathered from the Performance and Test Department at the various Power Station indicate that in the absence of an Eskom standard, each station generated its own unique procedure based on BS 893:1978 or from ISO9931 for the PF sampling.

During the course of this study an Eskom Standard (240-76440331) was developed for PF sampling in Eskom. This standard references ISO 9931, which details the use of a rotoprobe sampler, however the Eskom Standard described the use of a manual sampler and does not reference the previous Eskom Standard GGP0855, BS893:1978 or the TRR/P089/022 procedure which was the basis for the development of the manual sampler. GGP0855 was more comprehensive than 240-76440331. This could lead to stations reverting back to their own procedures and encourage non standardisation. This is evident in the various methods of PF sampling undertaken at the power stations. Accurate measurement for a critical process such as combustion is crucial and must be improved in Eskom. Therefore, a comprehensive assessment was required to evaluate standards, procedures and measurement practices in Eskom and development of a best practice for the accurate measurement of PF mass flow and size distribution. This is imperative for combustion optimisation and implementation of LNBS

To have a positive impact on optimisation of combustion the sampling must be carried out accurately, with the most suitable equipment and skilled operators. The best practice must be benchmarked and made a standard throughout the PU.

Online PF mass flow monitoring equipment has been installed at three of Eskom's Power Plants. The sensors were installed on a horizontal pipe at one of the sites. This site often suffers blockages and renders the sensors inoperable. The second site was affected by budget constraints and the online system currently requires maintenance and calibration, which is on hold. The third site has an ideal setup and is in the process of carrying out final calibrations before the online system can be verified against Iso-kinetic sampling.

Online systems require dedicated personal and budgets for maintenance and calibrations. This is a must if these systems prove to be the best in terms of monitoring, measuring and controlling. Systems of this nature have yielded impressive results at power plants in Europe.

1.5 Research Questions

- What standards and procedures are being utilised for PF sampling at the various power stations in South Africa?
- What technologies can be utilised for PF sampling?
- How accurate are the results of these technologies?
- How repeatable are the results from these technologies?

1.6 Dissertation Layout

Figure 1-1 show a preview of the organisation of the remainder of the dissertation.

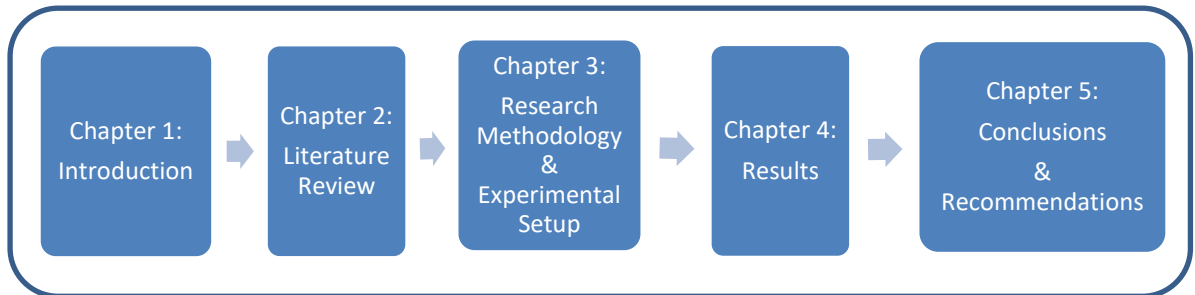


Figure 1-1: Dissertation Layout

Chapter 2 Literature Study

2.1 Introduction

A drum assisted, 2 pass coal fired power plant layout is shown in Figure 2-1. The process of producing electricity starts where coal is pulverised into a fine powder in large mills. This fine powder is known as pulverised fuel (PF). The powder is transported pneumatically to burners, at the boiler, where it combusts to produce heat. The boiler is made up of thousands of kilometres of metal tubes that contain water. The heat generated from the coal combustion is transferred to the water in the tubes and the water is converted to steam. The superheated steam is directed via pipework to the turbine and as it passes over the turbine blades it forces the blades to rotate. The turbine shaft housing the blades is coupled to a generator rotor which is an electromagnet and induces electric current as it rotates inside a stator consisting of copper windings. Once the steam passes through the turbine it is cooled and condensed in a condenser and pumped back to the boiler tubes for reheating. In a separate circuit water used for cooling in the condenser is evaporated in the cooling towers. Gasses from the combustion process pass through bag filters or precipitators where most of the ash is removed before being released in the smoke stacks. Of particular interest to this study is the milling plant system.

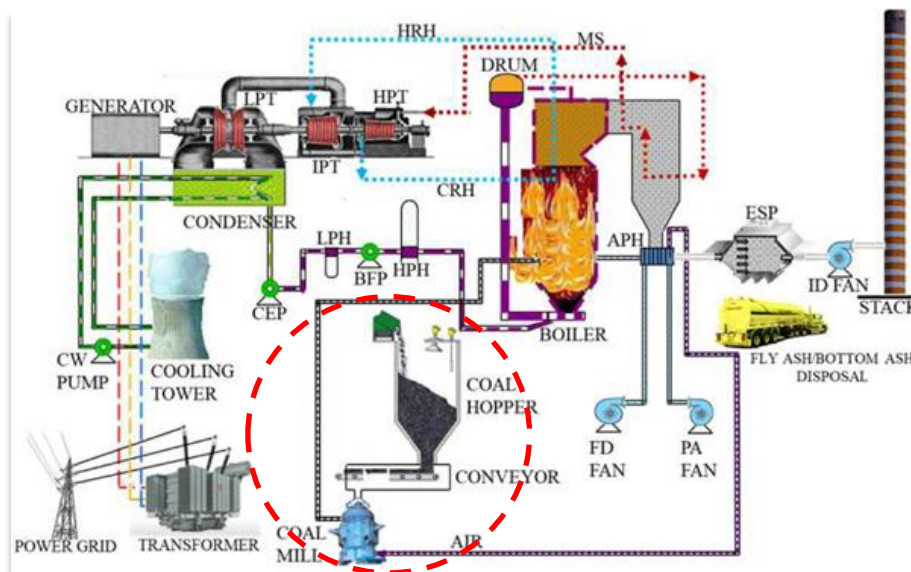


Figure 2-1: Power Plant Layout (Tharun Kanth Ventrapati et al., 2019)

2.2 Milling Plant at Eskom

Table 2-1: Summary of Information on Mills at Eskom (Courtesy Eskom)

Name	Size MW	No Units	Type of Circulation	Reheat	Layout	Burner configuration	Furnace type	Mill OEM	Mill type	Coal Nett CV Mj/kg	Coal CV Btu/lb	Volatiles (%)	Ash (%)	Fuel oil	No of mills per unit
PS1	350	1	Drum, Assisted	Yes	2 pass	T - fired tilting	Twin	Stein	Tube	22,00	9 460	22,0	23,0	Light Oil	3
	350	5	Drum, Assisted	Yes	2 Pass	T - fired tilting	Twin	Loesche	Vertical Spindle	22,00	9 460	22,0	23,0	Light Oil	6
PS2	200	8	Drum, Natural	No	2 pass	Front wall	Single	Lopulco	Vertical Spindle	24,65	10 600	24,5	18,0	Bunker 150	5
PS3	600	4	Once Through	Yes	Tower	Hor Opposed	Twin, DW	Babcock 12.9 E	Vertical Spindle	23,60	10 148	24,5	26,5	Bunker 150	6
	600	2	Once Through	Yes	Tower	Hor Opposed	Twin, DW	Loesche	Vertical Spindle	23,60	10 148	24,5	26,5	Light Oil	6
PS4	200	5	Drum, Natural	No	Tower	Hor Opposed	Twin, DW	Babcock 8.5 E	Vertical Spindle	20,18	8 677	21,6	25,0	Bunker 150	6
	200	1	Drum, Natural	No	2 pass	Hor Opposed	Twin, DW	Loesche	Vertical Spindle	20,18	8 677	21,6	25,0	Bunker 150	6
PS5	200	5	Drum, Natural	No	2 Pass	Hor Opposed	Twin, DW	Babcock 8.5E	Vertical Spindle	22,80	9 804	22,0	26,0	Bunker 150	6
	200	2	Drum, Natural	No	2 Pass	Hor Opposed	Twin, DW	MPS	Vertical Spindle	22,80	9 804	22,0	26,0	Bunker 150	6
	200	3	Drum, Natural	No	Tower	Hor Opposed	Twin, DW	PHI	Vertical Spindle	22,80	9 804	22,0	26,0	Bunker 150	6
PS6	686	6	Drum, Assisted	Yes	2 pass	T - fired tilting	Single	Kenedy van Saun	Tube	19,00	8 170	22,5	30,0	Bunker 150	5
PS7	100	5	Drum, Natural	No	2 pass	Front wall	Single	Babcock 8.5E	Vertical Spindle	21,00	9 030	21,0	30,0	Bunker 150	3
	125	4	Drum, Natural	No	2 pass	Front wall	Single	Mitchell	Tube	21,00	9 030	21,0	30,0	Bunker 150	3
PS8	500	3 (1-3)	Once Through	Yes	Tower	Hor Opposed	Twin, DW	Babcock 10.8E	Vertical Spindle	22,00	9 460	22,6	22,3	Light Oil	6
	500	3 (4-6)	Once Through	Yes	Tower	Hor Opposed	Twin, DW	Babcock 12 E	Vertical Spindle	20,70	8 901	21,8	27,2	Light Oil	6
PS9	618	6	Drum, Natural	Yes	2 pass	Hor Opposed	Single	Riley	Tube	14,40	6 192	19,6	40,0	Bunker 150	6
PS10	657	3	Once Through	Yes	Tower	Hor Opposed	Single	Stein	Tube	22,20	9 546	22,0	25,0	Bunker 150	5
	713	3	Once Through	Yes	Tower	Hor Opposed	Single	Stein	Tube	22,20	9 546	22,0	25,0	Bunker 150	5
PS11	665	6	Once Through	Yes	Modified Tower	T - fired fixed	Single	Stein	Tube	20,89	8 983	22,0	25,8	Bunker 150	5
PS12	600	6	Drum, Natural	Yes	2 pass	Hor Opposed	Single	Babcock 12.9 E	Vertical Spindle	20,00	8 600	23,0	28,0	Bunker 150	6
PS13	609	6	Once Through	Yes	Tower	Hor Opposed	Twin, DW	Stein	Tube	20,00	8 600	23,0	27,0	Bunker 150	6

Amongst other information Table 2-1 shows that the Eskom utilises medium speed Vertical Spindle and low speed Tube-ball mills as shown in Figure 2-2 to pulverise coal. The information was requested in order to choose a suitable site to carry out the evaluation of PF sampling equipment. More important than the mill type, a unit that was equipped with gravimetric coal feeders was sought.

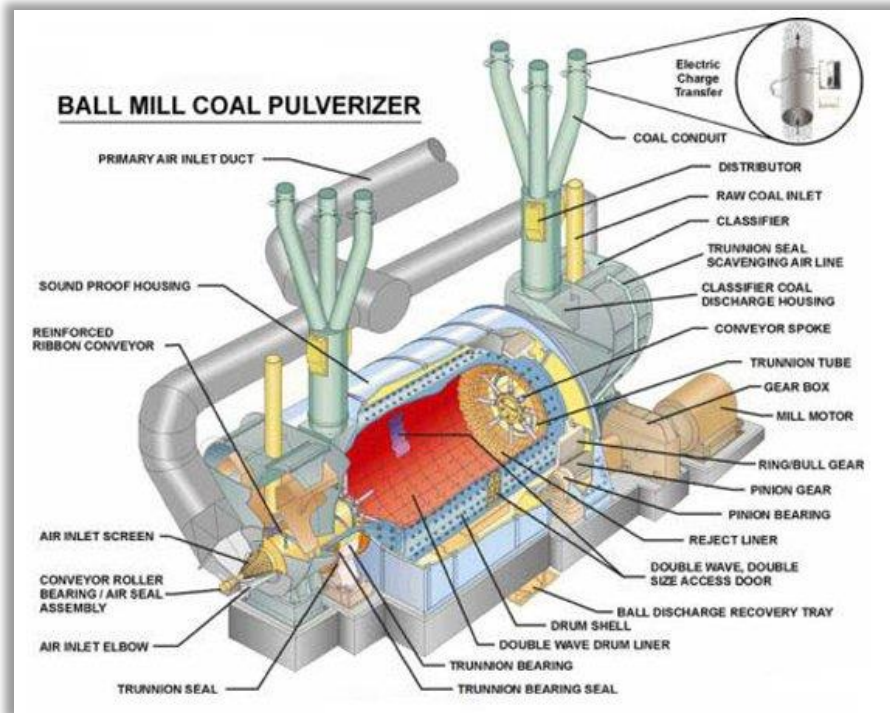


Figure 2-2: Tube Ball Mill (Imperial World Trade Pvt Ltd., 2021)

2.3 Burner Arrangement for a Tangential Fired Boiler

PF pipes pneumatically transport the PF from the mills to the burners located at the furnace. The boiler of Power station A, where this study was undertaken is shown in Figure 2-3 and has a tilting tangential firing system, consisting of 8 burner boxes per level on the boiler. Four of the boxes are located at the corner of the furnace and four on the boiler rear and front walls. As shown in Figure 2-3 the burners form two imaginary furnaces without a division wall.

The tilting mechanism of the burners allows the fire vortex to be shifted up or down to achieve steam or load parameters.

The arrangement of the burners does not have an impact on the PF sampling.

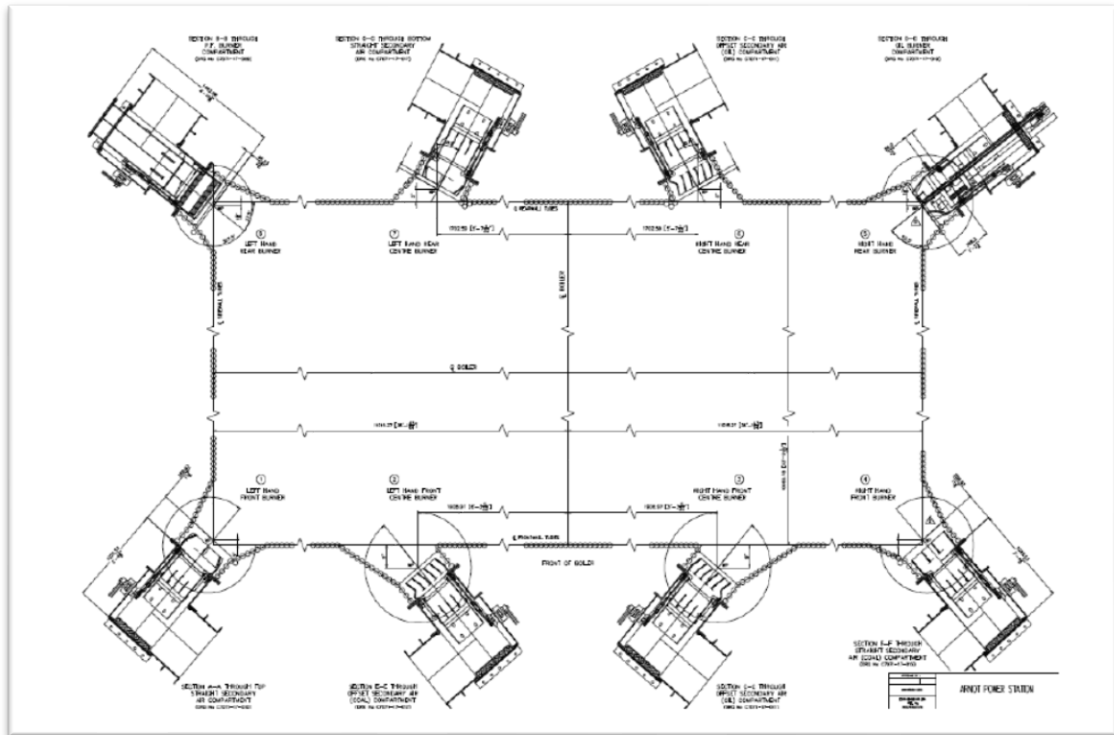


Figure 2-3: Classified Drawing of Power Station A Tangential Burner Layout (Power Station A, 2015)

2.4 Multiphase Flow

Marcus, et. al., (1986) describes multiphase flow as a complex subject. As the name suggest multiphase flow encompasses combinations of different phases such as liquid-solid or solid-gas interacting and flowing in a duct or pipe. Of particular interest for this study is the dynamics of solid particles transported in a gas medium, i.e. a pneumatic conveying system.

Pneumatic conveying can simply be defined as the movement of solid particles in a gas stream (usually air) from one point to another. There are numerous industrial applications for pneumatic conveying. The application of interest for this study is pulverised fuel (PF) suspended in air, flowing from the mill to the various burners. This complex network of pipes and bends is a typical pneumatic transport system. Bends are primarily responsible for rope formation. These physical arrangements and flow phenomena impact significantly on the particle mass distribution between burners.

2.5 Dense and Dilute Phase Flow

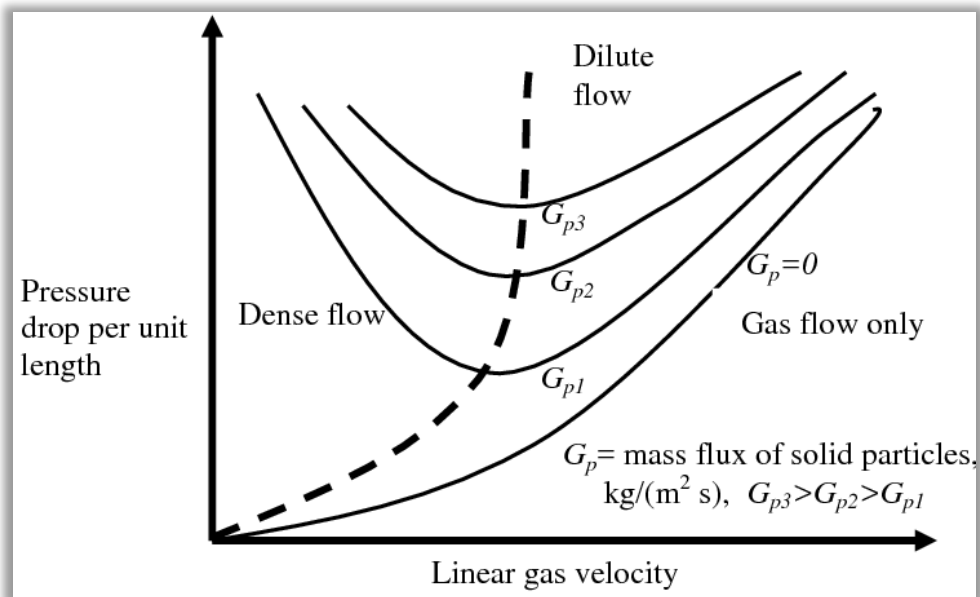


Figure 2-4: Dense vs. Dilute flow (Fan, Zhu and Varma, 1998)

As illustrated in Figure 2-4, flow regimes can broadly be defined as either dense or dilute phase flow. If the conveyed material is suspended in air throughout the pipeline, the regime falls under dilute phase flow. If the material is conveyed at low velocity in a non-suspension mode, the flow is considered to be dense phase flow. Dilute phase flow is required for the transport of pulverised coal.

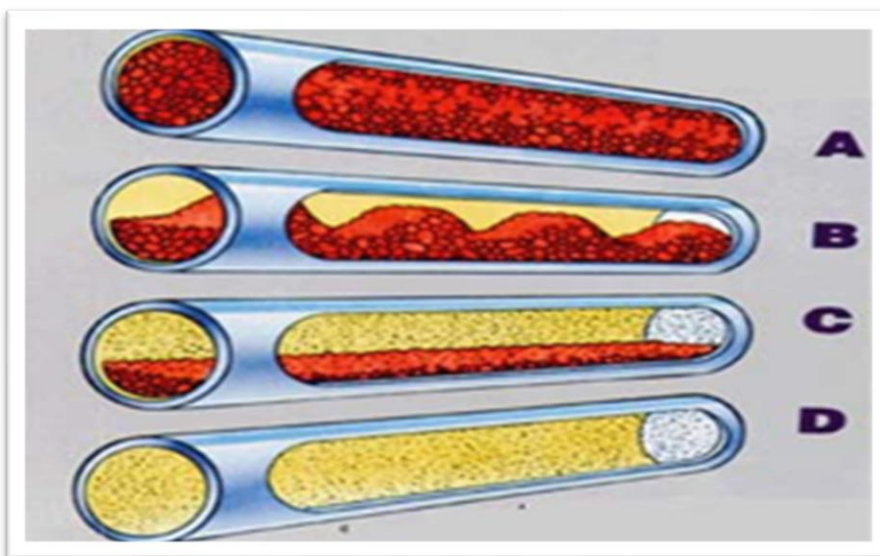


Figure 2-5: Different Flow Regimes (Macawberindia.com. 2016)

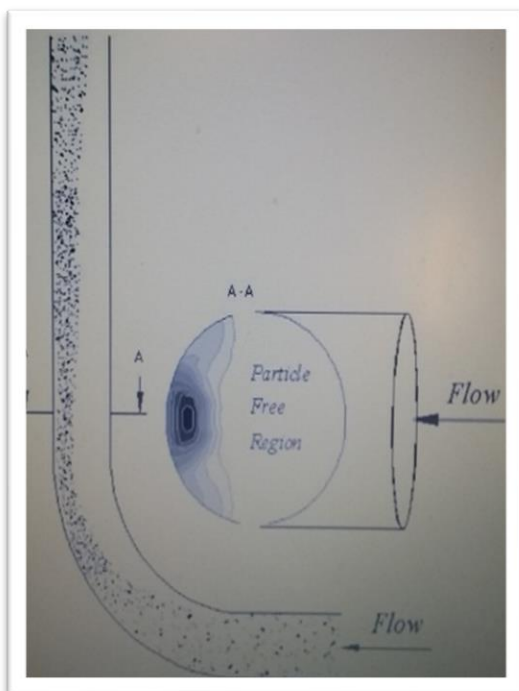
Figure 2-5: Pipes A, B & C illustrate different dense phase flow regimes. The flow in Pipe A is called Solid Dense Phase where the pipe is full of material and the material velocity is very low. Pipe B illustrates Discontinuous Dense Phase where the material velocity is low and moves in plug flow. In Pipe C the flow is Continuous-Dense Phase where there is a moving bed of material.

In Figure 2-5 Pipe D illustrates dilute phase flow where the gas velocities are high and the pressure gradients low. The material that is being transported is kept in suspension by sufficient volumes of gas flowing at velocity above saltation velocity. The material being conveyed does not accumulate on the bottom of the pipe and is transported continuously.

In order to prevent settling and blockages pneumatic transportation system in power plants are designed to operate above saltation velocity in the dilute phase. The most important differences between dilute and dense phase are the material and air velocity and solid loading ratio (air fuel ratio). In the dilute phase large amount of air (typically 3:1 for pulverised coal) is needed at low pressures and relatively high velocities.

2.6 Flow Phenomena

2.6.1 Roping



As shown in Figure 2-6 there are areas with very little or no PF and an area of high concentration of PF. As a result of inertia, PF flowing through a bend is usually directed towards the extrados which results in higher particle concentrations in this area.

This phenomenon is known as Roping and have been reported to disperses between 10 to 25 diameters from a bend. Due to design layout these lengths are usually not

Figure 2-6: Roping in a Bend (Bilirgen and Levy, 2001)

available on Power Plants and once a rope is formed it is likely to continue flowing throughout the remaining length of pipe. Roping has a significant impact on PF size and mass distribution and poses challenges in taking of representative PF samples.

2.6.2 Saltation Velocity

Cabrejos, et.al., (1994) studied the relationship of pickup and saltation with the prediction of the minimum conveying velocity of solid particles in horizontal pipelines for dilute-phase pneumatic transport. In this study the minimum conveying velocity was defined as the mean velocity of a gas stream required to transport solid particles in suspension through a horizontal pipeline without allowing them to settle on the bottom of the pipe.

Saltation velocity along with pressure drop and solid mass loading ratio are the most important variables in pneumatic transportation as they have the largest impact on the flow regime.

2.6.3 Flow Correlations for Saltation Velocity

A number of correlations have been developed for the calculation of saltation velocity; these include:

- Zenz (1964),
- Risk (1976),
- Thomas (1961,1962),
- Cabrejos and Klinzing(1994),
- Matsumoto et al. (1977),
- Schade (1987),
- Yi et al. (1998),
- Weber (1981)
- Geldart and Ling (1992),
- Mewing (1976),
- Rose and Duckworth (1969) and
- Doig and Roper (1963)

Variables that affect the saltation velocity include but not limited to, are the particle size, particle density and pipe diameter. Therefore, depending on the properties of the medium being transported; some correlations have proven to be more accurate than others.

Risks equation is frequently quoted in a number of articles. It is relatively simple to apply, but has limitations, in that it does not take factors like particle density into consideration.

2.6.4 Choking

Choking phenomena in vertical pipe flow is not well understood (Klinzing, Marcus, Rizk and Leung,1997). Choking in vertical pipes is described as being similar to saltation in horizontal pipes. Mills, (2004) describes choking occurring in vertically upward flow and is the process that commences when solid particles near the pipe wall begin to flow downwards. This can eventually result in the pipe becoming blocked or choking. The choking point is the minimum transport velocity for a vertical pipe.

The saltation velocity is always larger than the choking velocity and can be in the order of 3 to 6 times higher for fine particle (Chemicalprocessing.com. 2021). This margin would be smaller for coarse particles.

2.6.5 Flow Correlations for Choking

Correlations for choking include:

- Barth (1954)
- Gunther (1957)
- Zenz and Othmer (1960)
- Doing and Roper (1963)
- Rose and Duckworth (1969)
- Leung et al. (1971)
- Yousifi and Gau (1974)
- Knowlton and Bachovchin (1976)
- Yang (1975)
- Punwni et al. (1976)

Yousifi and Gau was found to be reliable by Chong and Leung, (1986).

As mentioned above, empirical correlation are utilised to calculate important parameters, such as operating velocity. The operating velocity is based on choking, saltation or pickup velocity for multiphase flow in pipes.

The accuracy and applicability to pulverised coal flow of these correlations is questionable.

2.6.6 Review of Saltation velocity flow correlations

As mentioned above saltation velocity is 3 to 6 time greater than choking velocity. Therefore, a pneumatic conveying system that is designed to satisfy the requirements of saltation velocity, i.e. maintain a velocity that is sufficient to keep the solid particles in suspension as they are transported in the pipe, would also be adequate to ensure that choking does not occur in the vertical sections of the pipe.

Jones and Leung, (1978) conducted an evaluation of 8 correlations for saltation velocity. The study evaluated Thomas (1962), Zenz (1964), Matsumoto et al. (1974, 1975), Rizk (1973, 1976), Mewing (1976), Rose and Duckwort (1969) and Doing and Roper (1963). Jones and Leung evaluated the correlations on an R.M.S relative error basis and were able to assign a degree of accuracy to each of the correlations which is tabulated below.

Table 2-2: Jones and Leung, (1978) Evaluation of Saltation Velocity Correlations

Correlation	Year	E R.M.S relative error %
Doing and Roper	1963	90
Matsumoto et al., I	1974	60
Matsumoto et al., II	1975	53
Mewing	1976	50
Rizk	1973	60
Rose and Duckworth	1969	78
Thomas	1962	44
Zenz	1964	54

Table 2-2 from the Jones and Leung, (1978) study found the Thomas correlation to be the most accurate. Therefore, Jones and Leung, (1978) recommended the Thomas correlation to be utilised for pneumatic conveyor design. They also comment that Matsumoto et al. (1976) was the easiest to use when scaling up dimensionally.

Van der Merwe, (2014) study focussed on settling velocity of pulverised coal in a pneumatic conveying system. Van der Merwe referred to the work carried out by Dhodapkar, (2005), where Dhodapkar recommended that for coarse particles with a diameter greater than 500 μm , the Rizk (1973) and Matsumoto (1977) correlations should be utilised and for fine particles (<500 μm) the Matsumoto (1977) correlation should be utilised. It should be noted for combustion in a coal fired boiler the PF sizes required are below 300 μm . Van der Merwe, (2014) performed calculations and sensitivity analysis based on these correlations and a 1st principle approach utilising the VDI (Verein Deutscher Ingenieure) Heat Atlas approach used by Muschelknautz (1993). Van der Merwe found that the Rizk (1973) correlation for saltation velocity was suitable for the range of PF particle sizes which as stated above is typically up to 300 μm . Van der Merwe indicated that a safety factor of 1.5 as recommended by Rhodes, (2008) should be applied to the Rizk correlation. The Masumoto (1977) correlation significantly overestimated the saltation velocity, while the VDI 1st principle approach underestimated the saltation velocity for the PF size range.

Yi, (2001) provided a review of 11 correlations, information on corelations from Yi study was utilised to create Table 2-3 which provides a high level summary of the flow correlations. Yi concluded that despite minimum conveying velocity research being undertaken for several decades, the wide scatter and contradictions provided by the flow correlations in his study, confirmed that more effort is required in this area. Information for the Weber (1981) correlation was obtained from Ratnayake (2005) and Rabinovich and Kalman (2008) as Yi did not stipulate information on the Weber correlation.

Gomes et al., (2014) did an extensive review of 8 flow correlations which included an investigation into the application of the following correlations; Risk (1976), Matsumoto et al. (1977), Schade (1987), Weber (1981), Geldart and Ling (1992), Ochi (1991), Cabrejos and Klinzing (1994) and Kalman & Rabinovich (2008) which were identified by Gomes to be the main correlations to predict saltation velocity.

Table 2-3: Summary of Saltation Velocity Correlations

Correlation By	Year	Pipe internal diameter (mm)	Test Materials	Saltation Velocity Definition	Correlation	Equation
Zens	1964	31.75 & 63.5	Rice krispies, glass beads, sand, salt, cracking catalyst, soybeans & tenite.	The air velocity required to carry solids at a certain loading without allowing them to settle in any horizontal pipe run is defined as the minimum conveying velocity.	$\frac{G_s}{\rho_p} = 0.213 S_{\Delta}^{1.5} \cdot (U_s - U_{s0}) / U_{s0}$ Where S_{Δ} & U_{s0} are determined graphically	1
Rose & Duckworth	1969	32	Mustard seed, glass bead, steel bead & lead bead	The air velocity at which particles settled out of suspension and the flow became unstable.	$\frac{U_{min}}{U_t} = 3.2 (m^*)^{0.2} \left(\frac{D}{d_p}\right) \left(\frac{\rho_p}{\rho_f}\right)^{-0.7} \left(\frac{U_{min}^2}{g \cdot D}\right)^{0.25}$	2
Duckworth	1976	12.7 & 25.4	Glass, mustard seed & polystyrene	The air velocity at which particles settled out of suspension and the flow became unstable.	$\frac{U_{min}}{U_t} = f_1 \left(\frac{d_p}{D}\right) f_2(\theta) (m^*)^{0.3}$ Where $f_1 \left(\frac{d_p}{D}\right)$ and $f_2(\theta)$ are determined graphically	3
Rizk	1976	50, 100, 200 & 400	Styropor & polystyrol	The value at which the pressure drop reached a minimum value.	$m^* = \left(\frac{1}{10^{\delta}}\right) Fr_{min}^x$ where $\delta = 1.44 d_p + 1.96$. $x = 1.1 d_p + 2.5$ and d_p in mm	4

Table 2-3: Summary of Saltation Velocity Correlations (Continued)

Correlation By	Year	Pipe internal diameter (mm)	Test Materials	Saltation Velocity Definition	Correlation	Equation
Matsumoto	1977	26 & 49	Glass bead, copper bead & polystyrene	The minimum conveying velocity was defined as the velocity at which material began to settle out on the bottom of the pipeline and a stationary bed was formed.	for $d_p > 1.39D \left(\frac{\rho_p}{\rho_f}\right)^{-0.74}$ $m^* = 0.373 \cdot \left(\frac{\rho_p}{\rho_f}\right)^{1.06} \cdot \left(\frac{U_t}{10\sqrt{g \cdot d_p}}\right)^{-3.70} \cdot \left(\frac{U_s}{10\sqrt{g \cdot d_p}}\right)^{3.61}$ for $d_p < 1.39D \left(\frac{\rho_p}{\rho_f}\right)^{-0.74}$ $m^* = 5560 \left(\frac{d_p}{D}\right)^{1.43} \cdot \left(\frac{U_{min}}{10\sqrt{g \cdot D}}\right)^4$	5 6
Wirth	1983, 1985	10 & 40	Silica sand, glass bead & polystyrene	The minimum conveying velocity was at the velocity at which the first plug/slug occurred.	$\frac{\rho_f}{\rho_p \cdot (1.0 - \varepsilon)} \cdot m^* = 0.0018 F_{ri}^4$ $F_{ri} = \frac{\rho_f}{\sqrt{\left(\frac{\rho_p}{\rho_f} - 1\right) (1 - \varepsilon) D \cdot g \cdot f_r}}$	7

Table 2-3: Summary of Saltation Velocity Correlations (Continued)

Correlation By	Year	Pipe internal diameter (mm)	Test Materials	Saltation Velocity Definition	Correlation	Equation
Schade	1987	50, 60, 80, 100, 120 & 150	Granule, sand, styropor, rubber and Polystyrol	The air velocity at which the particle velocity became zero.	$\frac{U_{min}}{\sqrt{g \cdot D}} = (m^*) \cdot \left(\frac{D}{d_p}\right)^{0.0025} \cdot \left(\frac{\rho_p}{\rho_f}\right)^{0.34}$	8
Weber	1981	small scale model tests	coal	Free settling velocity of a single particle.	For $U_t \leq 3ms^{-1}$ $Fr_{min} = \left(7 + \frac{8}{3} U_t\right) \cdot (m^*)^{0.25} \cdot \left(\frac{d_p}{D}\right)^{-0.1}$ For $U_t > 3ms^{-1}$ $Fr_{min} = 15(m^*)^{0.25} \cdot \left(\frac{d_p}{D}\right)^{0.1}$	9 10
Geldart	1992	9.19 & 12.52	Fine coal with average particle sizes of 8, 18 and 26µm.	The minimum conveying velocity was obtained by setting a pressure differential between the feeder and reciever and measuring the solids flow rate at different gas velocities.	for $\frac{G_s}{D} > 4700$ $U_{min} = 8.7 G_s^{0.302} \cdot D^{0.153} \cdot \eta^{0.55} \cdot \rho_f^{-0.42}$ for $\frac{G_s}{D} < 4700$ $U_{min} = 1.5 G_s^{0.465} \cdot D^{-0.01} \cdot \eta^{0.55} \cdot \rho_f^{-0.42}$	11 12

Table 2-3: Summary of Saltation Velocity Correlations (Continued)

Correlation By	Year	Pipe internal diameter (mm)	Test Materials	Saltation Velocity Definition	Correlation	Equation
Ochi	1991	40, 50 & 60	Wheat, rape seed and Polyethylene pellets.	The minimum conveying velocity was defined as the limiting fluid velocity at which conveying is possible in a state in which particles are not stagnant on the bottom of wall of the pipe.	$U_{Min} = 1.41K \cdot U_t \cdot \cos \theta_r \cdot \sqrt{\sin \theta_r} + B$ where K and B are model constants and θ_r is the angle of response obtained from the gradient angle method using a cylinder.	13
Cabrejos & Klinzing	1994	50	Alumina, glass beads and polyester polymers	The definition for minimum conveying velocity was the air velocity at which the particles start to drop out of suspension and settle on the bottom of the pipe.	$\frac{U_{min}}{\sqrt{g \cdot d_p}} = \frac{U_{s0}}{\sqrt{g \cdot d_p}} + 0.00224 \left(\frac{\rho_p}{\rho_f} \right)^{1.25} \cdot (m^*)^{0.5}$	14

Gomes, (2014) concluded that for fine particles the only correlation for saltation velocity is Rizk (1976). To determine the saltation velocity for coarse particles Gomes recommended Rizk (1976), Matsumoto et al. (1977) and Cabrejos & Klinzing (1994). Course particles were defined as having an average particle diameter above 200 μm . Gomes also listed the range of pipe diameter from 25 to 200mm for the utilisation of these correlations.

Biobaku, Schmitz and Naidoo, (2019) focused part of the study on the application of correlations to the transport of PF at coal fired power stations. Biobaku considered the PF particle size range from 50 μm up to 150 μm for the study. Biobabaku chose to compare the following correlations for predicting saltation velocity, Rizk (1976), Matsumoto (1974,1977), Rose and Duckworth (1969), Mewing (1976) and Thomas (1962). The influence of the particle diameter, pipe diameter, solid mass flow and mass flow ratios on saltation velocity were investigated. The study also applied the correlations to a typical PF pipe application using a pipe diameter of 450mm and a particle density of 1550kg/m³. Solid mass flows ranged from 0.75kg/s to 1.75kg/s. Biobaku concluded that the Rizk correlation promises the best applicability to PF if a safety factor of 1.5 is applied as recommended by Rhodes, (2008). Biobaku recommended that the safety factor could be applied to other correlations like Thomas and Matsumoto that were deemed adequate in predicting saltation velocity. Biobaku also noted during the study that the Thomas correlation showed a reduction in the saltation velocity when the particle sizes increased. This raises a concern about the suitability of the Thomas correlation when considered for use in designing a pneumatic conveying system for PF.

In summary Jones and Leung, (1978) recommended the Thomas (1962) correlation to be utilised for pneumatic conveyor design. Yi, (2001) concluded that because of the wide scatter and contradictions provided by the flow correlations, much more effort is required in this field of study. Van der Merwe, (2014) found that the Rizk (1973) correlation for saltation velocity was suitable for the range of PF particle sizes (typically up to 300 μm). Gomes concluded that for fine particles the only correlation for saltation velocity is Rizk (1976). To determine the saltation velocity for coarse particles (<200 μm) Gomes

recommended Rizk (1976), Matsumoto et al. (1977) and Cabrejos & Klinzing (1994). Biobaku (2019) concluded that the Rizk correlation promises the best applicability to PF. Both Van der Merwe (2014) and Biobaku (2019) confirmed that a safety factor as recommended by Rhodes, (2008) should be applied to the Rizk correlation. Biobaku observation regarding the Thomas (1962) correlation would invalidate Jones and Leung, (1978) recommendation for a PF application.

The required PF particle size ranges from less than 75 μ m to 300 μ m, from the Eskom Standard, Zwiegelaar, (2015). Dhodapkar (2005) considered fine particles to be smaller than 500 μ m, while Gomes (2014) considered fine particles to be smaller than 200 μ m. The Eskom Standard requires that between 99.4 to 99.95% of the PF particles must be smaller than 200 μ m and 80 to 90% of the PF particles must be smaller than 90 μ m. Therefore, PF application would be considered as transportation of fine particles for the flow correlations.

Based on the extensive evaluations of the correlations by the studies mentioned above it appears that the Rizk (1976) correlation is the only correlation suitable for PF pneumatic conveying systems.

To obtain an appreciation of the application of the complexity of applying the correlations, four correlations were chosen to be utilised to determine the influence of particle size on the saltation velocity. The choice of the 4 correlations is discussed in Section 3.2 and application of the correlations to an actual PF pipe at a coal fired power station is discussed in Section 4.3.

2.7 Iso-kinetic PF Sampling

Iso-kinetic sampling can be defined as sampling at such a flow rate that the velocity and the direction of the gas entering the sampling nozzle are the same as that of the gas in the pipe/duct/stack at the sampling points (ISO 9096:2017, 2017).

Determination of the PF mass flow and size distribution for power plants are essential if combustion is to be optimised. Isokinetic PF sampling is currently widely utilised to determine both the PF mass and size distribution to burners. It also provides insight into the quality of the grinding process and the condition of

the mill. PF sampling gives a snapshot of the performance of the mill and the historical performance and trends can be drawn for previous and subsequent inspections. The major concern about PF sampling is the accuracy and repeatability of the results.

The recovery rate calculation is used to verify the validity of the PF sampling. The total mass flow measured in all the PF pipes of a mill is compared with the mass flow calculated from the raw coal feed rate. The tolerance is from 95% to 105% for an acceptable sample.

2.7.1 The LC-4 PF Sampler

The LC-4 Isokinetic PF sampler is shown in Figure 2-7. Isokinetic sampling is achieved by balancing the suction rate in two pressure lines (Figure 2-8) that measure static pressure in the PF pipe and the static pressure inside the sampling nozzle. The hole shown in Figure 2-8 is used to measure the static pressure in the PF pipe. A similar hole (as located by the arrowhead) on the other pressure line is tapped into the sampling nozzle to measure the static pressure in the sampling nozzle. For Isokinetic sampling these two static pressures are balanced manually to control the sample suction rate with the aid of a U-tube manometer as shown in Figure 2-7 on the LC-4 PF sampler.



Figure 2-7: Isokinetic PF Sampler Unit (Sampling Systems International, 2015)

Iso-kinetic PF sampling is not a simple task to perform, it requires skilled operators and there are many variables that could affect the sample, such as plant conditions, moisture, PF flow dynamics and operator skill and diligence to name a few. If sampling is not undertaken Iso-kinetically it can result in over or under sampling of coal particles.



Figure 2-8:LC-4 Isokinetic PF Sampling Nozzle

The Iso-kinetic PF sampler was developed in the 1989 at Eskom's Research department. The equipment was called the Pulverised Fuel Isokinetic Sampler. The LC-4 manual sampler (Sampling Systems International, 2015) utilised in this study, followed from further development of this sampler. A Procedure TRR/P089/022, "Development and instruction manual for pulverised fuel sampler" was compiled for operation of the sampler which was developed with reference to the BS 893:1978, "Measurement of the concentration of particulate material in ducts carrying gases". The sampler is currently widely utilised in Eskom for extracting PF samples from PF pipes.

Power stations have over time developed their own procedures derived from TRR/P089/022. Frequency of sampling varies from 2-3 month to twice a year. Recently an Eskom Standard 240-76440331, "Pulverised Fuel Sample Collection and Size Grading Standard", applicable Eskom wide was compiled.

2.7.2 Target Plate PF Sampling Equipment

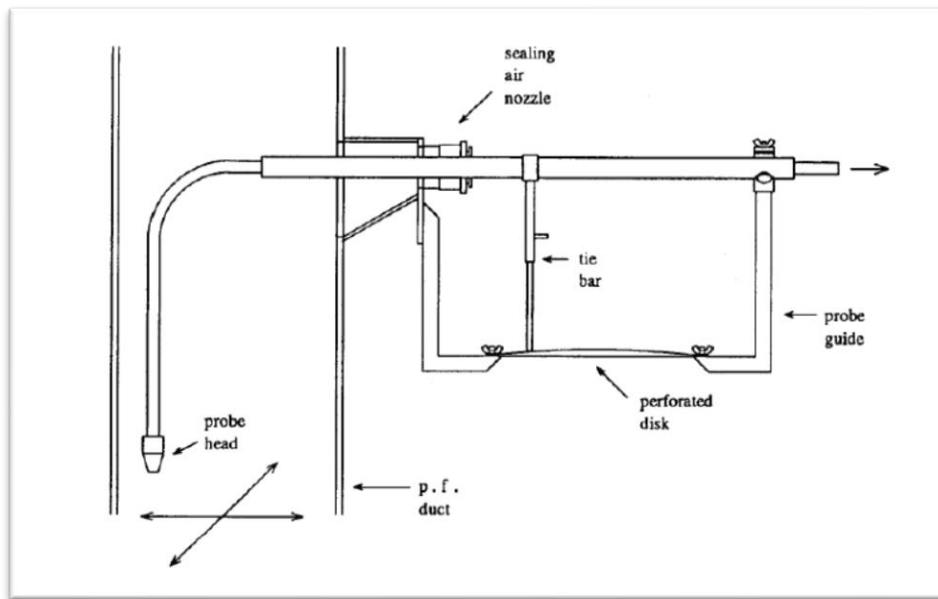


Figure 2-9: Target Plate PF Sampler (Steyn, 1999)

Standard Iso-kinetic PF sampling as shown in Figure 2-9 is performed through a single access port in the PF pipe. In this case a target plate Figure 2-10 is utilised to locate the sampling points within the PF pipes. The probe is moved from point to point and a sample is taken for a set time period.

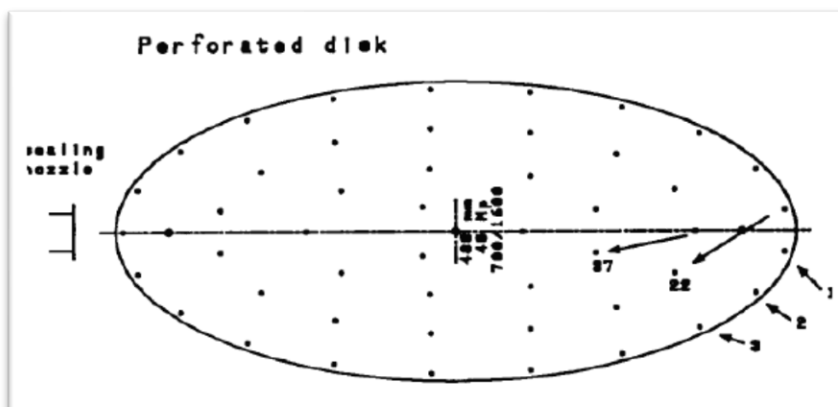


Figure 2-10: Target Plate (Steyn, 1999)

2.7.3 Three Axis Iso-Kinetic Sampling

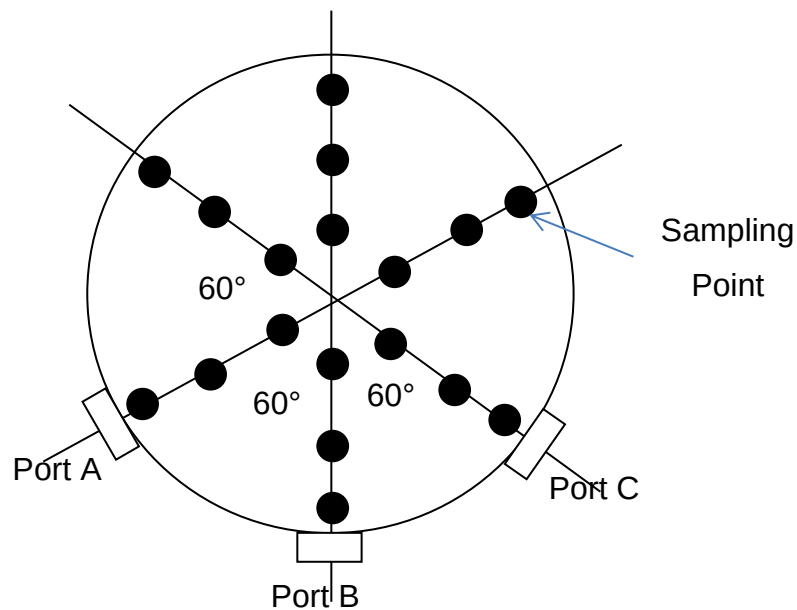


Figure 2-11: Cross Section of Pipe with 3 Access Ports

Standard LC-4 PF sampling equipment is utilised, however a target plate is not utilised. The cross-section of the pipe is divided into a matrix and the samples are obtained along three axes as shown in Figure 2-11 with access through three ports located 60° apart. The number of sampling points and location of points in the matrix will be dependent on the pipe internal diameter as described in BS893:1978. The corresponding location of points are marked on the section of the sampling nozzle that is perpendicular to the PF flow for easy location. For the 356mm pipe, there will be 8 sampling points per diameter. The sampling nozzle is held at each sampling point for approximately 30 seconds as the total sampling time is kept to 12 minutes. A collective sample for all the points is collected in a sampling jar.

2.7.4 Incremental PF Sampling

The process for incremental sampling is very similar to the 3 Axis Isokinetic sampling described in 2.7.3 above. BS893:1978 is utilised to determine the number of sampling points, which are accessed from 3 sampling ports as shown in Figure 2-11. The notable differences are that the sampling nozzle is held at each sampling point for approximately 120 seconds and individual samples are collected separately for each sampling point in the matrix. Therefore, one set of

incremental sampling will include 24 individual samples (for the 356mm pipe) that will be collected and analysed. The advantage of carrying out incremental sampling is that it can provide a graphical representation of the PF flow in the cross section of the PF pipe. This graphical representation can provide information on how homogeneous the PF flow is and to identify concentrations of PF, like Roping in the PF pipe. The major drawback is the additional time required for sampling and analysing of the PF samples.

2.8 Rotor Probe Sampling

2.8.1 Rotor Probe PF sampler

There is currently a standard ISO 9931:1991 “Coal - Sampling of pulverized coal conveyed by gases in direct fired coal systems”. This standard details the use of a Rotorprobe as shown in Figure 2-12 for the sampling of PF.



Figure 2-12: Rotorprobe PF Sampler (M&W Asketeknik, 2009)

The primary components of the Rotorprobe are a rotating head with 4 adjustable nozzles, a control unit, cyclone separator, piping and sample collection bottle. The adjustment of the nozzles relative to the central head is calculated based on the dimensions of the PF pipe to be sampled. The control unit is equipped with a heating unit and provides the suction for the sample extraction. The control unit requires input parameters which are provided by the Dirty Air Probe (DAP) and described below. The Rotorprobe is coupled to the PF pipe by means of a Quick Connection as shown in Figure 2-13.



Figure 2-13: Rotoprobe Quick Connection

The Quick Connection screws into a 50mm socket on the PF pipe and is fed with compressed air. The Quick Connection facilitates the coupling of the Rotoprobe to the PF pipe and also prevents PF from flowing out of the PF pipe during the sampling process. The Rotoprobe system is automated and once coupled to the quick connect, and the required parameters are entered into the control units, the Rotoprobe samples at a rate based on the average velocity provided by the DAP.

This system rotates the nozzles in the PF pipe extracting the PF sample. The PF sample is then separated in the cyclone separator and collected in the sampling bottle. The sample is weighed on the control unit and bottled/bagged for further analyses. The system calculates the PF mass flow, which can be read of from the control unit display. Alternatively, the mass flow can be calculated based on the mass of the sample similar to the LC-4 process.

2.8.2 Dirty Air Probe

As mentioned above, inputs such as temperature of the PF air mix, differential pressure and velocity in the PF pipe are required by the Rotoprobe control unit. A Dirty Air Probe is utilised to traverse the PF pipe prior to the sampling process to obtain these inputs.

The DAP is equipped with a digital manometer and a thermocouple Figure 2-14. The DAP is used to traverse the pipe to determine the differential pressure, velocity and temperature at the pre-calculated sampling points within the PF pipe. The DAP utilises a reflective disc principle to determine the differential pressure by comparing the total vs static pressure in the PF pipe. This in turn is used to calculate the velocity. Velocity and temperature are inputs onto the control unit of the Rotoprobe sampler.

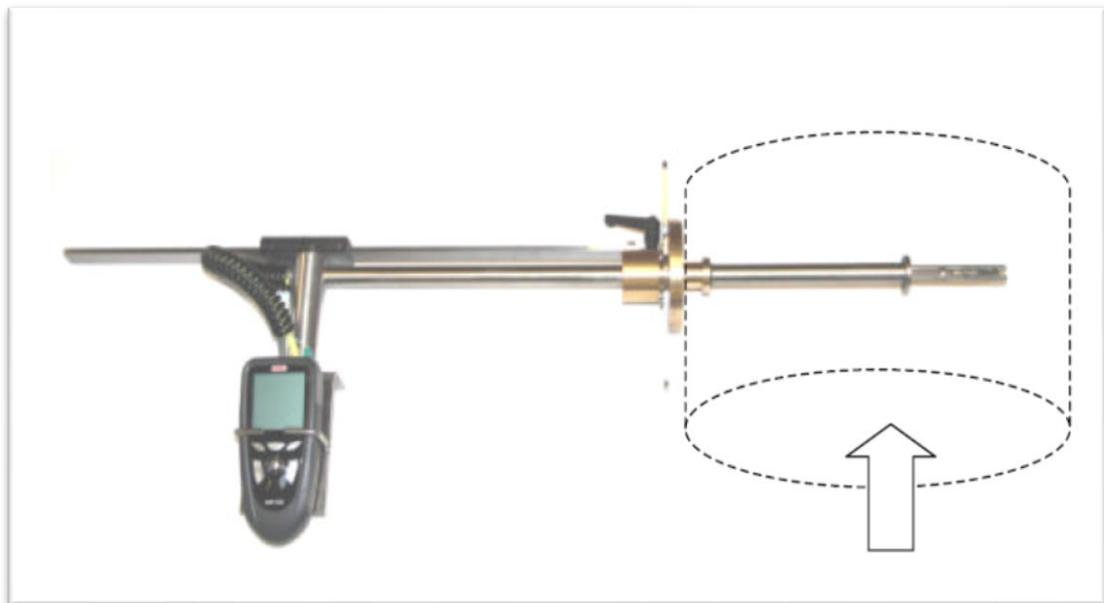


Figure 2-14: Dirty Air Probe (M&W Asketeknik, 2013)

2.9 ASME PTC 4.2 PF Sampler



Figure 2-15: ASME PTC 4.2 Coal Sampler (Airflow Sciences Equipment, 2021)

The ASME PTC 4.2 Isokinetic Coal sampling system is shown in Figure 2-15. The sampling probe has a slotted nozzle Figure 2-16, which is inserted into the PF pipe and traversed to extract PF at specified locations to cover the cross section of the PF pipe. The sampler has a vacuum system and the extraction rate is set by the operator. The vacuum setting is based on the air velocity in the PF pipe and determined utilising a Dirty Air Probe. The PF is separated from the air by means of a cyclone separator and is collected in a bottle.

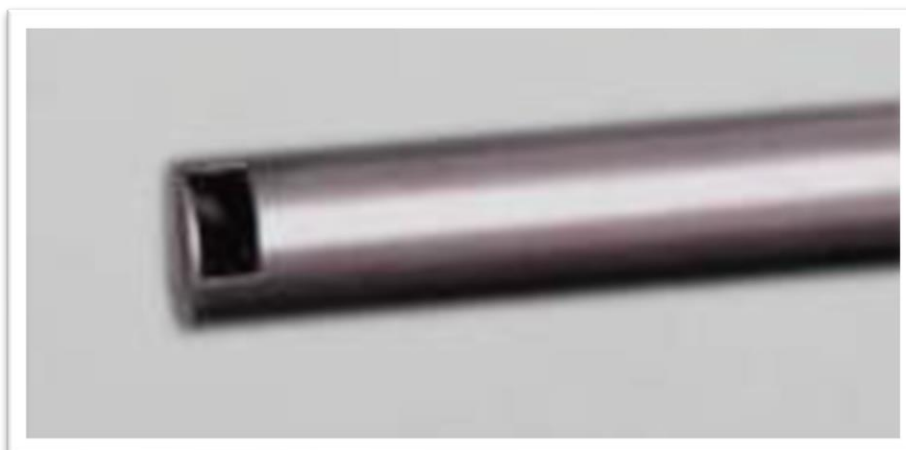


Figure 2-16: ASME PTC 4.2 Coal Sampling Slotted Nozzle (Airflow Sciences Equipment, 2021)

Figure 2-16 shows the front end of the sampling slotted nozzle. This sampler is not utilised in Eskom.

2.10 Challenges with PF Sampling

During an Investigation into milling plant at Eskom's Power Station D, (Hollis, 1985) noted blockages and carry over of PF in the sampler which could introduce inaccuracies in the PF sampling test results as well as general non repeatability of PF sampling results. Hollis made recommendations for improvements to the PF sampler, which were incorporated into the LC-4 sampler.

EPRI noted that the measurement uncertainty of PF sampling extractive coal sampling is not well known. EPRI also mentioned some of the suspected parameters that could influence PF sampling measurements, which included distance from flow disturbances, flow regime and air to fuel ratio.

2.11 Online Measurement

Numerous online measurement systems for coal mass flow and particle size distribution have been developed, including acoustic, electrostatic and microwave technology. Eskom has opted to install the microwave technology at three of its power stations.

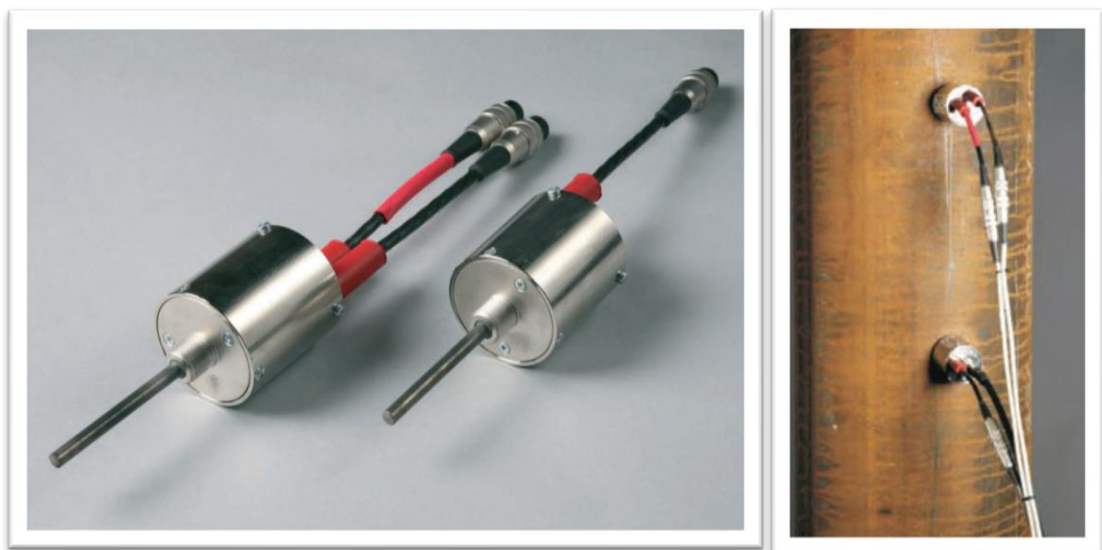


Figure 2-17: Microwave Sensors (Promecon, 2021a)

Microwave resonance is used for particle concentration and cross correlation for flow velocity. Suppliers claim that accurate and trendable online measurement of coal mass flow and coal velocity is possible. Figure 2-17 shows the online PF mass flow and velocity sensors.



Figure 2-18: Portable Particle Size Analyser (Promecon, 2021b)

Laser velocimetry is utilised for particle size analysis. According to the supplier 10 000 particles are counted each second for statistical measurement of the grinding process. Online measurement of the particle size distribution and particle velocity distribution is possible. Figure 2-18 shows the online particle size analyser.

A study by (Archary, 2014) revealed that several factors around the set-up and operation of the Particle Size Analyser instrument have an influence on the results. The instrument showed good precision and repeatability. Results were however influenced by

orientation of the sampling probe, intensity of the purging air pressure, purging time and insertion depth of the probe.

Advantages of online PF measuring systems include giving a live picture of size and mass distribution of PF to burners. It eliminates the need for further lab analysis, as required by Iso-kinetic sampling. It affords Power Plants the opportunity to make adjustments to mills, classifiers or control dampers and to immediately see the effects. PF sampling results are accessed via a computer terminal connected to the sensors.

These systems are expensive to install and require calibration and maintenance. Calibration of the system has proven to be challenging at one of the Power

Stations as a result of the short vertical PF pipe sections on the bottom row of burners. This has had a major impact on the commissioning of the system.

2.12 EPRI Coal flow Measurement Laboratory

EPRI built a coal flow measurement and control laboratory in 2004 (Power Engineering, 2004). The laboratory has the capability to measure and control coal flow in a controlled manner. Transport velocity, temperature, humidity and air to coal ratios are parameters that can be controlled at the facility. A report documenting the evaluation of the Rotoprobe and the ASME method of sampling was published in 2005. Various aspects including number of sampling points, number of sampling diameters, horizontal vs vertical sampling were evaluated at the laboratory. The ASME method provided a measurement difference which ranged between 9% and 35%, while the Rotoprobe provided a measurement error of 8% (Mudry, Fleming, Brown and Sanchez, 2005).

2.13 Sieving Methods

Sieving is utilised to determine particle size distribution in many industries such as the construction, food, pharmaceutical and the power generation sector. Sieving is utilised for particle size distribution because of its ease of handling, relatively low investment cost and supplier quoted high accuracy. The sample is separated based on particle size by applying a mechanical force.

Air jet, wet and dry sieving are the three methods of sieving that could be utilised to separate the samples into size fractions. Vibrational sieving is utilised for both wet and dry sieving where the stack of sieves experiences a circular motion as well as a vertical throwing motion. This movement allows for the particles on the sieve to be spread out across the sieve and rotated in different orientations to be compared to the aperture size of the sieves. Where particles experience electrostatic charge, agglomeration or a high degree of fineness, supplier recommends the usage of wet sieving where the process is the same as described above with the addition of a medium like water to aid the sieving process.



Figure 2-19: Air Jet Sieving (RETSCHE GmbH., 2019)

For air jet sieving a single sieve is utilised instead of a stack of sieves as in the case of vibrational sieving. In this case the sieve is not subject to movement. An industrial vacuum cleaner is utilised to create low pressure in the sieve chamber, where the sucked-in air escapes with high speed from the rotating slit nozzle, Figure 2-20, found below the sieve. Particles are spread, hit the sieve lid and are de-agglomerated as a result of the escaping air from the slit nozzle. Particles are then compared to the sieve apertures. These particles can be collected in a cyclone or the vacuum cleaner.

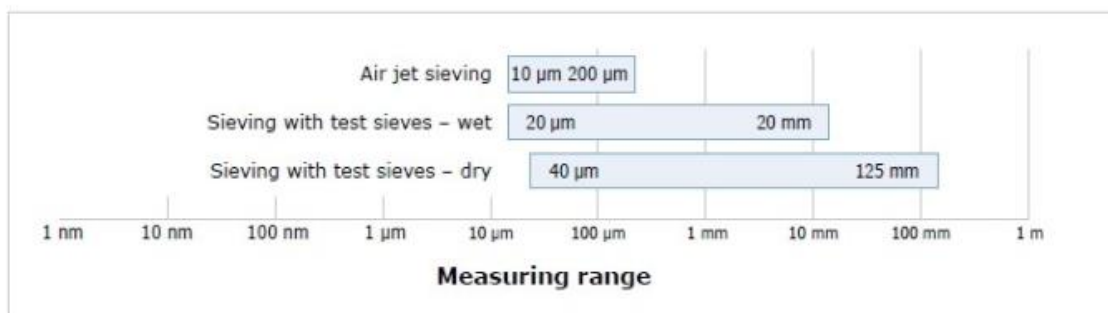


Figure 2-20: Measuring Range of Sieving Methods (RETSCHE GmbH., 2019)

Figure 2-20 provides a guideline for the application of dry, wet and air jet sieving based on particle sizes. The recommended range for dry sieving by Reutch is from 40µm to 125mm, while wet sieving ranges from 20µm to 20mm and air jet is recommended to be utilised for particle sizes ranging from 10µm to 200µm.

Dry sieving is commonly used in Eskom to determine the particle size distribution for pulverised coal. Based on the values quoted in Figure 2-20 and the expected particle size range listed in Eskom standard 240-7640331, wet sieving and air jet sieving could also be utilised for PF sampling applications.

2.14 Literature Study Conclusion

Design of Pneumatic transport systems for the conveying of solid particle like PF relies on empirical correlations. There are a number of correlations, each providing different values for important flow parameters such as operating velocity which is derived from saltation velocity. It is essential that the most accurate/appropriate correlation is utilised for the calculation of parameters such as operating air velocity. In this case, a too high velocity will result in high wear of components and premature failure, which will require costly replacement maintenance. If the velocity is too low this will result in in blockage of the PF pipes as a result of saltation in the horizontal pipes or choking in the vertical PF pipes.

Various methods exist to capture PF samples, with the objective of determining the mass flow and size classification of the PF. Inaccuracy of the methods and their application is highlighted in literature.

One of the primary differences between the Rotoprobe and the LC-4 sampler is that the LC-4 continuously measures the velocity of the PF air mix (entering the nozzle) during sampling and allows for the extraction rate to be controlled by the operator to compensate for fluctuations. Therefore, ensuring isokineticity. For the Rotoprobe a Dirty Air Probe is used to measure the fluctuations prior to the PF sampling. Therefore, the Rotoprobe does not account for fluctuations in velocity in the cross section of the PF pipe while PF samples are extracted, but rather operates on a predetermined average velocity. The impact of this averaged predetermined velocity will be investigated as it will influence the accuracy of the Rotoprobe sampler.

Chapter 3 Research Methodology and Experimental Setup

3.1 Methodology

The process followed to attain the objectives of determining the level of precision and accuracy of the PF sampling methods for the study is shown in Figure 3-1. Literature, questionnaire responses, Standards and Procedures were reviewed and directed interviews were carried out at five Eskom Power Stations. Subject Matter Experts within the organisation were also consulted. The following hypothesis; “Current standards and practices for PF measurement used in Eskom are not accurate enough to control the PF distribution to the required accuracy for improving combustion efficiency and LNB implementation” was then formulated and the experimental sampling scope (Appendix C) of the project was defined.

Testing this hypothesis involved evaluation of PF sampling equipment through site tests at one of Eskom’s Power Stations. As described in the literature study one of the methods of applying the LC-4 sampler involved angling the nozzle (pitch and yaw angle), these site results will be compared to that obtained from a CFD model.

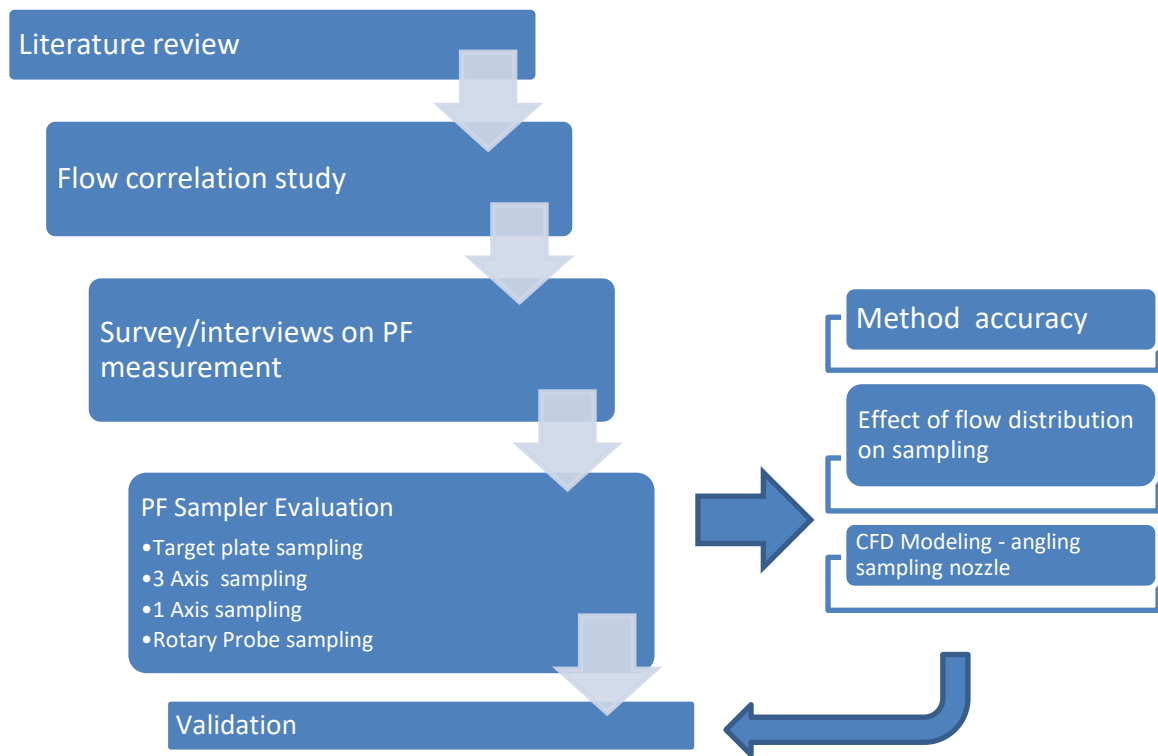


Figure 3-1: Flowchart: Research Outline

3.2 Flow Correlation Study

A number of flow correlations were identified in the literature review of this study for the calculation of choking and saltation velocity for pneumatic transport of solid particles in a gas stream. As mentioned in the literature review, if a pneumatic conveying system is designed for saltation velocity, this velocity will be adequate to overcome choking as the choking velocity is about a third of the saltation velocity. Operating parameters from one of Eskom power station will be used in the calculations of saltation velocities utilising four different flow correlations, in order to compare the variability in delivered results.

The literature review informed the decision as to which 4 flow correlations were chosen to demonstrate the influence of particle size on the saltation velocity. The following was considered when the correlations were chosen.

The Rizk (1976) correlation was chosen as it was recommended in a number of studies to be utilised for pneumatic conveying. The Rizk (1976) will be used in this study as the benchmark for the other correlations to be compared. The Matsumoto et al., (1976) correlation was recommended in certain studies and did

show potential, however its application to PF pneumatic conveying is questionable. Matsumoto was therefore chosen to investigate its application in the context of PF pneumatic conveying. In the Gomes et al., (2014) study it was observed that the Weber (1981) correlation had a similar gradient to that of the Rizk (1976) correlation when the influence of the particle size diameters on the saltation velocity was investigated. The Gomes study however looked at a particle size range of 200 to 4000 μm . Therefore, the Weber (1981) correlation was chosen to investigate its applicability to a PF application for a more representative particle size range (0 to 2500 μm). In the same study the Shade (1987) correlation provided a contradictory gradient with a decrease in the saltation velocity with an increase in the particle size. Shade was therefore chosen to display the contradicting nature of the correlation when applied to a PF application.

3.3 Survey/Directed Interviews

A survey was carried out to obtain an appreciation of the complexity associated with the sampling of PF from a pneumatic transport system. For this activity a questionnaire was sent to all 13 of the PU Plants. Subsequently 5 stations were visited for discussions with the Performance and Test Managers to obtain additional information and to observe the PF sampling process on site.

The aim of these activities was to establish which sampling method was utilised by the Plant, how the sampling method were applied, the frequency of the sampling, what standards were utilised and if the PF sampling was contracted out or carried out in house. Most importantly a hands-on experience and appreciation of PF sampling and the problems associated with sampling of this nature was required.

3.4 PF Sampler Evaluation

3.4.1 Sampling Methods

An automated rotating 4 nozzle sampler, Rotoprobe and a single nozzle manual sampler, LC-4 were identified as the current equipment utilised by Eskom for PF sampling. The LC-4 sampler was utilised in one of three ways at different sites.

Samples could be extracted by carrying out a 1 Axis traverse, a 3 Axis traverse or in conjunction with a target plate. Additional information on the samplers and sampling methods is provided in the literature review. The accuracy and repeatability of these four methods of sample extraction were investigated during the site tests. In addition to the 3 manners of applying the LC-4 sampler mentioned above, incremental sampling was also undertaken for this study to determine if the flow in the PF pipe was homogeneous. Incremental sampling data was also used to carry out cross checks on the accuracy of the flow calculations for P1 and P2, which is described later.

3.4.2 Site Selection

The following criteria was considered when a Power Station was selected to perform the study:

- Power Stations that were willing to collaborate in the study, as one would require access to the site. Sampling sockets would have to be installed in the correct locations, requiring a modification to the PF pipes. Plant conditions would have to be set to optimise PF sampling.
- Expertise level of the Performance and Test Staff with respect to PF sampling. Training would be required to operate the PF sampling equipment and assistance would be required during the testing phase of the study.
- Accessibility to PF sampling equipment. If PF sampling equipment was not available it would have to be purchased, contracted in or alternatively loaned from another site.
- Eskom sites that utilise gravimetric feeders to feed coal into the mills as these mills could provide an accurate measure of the raw coal fed into the mills.

From the 15 Power stations that were considered for undertaking this study, Power Station A was chosen for the following reasons. Power Station A was prepared to participate in the study and they had gravimetric feeders. They had both the LC-4 and Rotoprobe PF sampling equipment and were prepared to weld 50mm sockets on the PF pipes as required for the testing scope of work.

Furthermore, Power Station A had an experience staff member who was prepared to provide training on the sampling equipment and assistance with troubleshooting during the testing phase of this study.

3.4.3 Sampling Positions

Figure 3-2 shows the PF pipework arrangement and Figure 3-3 represents a simplified sketch of this PF piping arrangement and PF sampling positions for this study. Routine PF sampling by the Performance and Testing Department at the Power Station is usually carried out on Pipes B1, B2, B3 and B4 (location B) which is at the 45m level at this Power Station. Just below this point, the single pipe exiting the tube mill is split into 4 pipes via a riffle box arrangement, which then split into 2 pipes further downstream before the air/PF mixture is directed to a burner. Sampling at this location B (45m level) does not give an indication of the PF flow and size distribution to the individual burners as a result of the PF pipe split further downstream.

For this study additional sampling points were installed on P1 and P2. PF sampling was carried out at location B (vertical 508mm pipes), location H2 (horizontal 508mm pipes) and P1 & P2 (vertical 356mm pipes) as shown in Figure 3-3. Location B made it possible to determine the accuracy of the sampling methods as a first pass, by conducting a mass balance of the PF in the PF pipes compared to the raw coal delivered by the gravimetric feeders to the mill. It was also possible to calculate the recovery rate calculation as specified in the Eskom Standard (240-7640331). The usage of this information is presented later and a description of the reference flows as calculated thorough the system stems from the tests carried out at this location

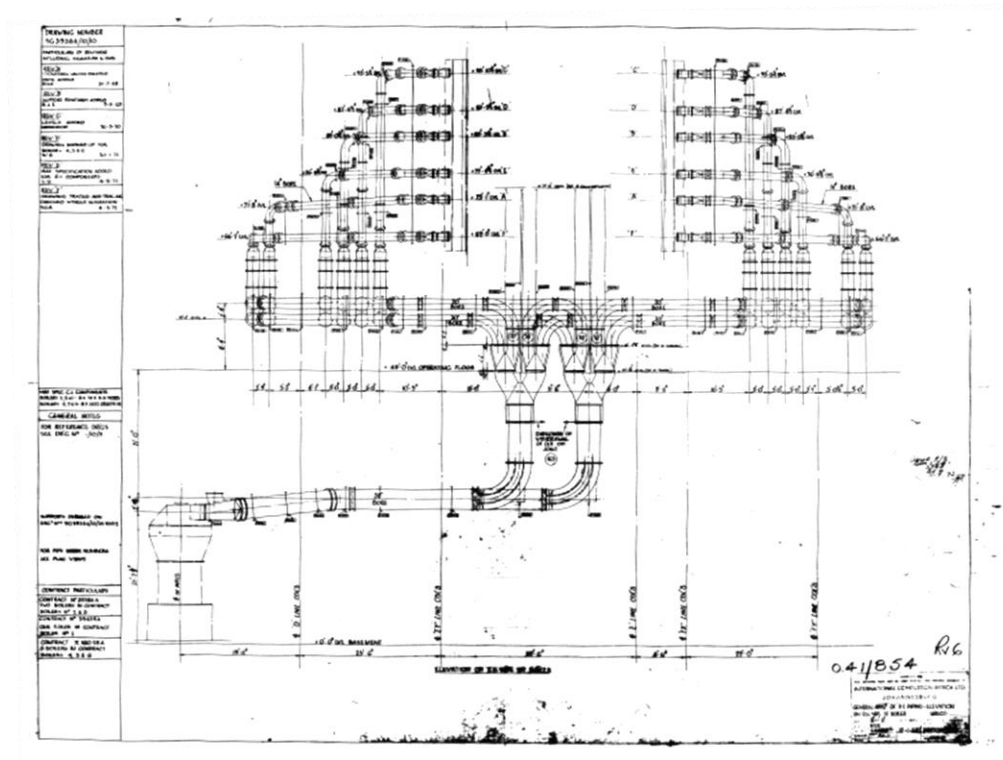


Figure 3-2: A Classified Drawing from International Combustion Africa LTD of PF Pipework Arrangement

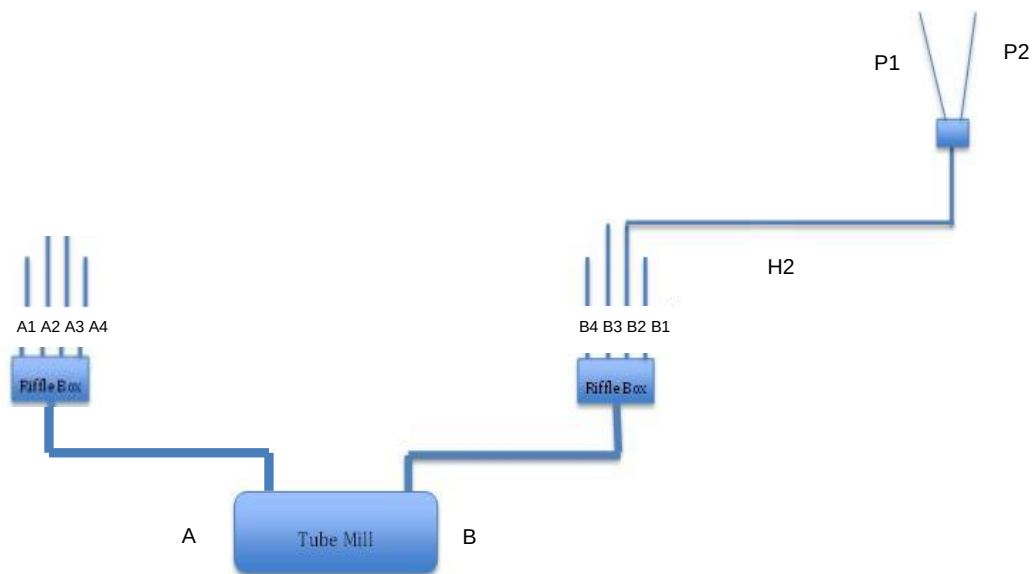


Figure 3-3: Schematic of Sampling Locations

For PF flow in a horizontal pipe settling or particle density gradient due to gravity could occur. Sampling at location H2 shown in Figure 3-3 facilitated the evaluation of the performance of the sampling methods when applied to horizontal pipes.

Sampling locations P1 and P2 were utilized to carry out the bulk of the sampling to determine the accuracy and repeatability of the sampling equipment. Sampling ports were specifically installed at this location as shown in Figure 3-4 for this study. Four points were installed on the PF pipe, which facilitated the 1 Axis, 3 Axis, target plate and Rotoprobe sampling. Incremental sampling was also carried out to determine the homogenous nature of mass flows at Pipe P1 and Pipe P2 to further investigate the accuracy of the sampling methods.



Figure 3-4: Sampling Ports at Pipe P1

3.4.4 Sampling Points within the PF Pipes

The location of the sampling points, on the sampling diameters within the PF pipe is based on an equal area method from BS893-1978, (1978). The sampling plane is divided into equal areas where each shaded portion has an equal area with the sampling points located at the centre of each area as shown in Figure 3-5.

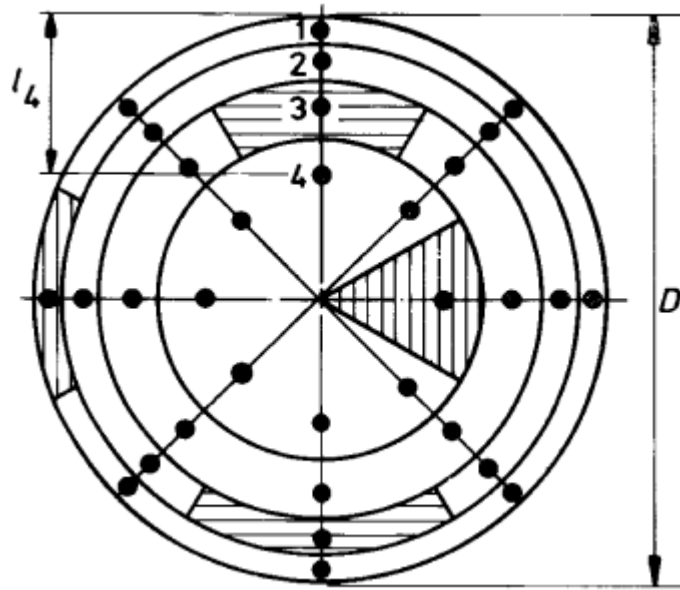


Figure 3-5: Sampling Points within the PF Pipe (BS893-1978,1978)

These sampling point locations (l_i) were calculated utilising the following equation;

$$l_i = \frac{1}{2} D \left[1 - \sqrt{1 - \frac{(2i-1)}{2n}} \right] \quad (15)$$

Where D is the diameter of the duct/pipe in (mm),

n_r is the number of sampling points on each radius and

i is the particular sampling point of interest

Table 3-1 and Table 3-2 show the traversing distances for the 356mm and 508mm pipes respectively.

Table 3-1: Calculated Traversing Distances for 356 mm PF Pipe

Position	Traverse Distance (mm)
l_1	11.49
l_2	37.28
l_3	69.00
l_4	115.07
l_5	240.93
l_6	287.00
l_7	318.72
l_8	344.50

Table 3-2: Calculated Traversing Distances for 508 mm PF Pipe

Position	Traverse Distance (mm)
l_1	16.41
l_2	53.20
l_3	98.46
l_4	164.20
l_5	343.80
l_6	409.54
l_7	454.81
l_8	491.60

The calculated sampling point locations provided by the equal area method, as the name suggests, the sampling points would be located in such a manner that each of the sampling segments would be of equal area. Therefore, one would note that sampling point are closer together as one approaches the pipe wall compared to those located near the centre of the PF pipe.

3.4.5 PF Flow Development, Incremental Sampling and Contour Plots

Flow pattern development was also studied during the site tests by carrying out incremental sampling on P1 and P2. Incremental sampling made it possible to

confirm the mass flow at the individual sampling points in the matrix (cross section of pipe as calculated using BS893:1978) by analysing each individual sample. The purpose of this investigation was to develop plots of PF mass flow, velocity and particle fineness (%particles pass through 75µm sieve) in the cross section of the pipe. Limited information could be obtained in literature on PF flow development on full scale plants. The information obtained was utilised to visualise the flow development through a cross section of PF pipes P1 and P2. From the mass flow plots the impact of flow distribution on the PF sampling methods could be further investigated. For example, if a PF rope were encountered in the pipe and the 1 Axis traverse was applied to the pipe, extremely varying results could be obtained of the rope fell within the sampling traverse or if the traverse missed the rope.

In addition to the mass flow plots the incremental sampling data was also utilised to carry out a verification of the PF mass flows in P1 and P2.

3.5 Establishment of Temperature and Duration for Drying PF Samples

The Eskom Standard 240-76440331 required the sample to be dried overnight at 100°C, while the previous Eskom Standard GGP 0855 required the sample to be dried at 90°C for 4 hours. The supplier of the LC-4 equipment recommended drying the sample for 1 hour at 110°C. This study investigated the optimum time and temperature for drying of a 50g PF sample. This time and temperature to remove moisture from the PF samples was determined as follows. The sample analysis was carried out in Johannesburg where the boiling point of water is 94°C. Any temperature above this value would be adequate to remove the moisture from the PF sample. Including a margin for fluctuations of temperature in the oven, 105 °C was chosen as the adequate temperature to remove the moisture from the PF sample for this study. To establish the adequate drying time a bulk sample of PF was split into 8 samples and 50 g of each was dried in an oven at 105°C. At half hour intervals a sample was removed from the oven and weighed to establish the reduction in weight due to the removal of moisture from the sample. It was found that after the first 30minutes there was a reduction in

the weight of the sample. In the subsequent samples from 1 hour to 3 hours, no additional change in the weight of the sample was observed. Therefore 1 Hour was found to be adequate time to remove the moisture from the samples. This time was found to be reasonable when a single technician is working in the laboratory and the drying is slotted into the other activities (See Figure 3-6) such as splitting, shaking, sieving and weighing of retained PF on sieves.

3.6 Grading of the PF Samples

A total of 924 PF samples were extracted and analysed in a laboratory to determine the moisture content and size fractions for this study

Once the sampling process was completed the samples were graded by size. The grading process that the PF underwent in the laboratory is shown in Figure 3-6.

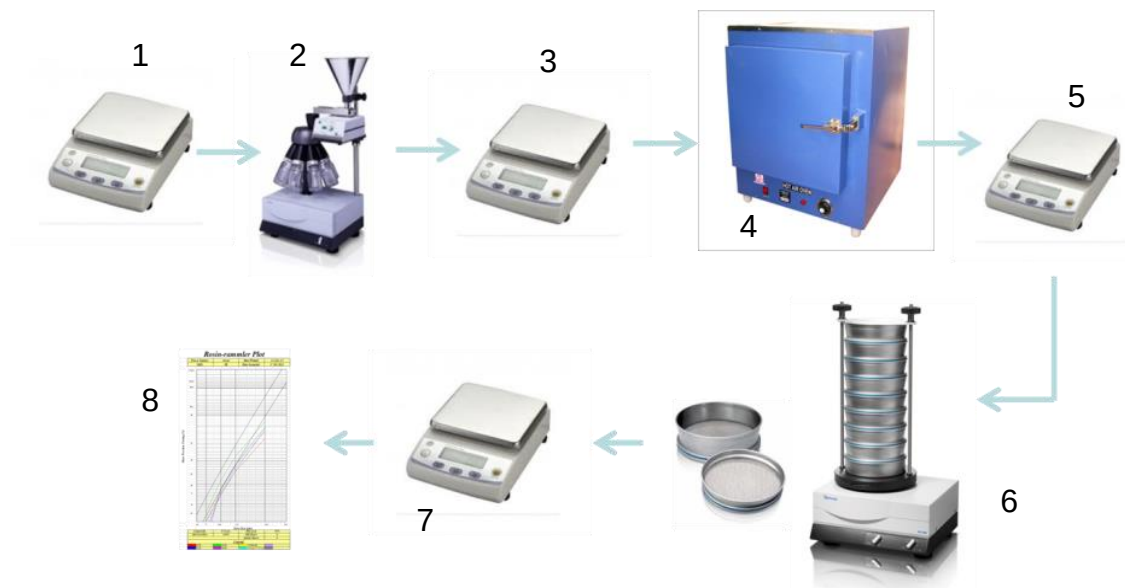


Figure 3-6: Grading Process after PF Sampling

The captured sample was firstly weighed (1) and then reduced to a representative sample of 60 grams by means of a mechanical/rotary splitter (2). The sample was then dried in an oven at 105°C for 60 minutes (3). The sample was again weighed (4) to determine the reduction in mass and the moisture content of the PF was calculated. Thereafter 50 grams (5) of the sample was

then passed through a series of sieves: 300 μ , 150 μ , 106 μ and 75 μ , by mechanical shaking (6) as stipulated in the Eskom Standard 240-76440331. The sieves were weighed (7) in turn to establish the retained PF on the sieve and the percentage of PF passing through the sieve was calculated. These figures were then plotted on the Rosin Rammler graph (8) which indicates the size distribution. The initial weight of the sample and the moisture content were utilised to determine the dry mass flow of the PF, which is described in more detail later.

The PF flow rates were calculated and compared to that provided by the Gravimetric Feeders to establish a degree of accuracy of the PF sampling methods. Raw coal which was also sampled at entry to the feeders during the PF sampling was analysed, particularly to obtain the moisture content for the mass balance.

3.7 Comparison of Vertical to Horizontal Pipe Sampling

Additional work was carried out to compare results yielded from sampling in vertical pipes to that obtained when sampling in horizontal pipes. Tests at locations B and H allowed this comparison.

3.8 CFD Modelling of PF Sampling Nozzle

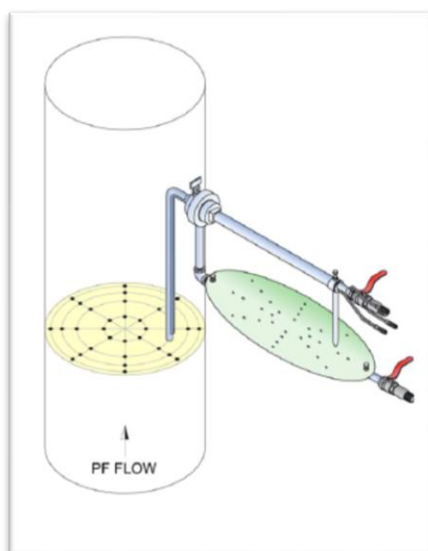


Figure 3-7: Angling of Target Plate Sampler (Sampling Systems International, 2015)

As shown in Figure 3-7, when utilising a target plate for PF sampling, the sampling nozzle will have to be swivelled at different angles to reach the sampling point locations within the PF pipe matrix. As shown in Figure 3-8. This results in a reduction to the inlet area of the sampling nozzle, as the nozzle profile relative to the axis of flow will change from a round profile to an oval. A CFD model was developed to simulate angles that a sampling nozzle would be subjected to and to predict the effect on the accuracy of the sample being extracted.

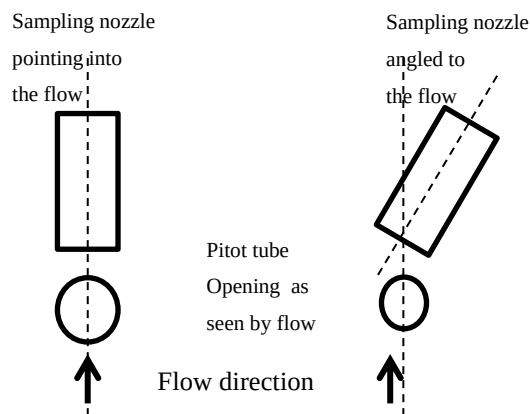


Figure 3-8: Effect of Angling Probe on Nozzle Inlet Area when Utilising a Target Plate

Chapter 4 Results

4.1 Introduction

Yang and Telionis, (2011) designed and tested instrumentation for Isokinetic sampling. The study facilitated the visualisation of isokinetic, over and under sampling. In Figure 4-1 the photo on the left, flow lines are directed towards the nozzle which will result in the entrapment of additional particles as they are forced away from their trajectory and into the nozzle. The effect of this would be the mass flow being overestimated.



Figure 4-1: Yang and Telionis (2011) Experimental Setup, to Visualise Flow

The converse is shown in the photo on the right where particles are drawn away from the mouth of the sampling nozzle, resulting in an underestimation of the coal mass flows. This sampling information would be utilised to calibrate coal feeders or make adjustment at the control panel. If the scenario where the mass flow is over estimated is considered this would warrant a compensation to reduce the coal fed to the boiler. An under-estimation of coal mass flow by sampling would require an increase to the actual coal flow rate to the boiler. These actions would be incorrect and may result in further complications, during the power plant operation, as discussed in the literature study. Desired sampling is depicted in the middle photograph, where the sampling is Isokinetic.

4.2 Survey Results

A questionnaire was sent out to the Performance and Test Departments from each Power Station. The responses to the questionnaires were not adequate to

formulate an understanding of the state of PF sampling at the PU. Therefore, the second round of the surveys was initiated, and this involved visits to Power Stations A, B C, D and further correspondence with Power Station E via email. These sites were selected based on their initial response to the questionnaire and their willingness to provide information. The interview questionnaire is available in Appendix A and the responses from the directed interviews are tabulated in Appendix B. Further discussions were also undertaken with combustion Specialists at Eskom.

Results from the survey at five Performance and Test Departments at the PU revealed that a whole bouquet of unique procedures are utilised for Isokinetic sampling of pulverised coal. Power Station A & C utilised the Rotoprobe as well as the LC-4 with a target plate for PF sampling. Power Station B utilised the LC-4 to carry out a 3 Axis traverse. While Power Station D utilised the LC-4 to carry out a 1 Axis traverse. Power Station E also made use of the LC-4 for PF sampling. These methods were described in Chapter 2.

The frequency of the sampling was also not consistent ranging from once every 2 (Power Station B) to 3 months (Power Station C) to twice a year (Power Station D) depending on the Plant. Some Plants have their own in-house teams who perform the sampling while others preferred to contract the service out.

This survey aided in gaining an appreciating of PF sampling at the Plants and in development of the testing scope for this project.

4.3 Flow Correlation Study

Empirical correlations are utilised to calculate important parameters, such as operating velocity (which are based on choking, saltation or pickup velocity) for multiphase flow in pipes.

The accuracy and applicability to pulverised coal flow of these correlations are questionable as many of them were tested utilising coarse media such as soy beans or popped rice, etc. To illustrate the challenges face by designers of pneumatic transport systems, typical parameters from one of Eskom power station were used in the calculation of saltation velocity utilising four empirical

flow correlations. These values were used to understand commentary from literature on saltation velocity and how it ties in with actual operating velocity values recorded during the PF sampling process in this study.

Table 4-1: Values (typical of Power Station D) used in Correlation Calculations

Parameter	Symbol	Value	Unit
Density solid	ρ_s	1550	kg/m ³
Density gas	ρ_f	0.8155	kg/m ³
Pipe diameter	D	0.45	m
Mass flow solid	M_p	1.5	kg/s
Mass flow gas	M_f	3.25	kg/s
Particle diameter	d_p	0.000075	m
Gravity	g	9.81	m/s ²

Utilising the data from Table 4-1 and varying the particle size, four correlations were selected to demonstrate the spread in saltation velocities calculated and the graph in Figure 4-2 was produced. The flow correlations selected were Rizk, Matsumoto, Shade and Weber.

For Rizk the correlation is

$$\frac{M_p}{\rho_f \cdot U_s \cdot A} = \left(\frac{1}{10^{(1440 \cdot d_p + 1.96)}} \right) \left(\frac{U_s}{\sqrt{g \cdot D}} \right)^{(1100 \cdot d_p + 2.5)} \dots \dots \dots (16)$$

Where:

M_p =Solids mass flow rate (kg/s)

ρ_f =Air density (kg/m³)

U_s =Saltation velocity (m/s)

d_p = Particle diameter (m)

D=Pipe diameter (m)

g=Gravitational acceleration (m/s²)

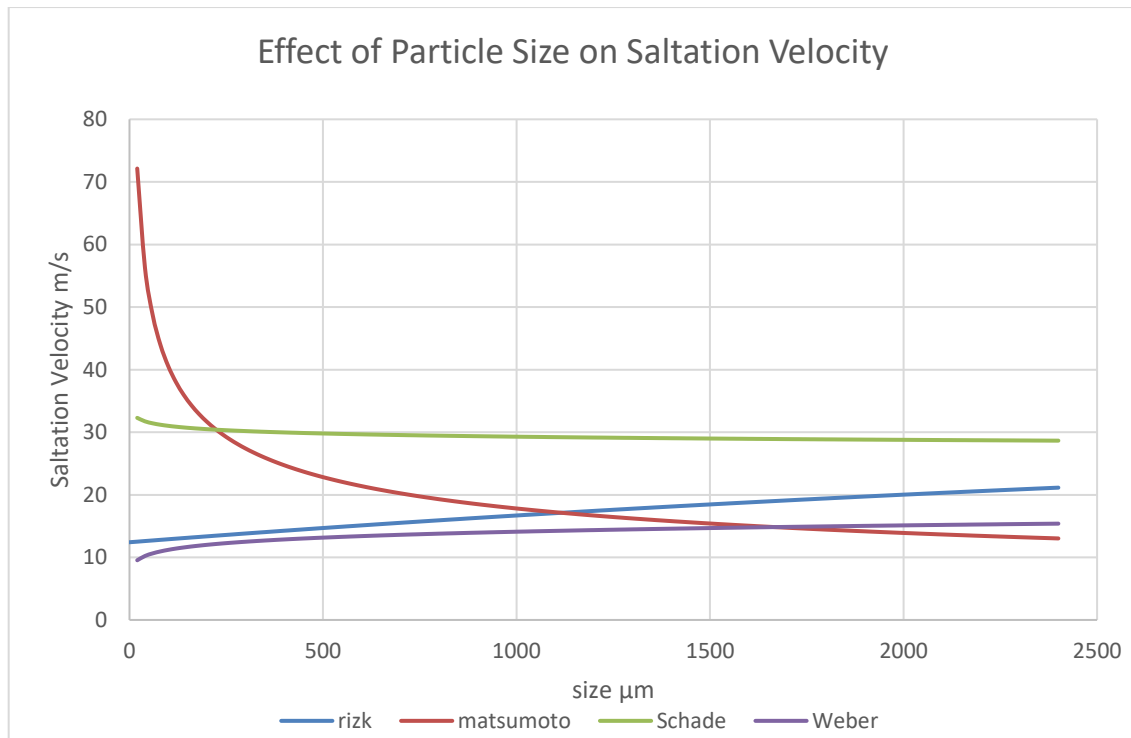


Figure 4-2: Effect of Particle Size on Saltation Velocity

Figure 4-2 highlights the large discrepancy in the calculation of saltation velocity by utilising different correlations and illustrates the challenge of choosing the most suitable correlation to utilise in designing a pneumatic transportation system and the specification of operating parameters such as operating velocity.

The following was noted from the literature review, Van der Merwe, (2014) found that the Rizk (1973) correlation for saltation velocity was suitable for the range of PF particle sizes (typically up to 300μm). Gomes concluded that for fine particles the only correlation for saltation velocity is Rizk (1976). Biobaku (2019) concluded that the Rizk correlation promises the best applicability to PF. Both Van der Merwe (2014) and Biobaku (2019) confirmed that a safety factor of 1.5 as recommended by Rhodes, (2008) should be applied to the Rizk correlation.

Sampling Systems International, (2015) recommends that the operating air velocity should be above 18m/s in order to prevent saltation from occurring. A factor of 1.5 is applied to the operating velocity which provides a saltation velocity of 12m/s. This value ties in with the empirical correlation saltation velocities calculated for 75 μm PF particles as shown in Figure 4-2 for Rizk and Weber.

Note that for low NOX burners the requirement from the Eskom Standard 240-76440331 is that 71% to 80% of the particles must be smaller than 75 μm .

Figure 4-2 shows that for the required PF particle size range of 1 to 300 μm , all 4 of the chosen flow correlations would provide a saltation velocity to facilitate dilute phase flow with particles entrained in the air stream from the mill to the burner. Matsumoto and Schade would provide operating velocities without having to apply the safety factor of 1.5, while as mentioned above Rizk and Weber would require the application of the safety factor. On a closer look at Figure 4-2 Matsumoto and Schade produced contradictory results with a decrease in the saltation velocity with an increase in the PF particle size. For Matsumoto even with the contradictory behaviour because it overestimated the saltation velocity it will still maintain dilute phase flow up to particle sizes of 1000 μm . Similarly, Shade demonstrated the same behaviour for the particle size range (0 to 2400 μm) chosen for this calculation. If one had to consider practical application of Matsumoto and Shade based on Figure 4-2, Matsumoto and Schade would require operating velocities in excess of 30m/s, even as high as 50m/s for Schade (for 75 μm particles), substantially larger than the required 18m/s recommended by Sampling Systems International, (2015). The effect of this would be a significant reduction of the useful life of components such as the PF pipes, classifiers and burners as a result of solid particle erosion.

Therefore as a result of the contradictory behaviour of Matsumoto and Schade providing a decrease in the saltation velocity with an increase in particle size as well as the overestimation of the saltation velocity, Matsumoto and Shade are not recommended for consideration for design of pneumatic piping systems for PF transportation. Based on the results produced in Figure 4-2 this study would recommend the utilisation of Rizk (1976) and the Weber (1981) correlations for the design of pneumatic transportation systems for PF applications with the application of the safety factor of 1.5 as recommended by Rhodes, (2008).

A sample of the velocity traverse measurements that were taken utilising a Dirty Air Probe (DAP) during the PF sampling process for this study are tabulated below.

Table 4-2: Operating Velocity in Pipes P1 & P2

Traverse Distance (mm)	Velocity P1 (m/s)	Velocity P2 (m/s)
wall	17.9	20.8
11.5	21.1	21.3
37.0	21.3	21.7
69.0	19.7	20.0
115.0	18.9	22.9
241.0	16.1	16.2
287.0	14.6	12.8
319.0	12.8	7.2
344.5	0	0

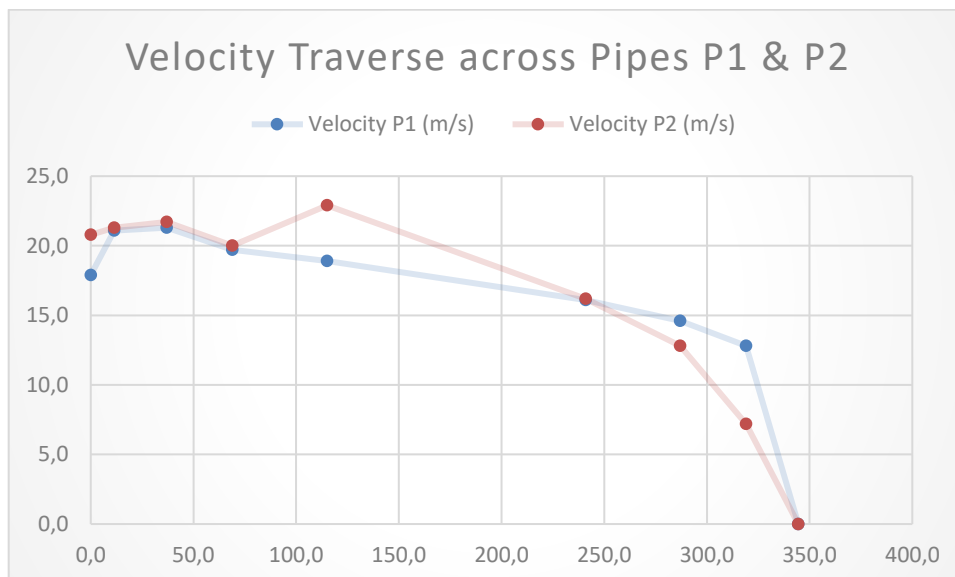


Figure 4-3: Velocity Traverse Across Pipes P1 & P2

The results Figure 4-3 revealed velocities above the 18m/s at majority of the traversing points. However, velocities below 18m/s were recorded close to the PF pipe walls. This means that particles could fall out of suspension close to the PF pipe walls. The required theoretical velocity is 12m/s and except for 3 positions close to the PF pipe wall, the values are larger. This could explain the requirement for the safety factor to increase the velocity up to 18m/s in order to overcome the wall effects.

4.4 The Reference Mass Flows

The only available measurement for mass flow of coal at this Power Station was that of the raw coal that was fed into each side of the tube mill from the gravimetric feeders. As there were 16 burners on this unit, it was not possible to take simultaneous PF samples at each PF pipe location, due to a limitation in the number of PF sampling equipment available. Although all sampling was carried out at a constant mill load, fluctuations in coal mass flow could jeopardize the accuracy. Therefore, the PF mass flows were required to be calculated at the respective sampling locations for the time period when the PF sampling was undertaken. These calculated PF mass flows were referred to reference mass flows.

For this study the reference mass flow is defined as the established accurate value of coal flow in kg/s at a particular location. The degree of accuracy of the reference mass flow is discussed later. The mass flows calculated from the PF sampling methods were compared to these reference mass flow in order to establish the degree of accuracy of the sampling methods.

This study required reference mass flows to be established for each pipe location (B2, H2, P1 and P2) respectively, where each set of sampling was undertaken. These reference mass flows were calculated based on the times when the PF sampling was carried out and on the moisture content of the raw coal.

From Figure 3-3, it can be seen that after the riffle box the vertical pipe B2 bends 90 degrees horizontally, and is routed around the boiler to Pipe H2 which is in the horizontal orientation. The pipe then bends vertically upwards and splits into two smaller diameter pipes at a riffle box where Pipes P1 and P2 are found. The PF pipe dimensions for Pipes B2 and H2 are 508mm and for Pipes P1 and P2 are 356mm.

To calculate the reference mass flows the following steps were taken.

- The dry raw coal mass flow was determined.
 - The trends of raw coal mass flows were downloaded from the Power Station control system.

- The flow bias between A Mill and B Mill was confirmed.
- The moisture content of the raw coal was established in a laboratory.
- The raw coal mass flow trends and moisture content was utilised to calculate the dry coal mass flow.
- The accuracy of the raw coal flows was confirmed by performing a Truck Test. (additional detail is provided in Section 4.4.4 & Appendix I)
- The relative flow bias between Pipes B1, B2, B3, B4 was established.
- The relative flow bias between Pipes P1 & P2 was established
- The raw coal mass flows, moisture content and flow bias were then utilised to calculate the reference mass flows for each sampling period.

Additional details are provided for each step below.

4.4.1 Obtaining the Raw Coal Fed into the Mill by the Gravimetric Feeders

The trends of the raw coal flow from the gravimetric feeders were downloaded from the control system of the Power Station from the 30 July 2015 to the 3 September 2015. These mass flows of the raw coal into the mill were averaged for the duration of each sampling period. The trend provided a reading of the raw coal mass flow fed into the mill in kg/s. An extract of the trends for the 17 August 2015 for the sampling duration (approximately from 19:00 to 22:00) can be found in Appendix G. Similarly, trends for each sampling period for this study were drawn from the control system (average values provided in Table 4-3). The raw coal contained moisture therefore the reading was the “wet” raw coal mass flow including moisture.

4.4.2 Determination of the Percentage Raw Coal Flow into Each Side of the AB Tube Mill

As can be seen from Figure 4-4 (Agrawal, Panigrahi and Subbarao, 2015) raw coal is fed into each side of AB Tube Mill. The pulverised fuel and air mix exits from side A as well as side B of the AB Mill. PF pipes then transport the PF to riffle boxes on the A side and B side respectively. Figure 3-3 in Section 3 shows a schematic of the PF pipe arrangement. The A side feeds 8 burners and the B side feeds 8 burners on the opposite side of the boiler.

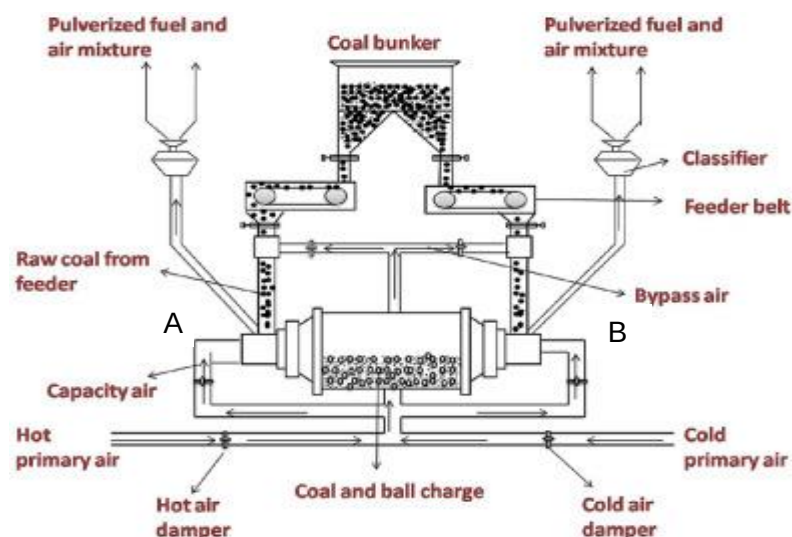


Figure 4-4: AB Tube Mill (Agrawal, Panigrahi and Subbarao, 2015)

The Power Station had reported that for the AB Tube Mill, the raw coal entering Mill A side would be equal to the PF exiting Mill A side, due to the differential pressure in the mill and the same would be applicable to Mill B side. To validate this, trends of the raw coal entering Mill A and Mill B were drawn from (for the sampling periods) and the averaged values for the sampling periods are tabulated in Table 4-3.

Table 4-3: Percentage Raw Coal Flow into Mill A and Mill B

Date	Flow in Mill A (kg/s)	Flow in Mill B (kg/s)
30/7/2015	9.00	9.06
4/8/2015	9.30	9.25
5/8/2015	8.81	8.83
6/8/2015	8.59	8.61
11/8/2015	8.74	8.65
13/8/2015	8.78	8.78
17/8/2015	8.83	8.86
18/8/2015	8.75	8.72
19/8/2015	8.72	8.88
20/8/2015	8.59	8.82
26/8/2015	8.82	8.85
27/8/2015	8.66	8.66
1/9/2015	8.38	8.37
2/9/2015	8.79	8.83
3/9/2015	9.81	9.83

The information from Table 4-3 was utilised to graphically represent the raw coal mass flows into Mill A and Mill B for each of the respective testing days for this study.

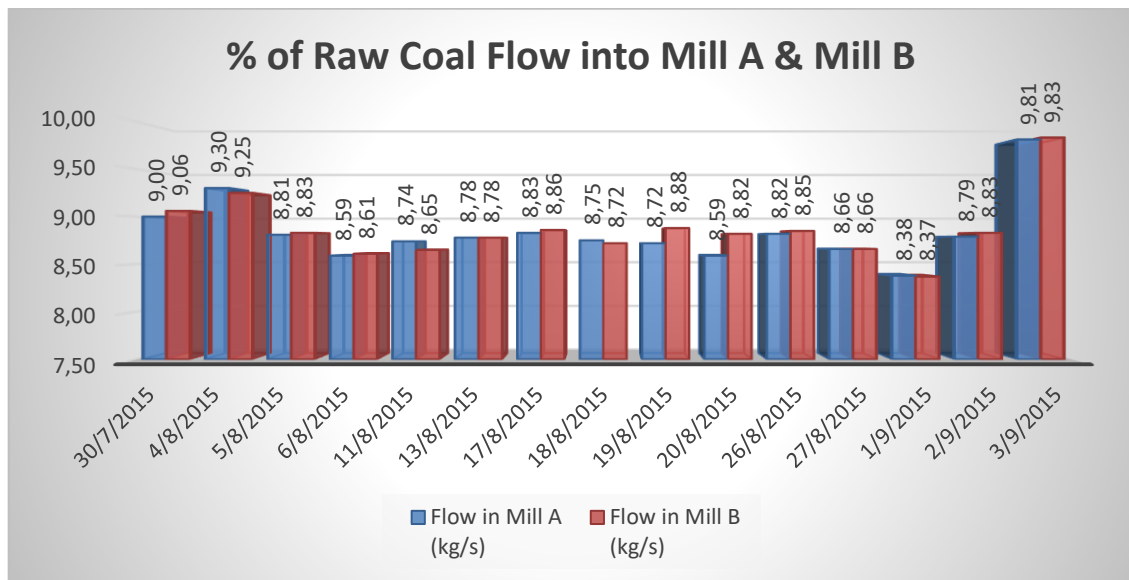


Figure 4-5: Percentage of Raw Coal Flow into Mill A & Mill B

From Table 4-3 and Figure 4-5 an example of the calculation for the 17 August 2015 is described. The average mass flow was 8.86kg/s flowing into Mill B, while the average mass flow for Mill A was 8.83kg/s (Appendix G for trend coal flow). Considering the sum of the average mass flow into the AB Tube Mill for the sampling period being $8.86\text{kg/s} + 8.83\text{kg/s} = 17.69\text{kg/s}$. Therefore, 50.08% of the coal entering Mill B and 49.92% entering Mill A during this sampling period. As can be seen from Table 4-3 the amount of coal fed to each side of the mill for all periods are in close agreement for each sampling period and is therefore assumed to be equal.

4.4.3 Determination of the Moisture Content in the Raw Coal

Raw coal was also sampled at entry to the gravimetric feeder during the PF sampling process and analysed at a laboratory to determine the total moisture content. Moisture from the raw coal could be extracted as the coal is ground into PF in the mill as a result of the mill temperature. Therefore, it was imperative to analyse the raw coal to determine the Total Moisture. For a more accurate comparison the PF was also dried in an oven and the PF and raw coal mass

flows were determined on a dry basis. The results of the laboratory analysis can be found in Appendix E. As can be seen in Appendix E the raw coal sample for the 17 August 2015 had a moisture content of 8.5%.

4.4.4 Accuracy of Readings Provided by the Gravimetric Feeders

The accuracy of the gravimetric feeder coal flows was established by conducting a truck test. For this calibration, both Mill A & B feeders were run at 20%, 40%, 60%, 80% and 100% of feeder speed control to load coal onto tipper trucks respectively. After each load the tipper trucks were weighed with the coal, offloaded and then weighed empty before collecting the next load. During each run the average ton per hour and feeder speed were recorded. The feeder flows were calibrated based on the results of these truck tests. The report for the calibration with detailed description of the test procedure is given in Appendix I.

4.4.5 Establishing the Relative PF Mass Flows between Pipes B1, B2, B3 & B4

From the classifiers exiting the mill Figure 4-4, a single pipe from each side of the AB Mill transports the PF pneumatically to a riffle box. Figure 4-6 and Figure 4-7 show the PF pipe arrangement at the 45m level. At this point the riffle box splits the PF flow from the single pipe to four 508mm pipes. Figure 4-7 shows pipes B1, B2, B3 and B4 with the sampling ports. Flow direction is upwards.

This section describes the steps taken to establish the flows in each of the pipes as well as the flow bias between the pipes. As can be see the outer 2 pipes B1 and B4 were shorter than the inner pipes B2 and B3.



Figure 4-6: PF Pipe Arrangement at 45m Level after 1st Riffle Box

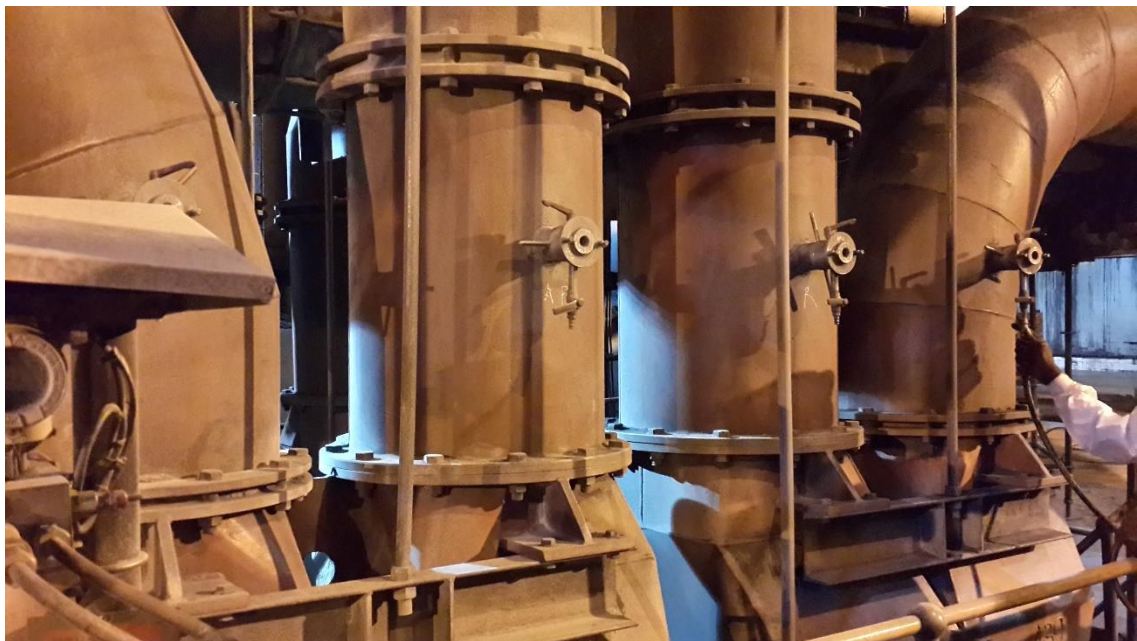


Figure 4-7: PF Pipes B1, B2, B3 & B4 (from left to right) Exiting Riffle Box at 45m Level

From the values for the 17 August 2015, raw coal mass flow of 8.86kg/s and the moisture content of 8.5% (Appendix E) of the raw coal and using the equation;

$$MRC_d = MRC_w - (MRC_w \cdot \%M_c) \quad (17)$$

Where,

Mass flow of raw coal (dry) = MRCd (kg/s)

Mass flow of raw coal (wet) = MRCw (kg/s)

% of moisture in raw coal = %Mc (%)

the dry coal flow was calculated to be 8.11kg/s. If the flows between the pipes (B1, B2, B3 & B4) were balanced, this would give a flow of 2.03kg/s for each of the burner pipes, exiting the riffle box (45m level). To establish if the riffle box distributed the mass flows evenly between the four PF pipes or if it created a flow bias (in percentage of total coal flow) between pipes B1, B2, B3 & B4 the Rotoprobe was utilised.

The relative coal flow bias between pipes B1, B2, B3 & B4 was determined as follows. Three (Appendix 0, Table A-21, Table A-22, Table A-23 & Table A-24) sets of tests were conducted per pipe with the Rotoprobe and the results were averaged (Appendix 0, Table A-25). The total flow was then calculated by summing the averaged values in each pipe. The flow in each pipe was divided by the total flow to establish the percentage of coal mass flow in each pipe, i.e. the bias of PF flow between the 4 PF pipes. Continuing from 4.4.1 the values from the 17 August 2015 were used and presented below in Table 4-4. The results are presented on a dry basis, i.e. the percentage moisture that was determined at Sizwe Laboratory (Appendix E) and subtracted from the mass of the PF sample.

Table 4-4: Flow Bias in PF Pipes (B1, B2, B3 & B4)

Pipe	B1 (kg/s)	B2 (kg/s)	B3 (kg/s)	B4 (kg/s)
Test 1	2.10	1.88	1.88	2.16
Test 2	2.17	1.88	1.91	2.18
Test 3	2.23	1.86	1.92	2.21
Average (kg/s)	2.17	1.88	1.90	2.18
Flow Bias %	26.67	23.06	23.42	26.84

As shown in Table 4-4 the PF mass flows was not evenly distributed between the PF pipes. The information in Table 4-4 was utilised to graphically represent (Figure 4-8) the % of PF mass flow that was split between Pipes B1, B2,B3 & B4. The riffle box succeeded in balancing the flow left and right (of the boiler), but it also biased more of the PF to the two outer pipes, i.e. B1 & B4.

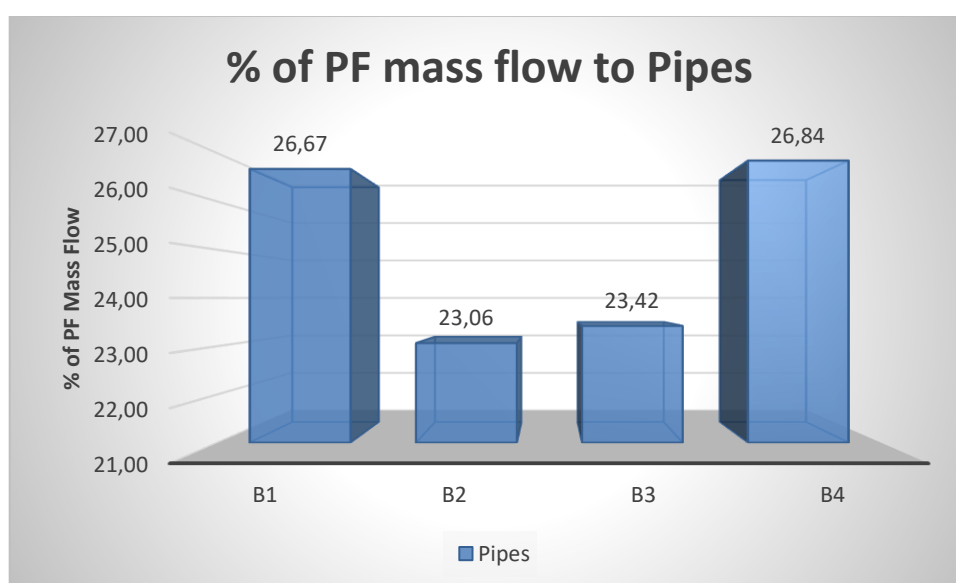


Figure 4-8: Percentage of PF Mass Flow to Pipes B1, B2, B3 & B4

4.4.6 Coal Mass Balance

To confirm the validity of this percentage coal flow bias approach, a coal mass balance was carried out. This involved a comparison of the raw coal fed into the mills with the sum of the PF distributed to the four PF pipes (B1, B2, B3 & B4).

The moisture content of the PF and the raw coal was determined during the analysis and the coal mass balances or recovery rate was calculated on a dry basis. This was considered to be more accurate than calculating the recovery rate on a wet basis, as a percentage of the moisture from the raw coal would have evaporated in the mill.

The following formulae was utilised to calculate the PF flow rate;

$$MF_d = \frac{M_d}{n.t} \left(\frac{D}{d_n} \right)^2 \quad (18)$$

Where;

Sampling time per point in seconds = t (s)

Number of sampling points = n

Sampling nozzle inner diameter = d_n (mm)

Pulverised fuel pipe inner diameter = D (mm)

Mass flow of pulverised fuel (dry) = MF_d (kg/s)

Total mass of pulverised fuel (after drying) = M_d (kg)

Equation (17) was utilised to calculate the raw coal mass flow;

$$MRC_d = MRC_w - (MRC_w \cdot \%M_c) \quad (17)$$

Where,

Mass flow of raw coal (dry) = MRC_d (kg/s)

Mass flow of raw coal (wet) = MRC_w (kg/s)

% of moisture in raw coal = $\%M_c$ (%)

It should be noted that the power station reported that there were no rejects for the tube mill.

For the mass balance,

Raw coal mass flow (MRC_d) = $\sum$ of mass of PF flow in B1+B2+B3+B4

Value from Table A-7 & Table A-9 were utilised to calculate the dry coal mass flow for 17 August 2015 as follows;

$$MRC_d = MRC_w - (MRC_w \cdot \%M_c) = 8.86_w - (8.86_w \cdot \%8.5_c) = \mathbf{8.11kg/s}.$$

From Table A-25 the sum of the PF mass flow for the 17 August 2015 was calculated as follows:

$$\sum \text{ of mass flow of PF in B1+B2+B3+B4} = 2.17+1.88+1.90+2.18 = \mathbf{8.13kg/s}.$$

The mass balance confirmed that the approach taken to establish the flow bias was sound.

This established flow bias was utilised to calculate the flow in pipes B2 and H2 using the raw coal mass flow and moisture content for the required sampling time periods during the evaluation.

4.4.7 Flow of PF Exiting Each Side of the AB Tube Mill

With a relatively even split of the coal entering Mill A and Mill B from Section 4.4.2 and with the out flow of PF equal to the raw coal fed into Mill B as shown in Section 4.4.6 it can be concluded that the PF exiting Mill A and Mill B will also be evenly split. This is supported by the Power Station experience that the raw coal entering one side of the tube mill is equal to the PF leaving that side of the Mill. Based on this observation the focus of the remainder of the study was on Mill B.

4.4.8 Establishing the Relative PF Mass Flows Between Pipes P1 & P2

There were no PF mass flow measurements available at the pipes P1 and P2. Essentially when PF sampling is conducted it should be conducted at the pipes that are entering the burners as this would provide information that could be utilised for the balancing of PF mass flows between burners and also provide information on the particle size distribution at the burners once the PF samples are analysed.

A similar approach that was described above to calculate the reference mass for flows for B2 was followed to calculate the reference mass flows in pipes P1 and P2. The initial step again involved establishing the flow bias between the two pipes. This process is described in more detail this section below.

After the 1st riffle box at the 45m level the PF pipes bend 90° to the horizontal orientation (Figure 4-6) and are routed around the boiler. At this point the pipes bend again 90° upwards to the vertical orientation where the pipes then enter another riffle box as shown in Figure 4-9. At this point the pipes are split into two 356mm diameter pipes.



Figure 4-9: PF Pipes P1 & P2 Exiting Riffle Box

In a similar manner as described above in which the flow bias between Pipes B1, B2, B3 and B4 were calculated, it was also possible to establish a flow bias of the coal flow between pipes P1 & P2 as split by a second riffle box, with the Rotoprobe. Five sets of tests were conducted per pipe with the Rotoprobe and

the results were averaged to establish the bias of PF flow between the two PF pipes. The results are presented on a dry basis, i.e. the % moisture was utilised to determine the dry mass of the PF samples as described above.

Table 4-5: Percentage Flow Bias in PF Pipes P1 & P1

Pipe	P1 (kg/s)	P2 (kg/s)
Test 1	0.84	1.04
Test 2	0.82	1.02
Test 3	0.84	1.03
Test 4	0.84	1.02
Test 5	0.78	1.06
Average (kg/s)	0.82	1.04
Flow Bias %	44.34	55.66

The information in Table 4-5 was utilised to graphically represent (Figure 4-10) the % of PF mass flow that was split between Pipe P1 and Pipe P2. The riffle box did not split the PF mass flow evenly, it rather biased the flow to Pipe P2 with 55,6% of the total PF from Pipe B2 flowing to Pipe P2. Therefore leaving 44,34% of the PF mass flow to flow into Pipe P1.

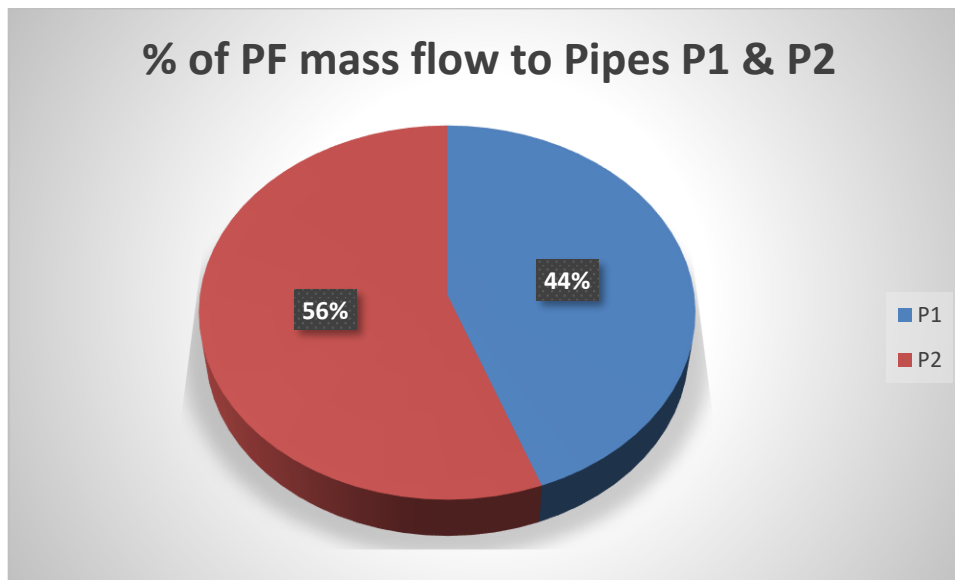


Figure 4-10: Percentage of PF Mass Flow to Pipes P1 & P2

By utilising the relevant calculated flow in pipe B2 (using the time when sampling was carried out), the percentage moisture content and the percentage flow bias in P1, the PF mass flow could be calculated for a particular sampling period.

For the 30 July 2015 the flow from the gravimetric feeders was 9.06kg/s. Using equation 2 and a moisture content of 7.4%. The dry raw coal flow was calculated to be 8.38kg/s. Multiplying this value by the flow bias of 23.06% from Table 4-4 the flow in B2 was calculated to be 1.93kg/s.

Using the flow in B2 and multiplying it by the flow bias of 44.34% from Table 4-5, the Reference PF flow in P1 was calculated to be 0.86kg/s.

Similarly the PF mass flow could be calculated for Pipe P2. These reference mass flows were calculated for each set of tests.

It is assumed that PF flows in pipe H2 is the same as the PF flow in pipe B2 as it is the same pipe.

The calculated reference mass flows for each sampling period are presented in Table 4-6

Table 4-6: Reference Mass Flow (kg/s)

Date	Reference Mass flow (kg/s)	Flow in B2 & H2 (kg/s)	Flow in P1 (kg/s)	Flow in P2 (kg/s)
30/7/2015	8.38	1.93	0.86	1.08
4/8/2015	8.56	1.97	0.88	1.10
5/8/2015	8.17	1.88	0.84	1.05
6/8/2015	8.15	1.88	0.83	1.05
11/8/2015	8.00	1.85	0.82	1.03
13/8/2015	8.12	1.87	0.83	1.04
17/8/2015	8.11	1.87	0.83	1.04
18/8/2015	8.07	1.86	0.82	1.04
19/8/2015	8.21	1.89	0.84	1.05
20/8/2015	8.16	1.88	0.83	1.05
26/8/2015	8.19	1.89	0.84	1.05
27/8/2015	8.01	1.85	0.82	1.03
1/9/2015	7.74	1.79	0.79	0.99
2/9/2015	8.17	1.88	0.84	1.05
3/9/2015	9.09	2.10	0.93	1.17

4.5 Verification of the PF Mass Flows in Pipe 1 and Pipe 2

In addition to the coal mass balance in Section 4.4.6 the incremental sampling data was utilised to verify the reference mass flow rates of the PF for P1 and P2. Incremental sampling was done utilising the LC-4 sampler where individual samples that were extracted as described in the preceding section were analysed for moisture content and the masses from each sample were summed. The average PF moisture content was utilised to calculate the dry PF mass flow. This mass flow was utilised to validate the mass flows in Pipe P1 and P2 that was obtained above.

Three sets of tests for each pipe (Pipe P1 and Pipe P2) were carried out, with 24 samples per test and a total of 144 samples for both pipes. The incremental sampling was carried out on 18, 19 & 20 August 2020 for Pipe P1 and Pipe P2. A summary of the incremental sampling results are presented in Table 4-7. The weights of the 24 samples per test were summed and utilised to calculate the PF mass flow.

Table 4-7: PF Mass Flow in Pipe 1 & Pipe 2 from Incremental Sampling

Pipe #	t (s)	n	d mm	D mm	mass (g) wet	Moisture in PF	mass (g) dry	Md (kg)	MFd (kg/s)	MFw (kg/s)	Totals ave kg/s
P1	120	24	13	356	3363.60	2.33	3285.23	3.29	0.93	0.95	
P1	120	24	13	356	3045.30	2.33	2974.34	2.97	0.84	0.86	
P1	120	24	13	356	3197.20	2.33	3122.71	3.12	0.88	0.90	0.88
P2	120	24	13	356	3335.50	2.33	3257.78	3.26	0.92	0.94	
P2	120	24	13	356	3824.70	2.33	3735.58	3.74	1.05	1.08	
P2	120	24	13	356	3491.10	2.33	3409.76	3.41	0.96	0.98	0.98
											1.86

Based on the dry PF mass flow an average PF mass flows of 0.88kg/s and 0.98kg/s were calculated for Pipe 1 and Pipe 2 respectively, which cumulatively provided a total of 1.86kg/s as shown in Table 4-7.

Table 4-8: Verification of Reference Mass Flow (kg/s) in Pipe 1 & Pipe 2

Date	Reference Mass flow (kg/s)	Flow in B2& H2 (kg/s)	Flow in P1 (kg/s)	Flow in P2 (kg/s)	Total
18/8/2015	8.07	1.86	0.82	1.04	
19/8/2015	8.21	1.89	0.84	1.05	
20/8/2015	8.16	1.88	0.83	1.05	
Average			0.83	1.05	1.88

From Table 4-8 the total reference mass flow for the sampling period from 18/8/2015 to 20/8/2015 for Pipe 1 and Pipe 2 was calculated to be 1.88kg/s. The reference mass flow of 1.88 compared favourably with the PF mass flow of 1.86kg/s provided by the incremental sampling. This verification utilising the incremental sampling again demonstrated adoption of the reference mass flow approach was suitable.

4.6 Accuracy of the PF Sampling Methods

The initial consideration was to carry out 30 tests with each sampler or sampling method at Pipe P1 and to compare this to the reference mass flow. 30 repeated test would have provided adequate information on the accuracy as well as the repeatability of the sampling method. However in order to perform cross checks and validate the approach by checking if the PF flowing from Pipe B2 to H2 and then being split to P1 & P2 was accounted for by doing a mass flow balance, the scope was expanded to include 10 test per sampling method on Pipe P2. The method and results are described in more detail below.

To determine the accuracy of the sampling methods, 30 repeated tests were carried out on Pipe P1 and 10 repeated tests were carried out on Pipe P2 with each PF sampling method. The 10 tests from Pipe P2 using each sampling method were carried on the same day and therefore required the calculation of a single Reference Mass Flow value. For Pipe P1 the sampling was undertaken over several days and the respective Reference Mass Flows were calculated for

each sampling period. After the samples were analysed to determine the weight and moisture content, the dry mass flows (kg/s) were calculated for each sampling method. These dry mass flow results were averaged and compared to the averaged Reference Mass Flows from Table 4-6. The detailed results can be found in the (Appendix J to Appendix N) and a summary of the mass flow results for Pipe P1 is provided in Table 4-9 and a summary of the mass flow results for Pipe P2 is provided in Table 4-11. The results are further analysed in a summary for the accuracy of the PF sampling methods which is expressed as the percentage of the recovery mass flow/rate and is presented below in Table 4-10 and Table 4-12 for Pipes P1 and P2 respectively. The recovery rate was simply obtained by dividing the Sampling PF mass flow by the Reference mass flow which providing a value in %. A value over 100% indicated over-suction and a value under 100% indicated an under-suction as shown in Figure 4-1.

Table 4-9: Comparative Mass Flows for Sampling Methods at Pipe P1 (kg/s)

Test	Date of Rotoprobe Sampling	Reference Mass Flow for Rotoprobe (kg/s)	PF Mass Flow Rotoprobe (kg/s)	Date of 3 Axis Sampling	Reference Mass Flow for 3 Axis (kg/s)	PF Mass Flow 3 Axis (kg/s)	Date of 1 Axis Sampling	Reference Mass Flow for 1 Axis (kg/s)	PF Mass Flow 1 Axis (kg/s)	Date of Target Plate Sampling	Reference Mass Flow for Target Plate (kg/s)	PF Mass Flow Target Plate (kg/s)
1	06/08/2015	0,83	0,85	05/08/2015	0,84	0,86	30/07/2015	0,86	0,99	04/08/2015	0,88	1,36
2	06/08/2015	0,83	0,71	05/08/2015	0,84	0,69	30/07/2015	0,86	1,39	04/08/2015	0,88	1,34
3	06/08/2015	0,83	0,81	05/08/2015	0,84	0,81	30/07/2015	0,86	2,19	04/08/2015	0,88	1,37
4	06/08/2015	0,83	0,82	05/08/2015	0,84	0,78	30/07/2015	0,86	1,95	04/08/2015	0,88	1,32
5	06/08/2015	0,83	0,84	05/08/2015	0,84	0,84	30/07/2015	0,86	2,59	04/08/2015	0,88	1,12
6	06/08/2015	0,83	0,86	05/08/2015	0,84	0,90	05/08/2015	0,84	0,91	04/08/2015	0,88	1,36
7	06/08/2015	0,83	0,83	05/08/2015	0,84	0,84	05/08/2015	0,84	0,90	04/08/2015	0,88	1,27
8	06/08/2015	0,83	0,85	05/08/2015	0,84	0,78	05/08/2015	0,84	0,87	04/08/2015	0,88	1,31
9	06/08/2015	0,83	0,85	05/08/2015	0,84	0,74	05/08/2015	0,84	0,83	04/08/2015	0,88	1,33
10	06/08/2015	0,83	0,79	05/08/2015	0,84	0,85	05/08/2015	0,84	0,86	04/08/2015	0,88	1,15
11	06/08/2015	0,83	0,89	06/08/2015	0,83	0,85	06/08/2015	0,83	0,84	06/08/2015	0,83	1,19
12	06/08/2015	0,83	0,85	06/08/2015	0,83	0,85	06/08/2015	0,83	0,83	06/08/2015	0,83	1,23
13	06/08/2015	0,83	0,87	06/08/2015	0,83	0,81	06/08/2015	0,83	0,84	06/08/2015	0,83	1,18
14	06/08/2015	0,83	0,84	06/08/2015	0,83	0,83	06/08/2015	0,83	0,79	06/08/2015	0,83	1,23
15	06/08/2015	0,83	0,85	06/08/2015	0,83	0,89	06/08/2015	0,83	0,78	06/08/2015	0,83	1,14
16	06/08/2015	0,83	0,76	11/08/2015	0,82	0,87	11/08/2015	0,82	0,88	11/08/2015	0,82	1,11
17	06/08/2015	0,83	0,83	11/08/2015	0,82	0,81	11/08/2015	0,82	0,84	11/08/2015	0,82	0,90
18	06/08/2015	0,83	0,83	11/08/2015	0,82	0,86	11/08/2015	0,82	0,84	11/08/2015	0,82	0,83
19	06/08/2015	0,83	0,82	11/08/2015	0,82	0,88	11/08/2015	0,82	0,82	11/08/2015	0,82	0,73
20	06/08/2015	0,83	0,84	11/08/2015	0,82	0,83	11/08/2015	0,82	0,80	11/08/2015	0,82	0,76
21	06/08/2015	0,83	0,85	17/08/2015	0,83	0,89	17/08/2015	0,83	0,91	17/08/2015	0,83	1,13
22	06/08/2015	0,83	0,84	17/08/2015	0,83	0,85	17/08/2015	0,83	1,00	17/08/2015	0,83	1,10
23	06/08/2015	0,83	0,84	17/08/2015	0,83	0,81	17/08/2015	0,83	1,01	17/08/2015	0,83	1,08
24	06/08/2015	0,83	0,84	17/08/2015	0,83	0,75	17/08/2015	0,83	0,97	17/08/2015	0,83	1,02
25	06/08/2015	0,83	0,87	17/08/2015	0,83	0,84	17/08/2015	0,83	0,80	17/08/2015	0,83	1,05
26	06/08/2015	0,83	0,84	17/08/2015	0,83	0,86	17/08/2015	0,83	0,85	17/08/2015	0,83	1,28
27	06/08/2015	0,83	0,85	17/08/2015	0,83	0,97	17/08/2015	0,83	0,90	17/08/2015	0,83	1,37
28	06/08/2015	0,83	0,67	17/08/2015	0,83	0,80	17/08/2015	0,83	0,95	17/08/2015	0,83	1,26
29	06/08/2015	0,83	0,83	17/08/2015	0,83	0,73	17/08/2015	0,83	1,02	17/08/2015	0,83	1,05
30	06/08/2015	0,83	0,81	17/08/2015	0,83	0,75	17/08/2015	0,83	0,78	17/08/2015	0,83	1,14
Average		0,830	0,827		0,832	0,828		0,835	1,032		0,845	1,157

Table 4-10: Recovery Rate for P1 (Accuracy)

Sampling Method	Reference Mass Flow (kg/s)	Sampling PF Mass Flow (kg/s)	Recovery Rate (%)	% Error
Rotoprobe	0,830	0,827	99,68	0,32
3 Axis				
Traverse	0,830	0,830	99,53	0,47
1 Axis				
Traverse	0,835	1,032	123,55	23,55
Target Plate	0,845	1,157	136,96	36,96

Table 4-11: Comparative Mass Flows for Sampling Methods at Pipe P2 (kg/s)

Test	Reference Mass Flow Rotoprobe (kg/s)	PF Mass Flow Rotoprobe (kg/s)	Reference Mass Flow 3 Axis, 1 Axis & Target Plate (kg/s)	PF Mass Flow 3 Axis (kg/s)	PF Mass Flow 1 Axis (kg/s)	PF Mass Flow Target Plate (kg/s)
1	1,05	1,03	1,08	1,47	2,22	1,46
2	1,05	1,07	1,08	1,27	1,66	1,41
3	1,05	1,05	1,08	1,52	1,64	1,35
4	1,05	1,12	1,08	1,15	1,52	1,27
5	1,05	1,06	1,08	1,27	1,89	1,25
6	1,05	1,07	1,05	0,95	1,37	1,17
7	1,05	1,06	1,05	0,88	1,76	1,19
8	1,05	1,06	1,05	0,77	2,12	1,22
9	1,05	1,06	1,05	0,96	2,30	1,09
10	1,05	1,10	1,05	1,05	2,11	1,10
Average	1,05	1,07	1,07	1,13	1,86	1,25

Table 4-12: Recovery Rate for P2 (Accuracy)

Sampling Method	Reference Mass Flow (kg/s)	Sampling PF Mass Flow (kg/s)	Recovery Rate (%)	% Error
Rotoprobe	1,05	1,07	101,90	1,90
3 Axis				
Traverse	1,07	1,13	106,10	6,10
1 Axis				
Traverse	1,07	1,86	174,65	74,65
Target Plate	1,07	1,25	117,37	17,37

Table 4-13: Degree of Accuracy of Sampling Methods

Sampling Method	% Error P1	% Error P2	Combined % Error	Degree of accuracy (%)
Rotoprobe	0,16	0,95	1,11	98,89
3 Axis				
Traverse	0,23	3,05	3,29	96,71
1 Axis				
Traverse	11,78	37,32	49,10	50,90
Target Plate	18,48	8,69	27,17	72,83

Even though 30 samples were taken on P1 and 10 on P2, the combined % Error was average to provide a 50% contribution from P1 and 50% from P2. The consideration for taking this approach was the homogeneous nature of the flow in Pipe P1 (Figure 4-11). This would result in approximately the same average if 10 samples were taken or if 30 samples were taken. Consideration of the inhomogeneous (Figure 4-12) contribution from Pipe P2 with a 50 % contribution provided as a more realistic approach. The average % Error and most important the degree of accuracy of the sampling methods are presented in Table 4-13.

Based on this principle the PF sampling methods were evaluated on a recovery rate basis, a value above 100% would indicate a degree of over-recovery and a value less than 100% would indicate under-recovery.

As can be seen from Table 4-13 the Rotorprobe sampler produced the most accurate results (98.89%) followed closely by the 3 Axis traverse (96.71%). The target plate and 1 Axis traverse samplers over-recovered PF samples with accuracy results of 72.83% and 50.90% respectively. The recovery rates for the 1 Axis traverse and target plate samplers were outside the Eskom standard (240-76440331) for a representative sample (range between 95% and 105%).

4.7 Contour Plots of PF Velocity, Mass flow and Fineness

In addition to the verification of the PF mass flow in Pipe P1 and P2 in Section 4.5, the individual incremental PF sampling measurements were utilised to produce the contour plots below in Figure 4-11 and Figure 4-12 show the velocity (Top), mass flow (Middle) and % of particles passing through the 75 μm sieve (Bottom) for Pipe P1 and P2 respectively. The velocity plot at the top was determined utilising the dirty air probe. The middle plot of the mass flow of PF at the specific sampling points was produced after the individual samples were captured utilising the LC-4 sampler, analysed and the PF mass flow was calculated at the specific sampling points in the pipe. The points for the bottom plot was derived from the percentage of particles passing through a 75 μm sieve determined during the analysis.

From the mass flow plots it can be seen that the flow in Pipe P1 was more homogenous when compared to the flow in Pipe P2 (shown in Figure 4-11 and

Figure 4-12). This visualisation aided in understanding the variation in results obtained from methods such as the 1 Axis traverse. If the flow in the pipe is perfectly homogenous, the number of sampling points and sampling diameters would not matter as even a single sample retrieved from any point in the pipe would be representative of the PF flowing in the pipe. The converse would also hold true, the more inhomogeneous the PF flow distribution across the pipe cross section of the PF pipe the more sampling points would be required to provide a representative sample. This minimum number of points is specified in the discontinued BS 893:1978 Standard.

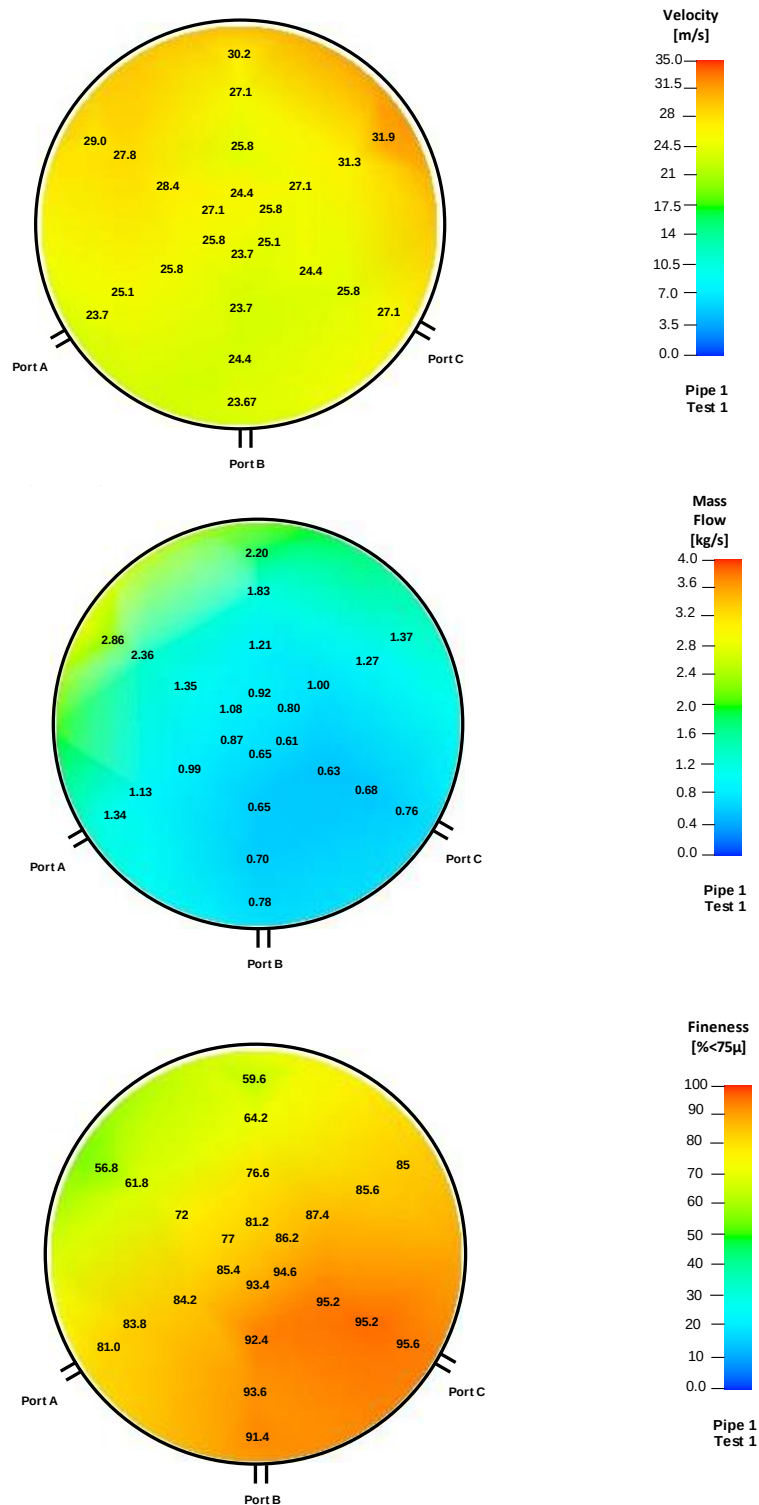


Figure 4-11: Contour Plots of Velocity, PF Mass Flow and Fineness – Pipe P1

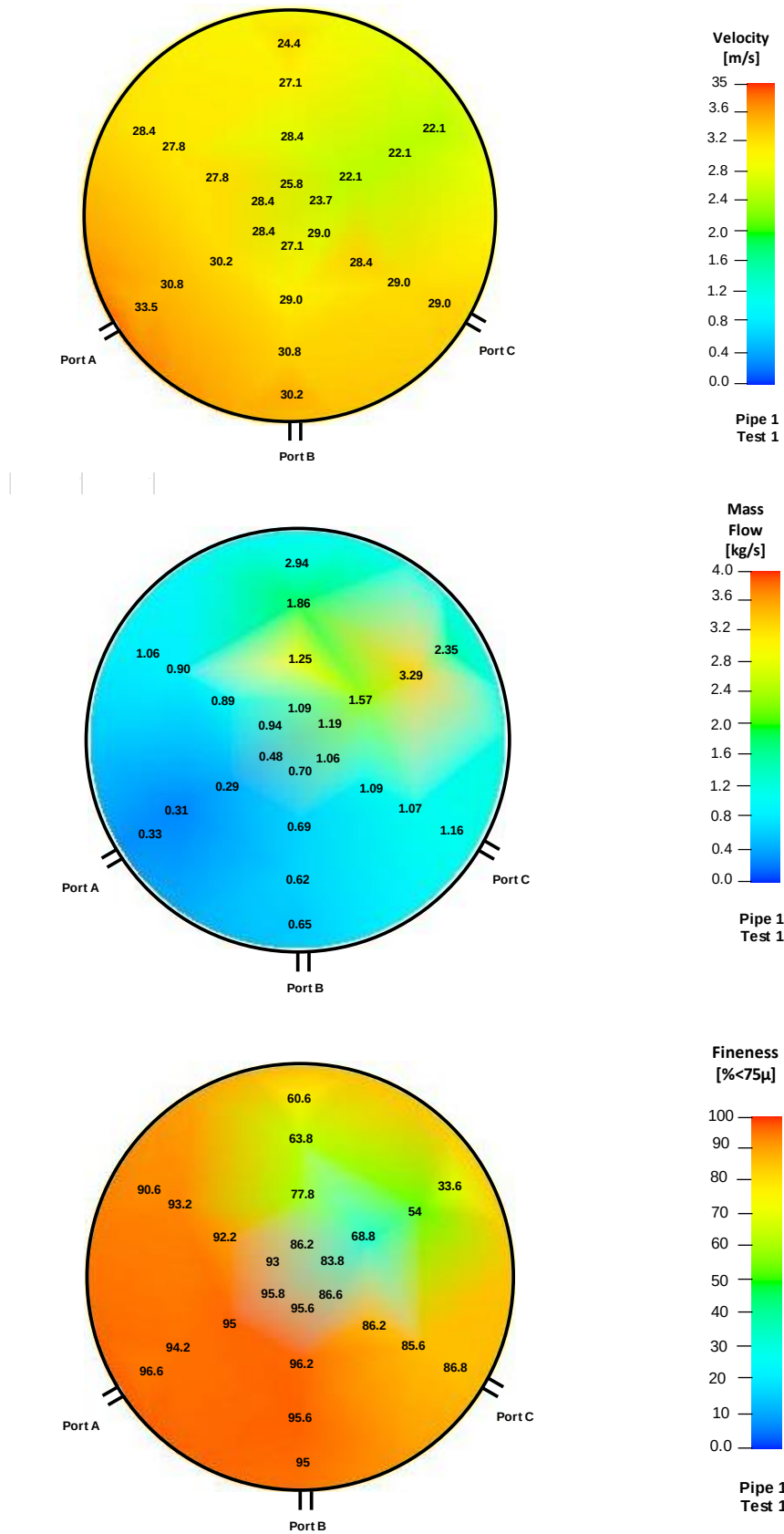


Figure 4-12: Contour Plots of Velocity, PF Mass Flow and Fineness – Pipe P2

4.8 Repeatability of Sampling Methods

For the assessment of the repeatability of the sampling methods the results of the 30 and 10 tests per method from Pipe P1 and P2 respectively, were again utilised. The flow rates of the samples that were extracted from Pipe P1 for the four sampling methods were calculated and are presented in Figure 4-13. Detailed calculations are presented in the Appendix J to Appendix N.

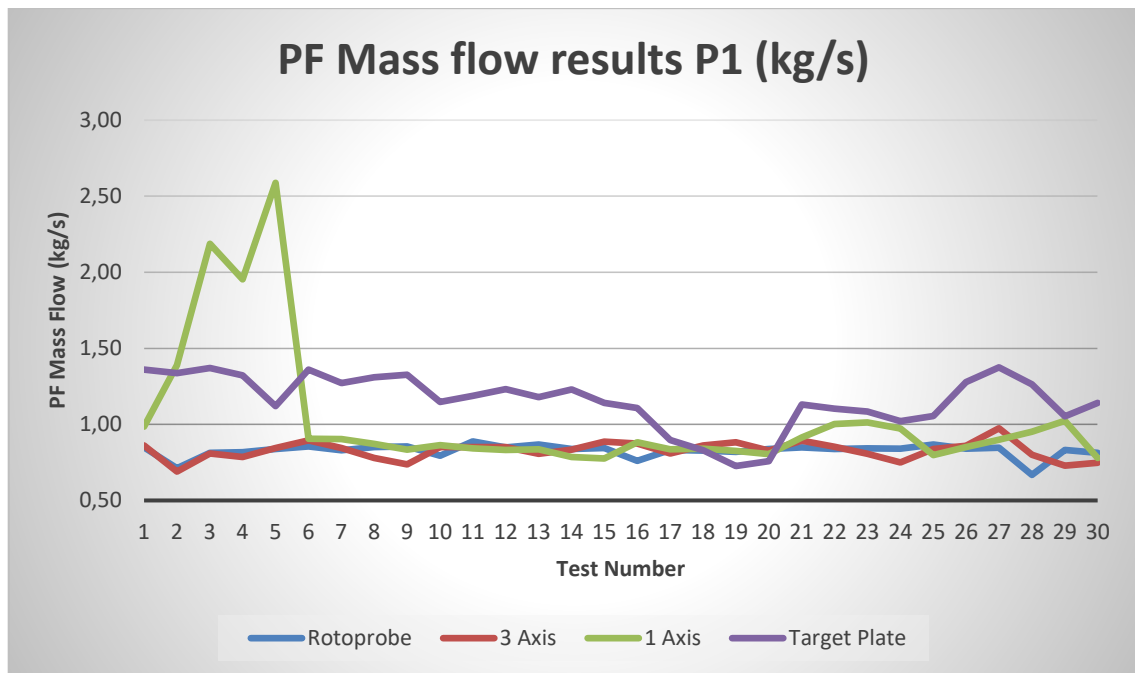


Figure 4-13: Graph of Sampling Methods for Repeatability – Pipe 1

A total of 30 tests were carried out on Pipe P1 and 10 tests were carried out on Pipe P2 per sampling method. The coal mass flow on the Y axis is plotted against the test number on the X-axis. Figure 4-13 illustrates the variability of the results obtained for the 30 tests from P1. Sampling was carried out over a number of days as a result of the magnitude of the testing scope. The mill load was kept constant at 90% mill demand in order to ensure that testing conditions remained the same for the duration of the evaluation. The 1 Axis traverse produced very erratic results for tests 1 to 5. The source of this variation is unknown; however it is speculated that it is due to operator error considering the stability of the results for the remainder of the tests.

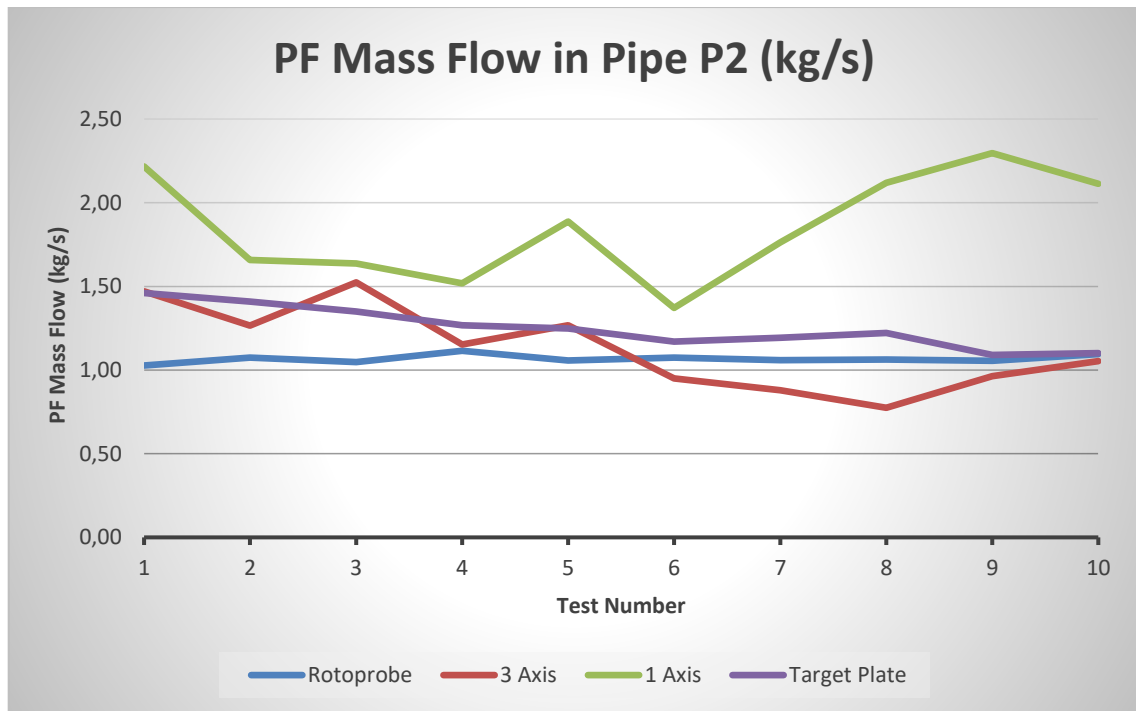


Figure 4-14: Graph of Sampling Methods for Repeatability – Pipe 2

PF mass flows for Pipe P2 for the four sampling methods were calculated and are presented in Figure 4-14. The contour plots for Pipe P2 (Figure 4-12) confirmed that the PF flow was less homogeneous than the flow in Pipe P1 (Figure 4-11). This would explain the erratic results obtained for the 1 Axis method.

Figure 4-15 is a snapshot of Figure 4-13 focussing on the tests T11 to T15 on Pipe P1, where the sampling was carried out on the same day utilising the four different sampling methods.

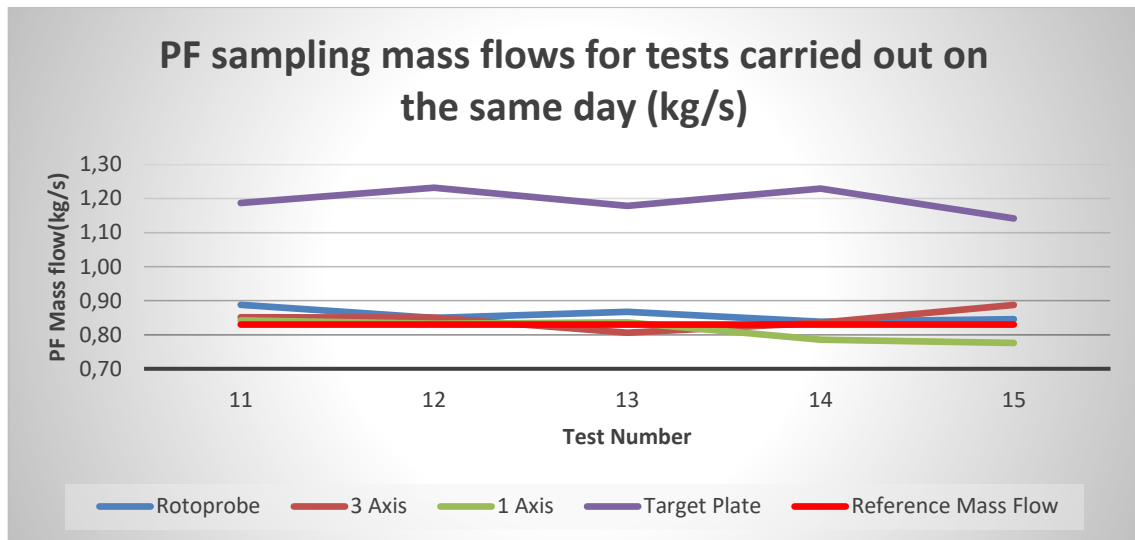


Figure 4-15: Tests 11 to 15 Carried Out on the Same Day with all 4 Sampling Methods

For this data set the Rotoprobe, 3 Axis and 1 Axis provided comparable results. On comparing the flow distribution as shown in Figure 4-11 and Figure 4-12 from the contour plots, the flow of PF in Pipe P1 was significantly more homogeneous when compared to the flow in Pipe P2. Additionally looking at the graph Figure 4-15 (Pipe P1) it can be seen that applying a 1 Axis traverse to a pipe with homogeneous flow would produce comparable results to that obtained from a 3 Axis traverse or Rotoprobe sampler. However when the 1 Axis traverse is applied to a Pipe P2 where the flow is not as homogeneous as Pipe P1, Figure 4-14 the PF sampling results are very erratic and differ significantly from the other method results.

As can be seen from Table 4-13 the target plate sampler yielded much higher (27,13%) mass flow results. Sampling continues when moving from one sampling diameter to another and moving between sampling points. This was investigated as the source of the oversampling experienced when using the target plate sampler. This theory was disproven following discussion with the supplier and operators of the equipment. As it was confirmed that this was not possible as the total sampling time (in this case 8 minutes) would be maintained for the duration of the sampling. As the angling of the probe was the only other variable between applying the equipment to 3 Axis or target plate, it is concluded that the angling contributed to the increase in the mass flow of the PF. This phenomenon was further investigated in the CFD component of this study described below.

4.9 Statistical Comparison (Standard Deviation)

The standard deviation method was employed to determine the repeatability of the sampling method results and was calculated for the four methods over 30 tests on Pipe P1 and the 10 tests on Pipe P2 using the following equation:

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \quad (19)$$

The results of the standard deviation calculations are presented in Table 4-14. The standard deviation calculations were based on the calculated PF flows (kg/s) from Table A-20 and Table A-19 in Appendix M.

Table 4-14: Standard Deviation of Sampling Methods

Standard Deviation			
	P1	P2	Weighted Average
Rotoprobe	0,044	0,025	0,040
3 Axis	0,059	0,250	0,107
T Plate	0,177	0,124	0,164
1 Axis	0,435	0,317	0,317

The standard deviation indicates the variation in the test results and measures how concentrated the data is around the mean. A smaller deviation would indicate less variation in the data and better repeatability of the sampling method.

As shown in Figure 4-16 the smallest standard deviation was provided by the Rotoprobe (0.04) followed by the 3 Axis (0.107) samplers. The 1 Axis provided the largest standard deviation of 0.317 followed by the target plate indicating a large variation (0.164) in the results.

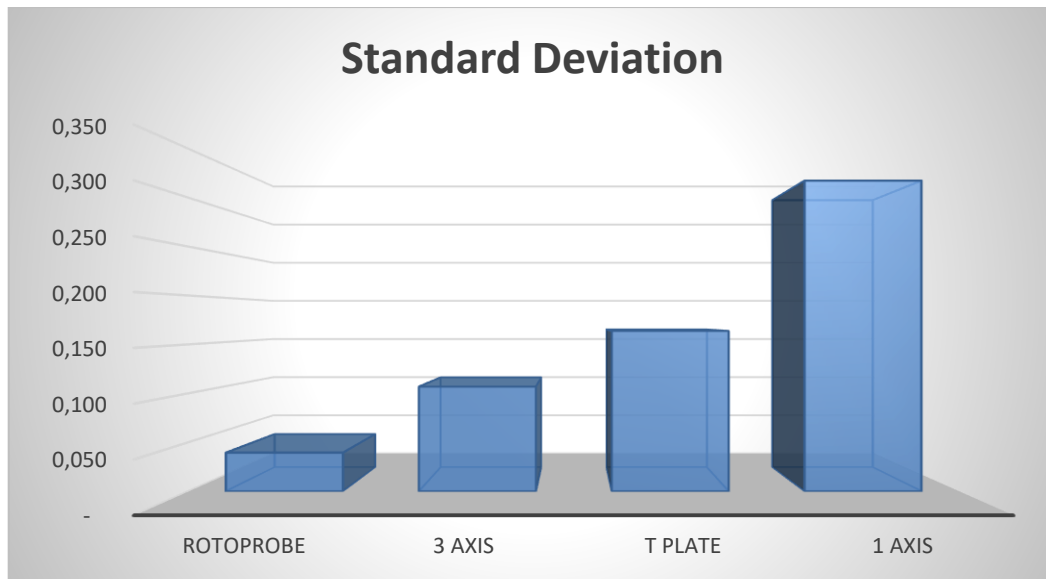


Figure 4-16: Standard Deviation of Sampling Methods

4.10 PF Sampling in Horizontal vs Vertical Pipes

With the accuracy and repeatability of the sampling methods established in the previous sections, comparison of the results obtained when sampling in a vertical pipe compared to sampling in a horizontal pipe was of particular interest to this study. The Rotoprobe was utilised to carry out this sampling at location B & H from Figure 3-3. With B being the vertical pipes and BH the horizontal pipes.

From Table A-25 and Table A-26 in Appendix O the Rotoprobe samples were extracted for the four vertical pipes B1, B2, B3 & B4 Table 4-15 and for the four horizontal pipes BH1, BH2, BH3 & BH4 Table 4-16 respectively.

Table 4-15: Vertical Pipes B1, B2, B3, B4 Rotoprobe Results

Date	Test Method	Test #	Pipe	ave Md per test set (kg/s)	Raw coal Flow (kg/s)	Raw coal Moisture Content (%)	MRCd (kg/s)
17/8/2015	Roto	T1-T3 - V	B1P1	2.17	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B2P2	1.88	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B3P3	1.90	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B4P4	2.18	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B1P1-B4P4	8.13	8.86	8.50	8.11

Table 4-16: Horizontal Pipes B1H1, B2H2 B3H3, B4H4 Rotoprobe Results

Date	Test Method	Test #	Pipe	ave Md per test set (kg/s)	Raw coal Flow (kg/s)	Raw coal Moisture Content (%)	MRCd (kg/s)
21/8/2015	Roto	T1-T3 - H	B1H1	1.32	8.84	7.60	8.17
21/8/2015	Roto	T1-T3 - H	B2H2	2.10	8.84	7.60	8.17
21/8/2015	Roto	T1-T3 - H	B3H3	0.47	8.84	7.60	8.17
24/8/2015	Roto	T1-T3 - H	B4H4	1.40	8.83	7.60	8.16
21&24/8/2015	Roto	T1-T3 - H	B1H1-B4H4	5.29	8.84	7.60	8.17

The PF mass flows were summed for the four vertical and four horizontal pipes and compared on a dry basis to the raw coal flow. As can be seen from Table 4-15 and Table 4-16, sampling of the vertical pipes produced substantially more accurate results of 8.13kg/s for PF mass flow compared to a raw coal flow of 8.11kg/s. While the sampling in the horizontal pipes produced 5.29kg/s for PF mass flow vs a raw coal flow of 8.17kg/s. The recovery rate was calculated by dividing the sampling mass flow by the raw coal flow. For the vertical pipes the recovery rate was calculated to be 100.25%. Comparatively the recovery rate for the horizontal pipe sampling was calculated to be 64.75%. From this experiment it is clear that sampling in the vertical PF pipes produces more accurate representation of the mass flow results than sampling in the horizontal pipes.

4.11 CFD Modelling of Sampling Nozzle

Computational Fluid Dynamics (CFD) utilises applied mathematics, physics and computational software to visualise how a gas or liquid flows. The software also visualises how the fluid interacts with or is influenced by components in the flow domain as it flows past. CFD utilise Navier-Stokes Equations which describe how pressure, temperature, velocity and density of a moving fluid are related.

Measurement of an actual sampling nozzle were undertaken and a Lagrangian–Eulerian multiphase model was built using these and actual pipe and sampling nozzle dimensions in STAR-CCM+. The model was setup with multiple injectors to inject particles at the inlet of the pipe. Actual plant conditions were used as

inputs to the model for velocities, densities and flow of PF and air. Based on the length of the sampling nozzles and internal pipe diameters the maximum angle of tilt to reach the sampling points at the extremities was calculated to be at 30°, measured from the axial flow direction. The other angles of interest that were calculated based on the location of the sampling points were 15° and 22°. These are the angles that resulted in using the nozzle tilt to reach the sampling points according to BS893:1978. This tilt is guided by the target plate during sampling. The model was setup to simulate these angles as well as a nozzle oriented axial to the flow direction for comparative purposes.

Inputs to the model included a Rosin-Rammler particle size distribution ranging from 75µm to 300µm. The density of the coal used was 1550kg/m³ and the PF mass flow was 1.083kg/s. It was assumed that the particle and velocity distribution to be homogenous throughout the cross section of the pipe.

In order to maintain isokinetic sampling the exit velocity at the sampling nozzle was set to the value of the velocity at the tapping points on the outside of the nozzle Figure 2-8. This value is the velocity of the particle/air mix in the PF pipe in close proximity to the tapping points on the sampling nozzle. Figure 4-17 shows the sample nozzle oriented axial to the flow direction, while Figure 4-18 shows the tilted or angle sampling nozzle.

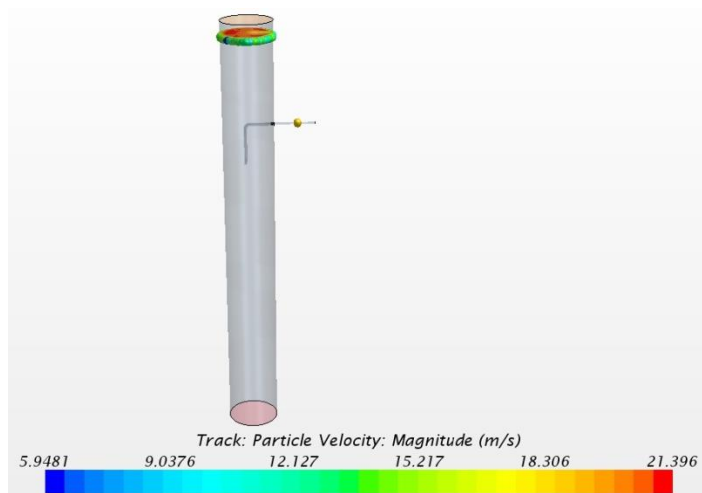


Figure 4-17: CFD Model of Sampling Probe Axial to the Flow

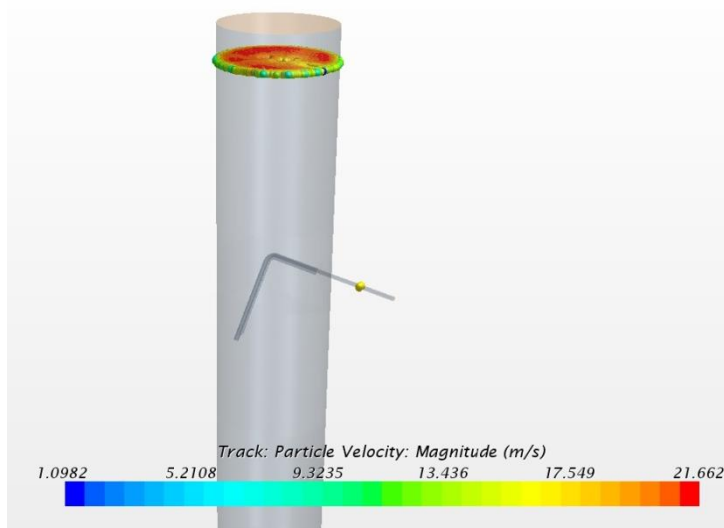


Figure 4-18: CFD Model of Sampling Probe Angled 30° to the Flow

A slice was made at the exit of the sampling nozzle where the number and volume of particles were tracked and counted for the 4 scenarios, i.e. with the sampling nozzle axial to the flow at 0° and angled at 15°, 22° and 30°.

Utilising the total number of particles collected with their respective volumes and the density of the coal of 1550kg/m³ it was possible to calculate the mass of the sample for the axial and angled nozzle, utilising $\rho = m/v$, where density (kg/m³)= mass/volume.

Table 4-17: Percentage Reduction or Increase in Mass of PF Sample when Sampling Nozzle was Angled in CFD Model

Angle	Total Volume (m ³)	Density (kg/m ³)	Sample Mass (kg)	% Change (%)
0°	9.12E-09	1550	1.41E-05	
15°	8.4E-09	1550	1.3E-05	-7.97
22°	1.26E-08	1550	1.96E-05	38.26
30°	1.27E-08	1550	1.97E-05	39.45

The percentage change in sample mass was obtained by comparing the mass obtained from the angled nozzle to that of the axially oriented sampling nozzle. From Table 4-17 angling the nozzle 15° resulted in 7.97% reduction in mass of the sample, while angling the nozzle at 22° and 30° provided an increase in the mass of the sample of 38.26% and 39.45% respectively.

4.12 Theoretical PF Mass Flow from CFD Model

In order to draw a comparison of the results yielded from the CFD model to that obtained from the actual sampling results at the Power Station, the results from the CFD modelling were utilised to calculate the theoretical PF mass flow. For a PF mass flow of 1.083kg/s, the sample mass when sampling at a single axial point was calculated to be at 40.06g using equation 18 (Page 64). Based on the values obtained from the CFD modelling for the reduction in mass of the sample at 15°, a sample of 36.86g was calculated. In the same manner based on the increase of sample for 22° and 30°, samples of 55.38g and 55.86g were obtained respectively.

The impact of the reduction (15°) and increase of mass of samples at the various points (22° and 30°) on the PF mass flow for the pipe utilising a target plate was calculated.

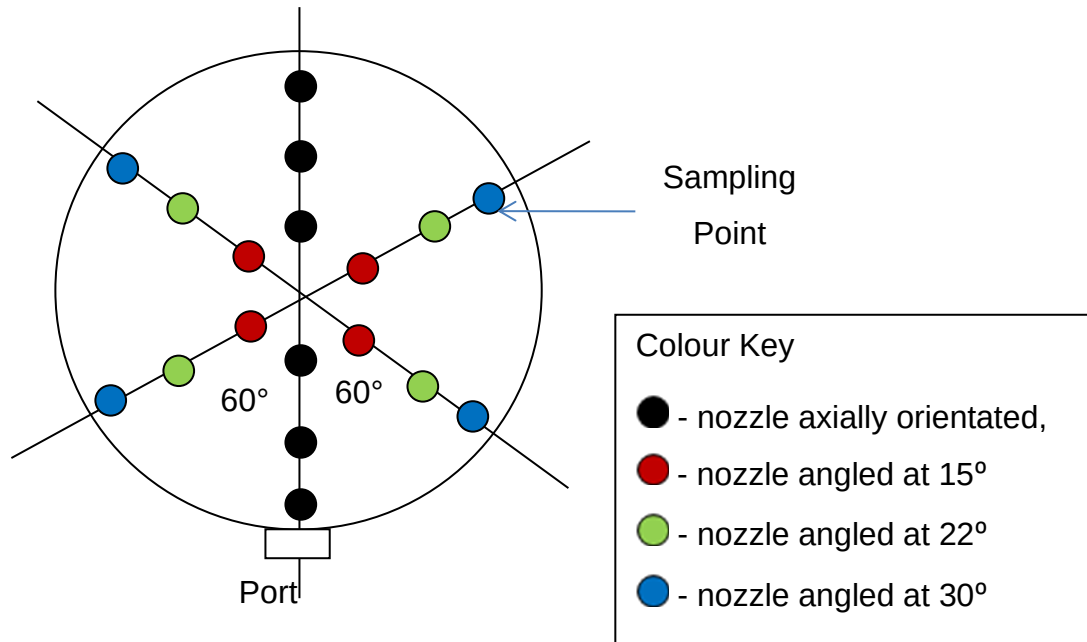


Figure 4-19: Sampling Points at Axial, 0°, 15°, 22° & 30°

From Figure 4-19, and carrying out PF sampling with a target plate at the single port, the sampling nozzle for the six black dots would be axial orientated, the sampling nozzle for the four red dots would be angled at 15°, the four green dots

would require the sampling nozzle to be oriented at 22°, while the four blues dots would require the sampling nozzle to be angled at 30°. By applying the respective increase and reductions to the samples at the respective sampling points, the total mass of PF sample for the pipe could be obtained.

Table 4-18: Determination of the Theoretical PF Sample Mass by Simulating Target Plate Sampling

Angle degree	# of Points	Mass (g)	Combined mass (g)
0	6	40.06	240.34
15	4	36.86	147.45
22	4	55.38	221.53
30	4	55.86	223.43
all 18 points			832.75

The theoretical PF mass flow was calculated for single samples at axial, 15°, 22°, 30° as well as a combined sample simulating the use of a target plate. The results are presented in Table 4-19.

Table 4-19: Determination of the Theoretical Mass Flow of PF by Simulating Target Plate Sampling

Test	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)	% Change
axial	30	1	12.5	356	40.06	0.040	1.08	
15	30	1	12.5	356	36.86	0.037	1.00	-7.97
22	30	1	12.5	356	55.38	0.055	1.50	38.26
30	30	1	12.5	356	55.86	0.056	1.51	39.45
combined	30	18	12.5	356	832.75	0.833	1.25	15.50

The CFD model provided results on the increase (22° & 30°) and reduction (15°) of the sample mass at the various sampling points. These masses were combined and the effect of utilising a target plate to carry out the sampling was simulated, for this pipe configuration and input parameters. Based on the CFD results an increase in PF mass flow from 1.083kg/s to 1.25kg/s was calculated which meant that the target plate sampling simulation overestimated the PF mass flow by 15.5%.

Additional literature on the pitch and yaw angle of pitot tubes was consulted in relation to the CFD modelling results and the results yielded from the target plate sampling, where the sampling nozzle is angled in relation to the flow direction at Power Station A .

4.13 Crowley, et al., (2013) Study into Impact of Angling a Pitot Tube

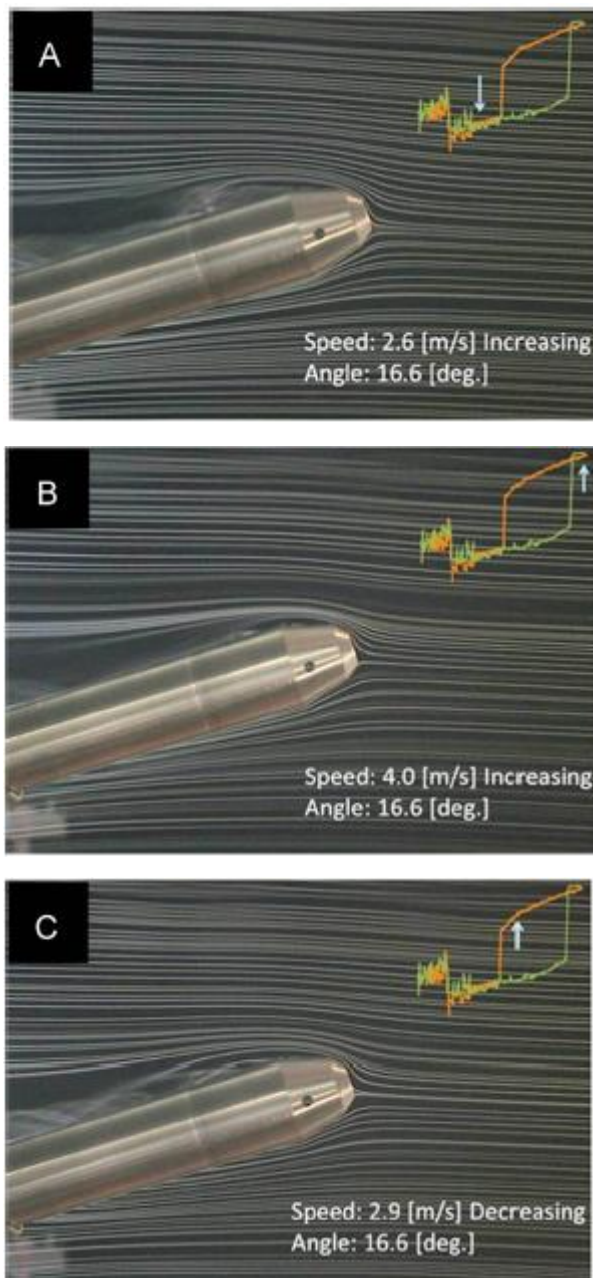


Figure 4-20: Flow Around an Angled Pitot Tube (Crowley, Shinder and Moldover, 2013)

Crowley, Shinder and Moldover, (2013) produced the images in Figure 4-20. In these images the pitot tubes are not aligned to the flow direction. As a result, a

recirculation zone is created when the Pitot tube or sampling nozzle is not held axial to the flow. This recirculation zone corresponds to the area where the static pressure tapping on the sampling nozzle (Figure 2-8) is located. The recirculation affects the static pressure measurement taken for the PF pipe. The impact of the recirculation zone on the static pressure measure would prompt the operator of the PF sampler to increase or decrease the suction rate. From the CFD results it was observed that this action is dependent on the angle at which the sampling nozzle is placed relative to the direction of flow. When the nozzle was angled at 15°, under sampling occurred, therefore the operator would have reduced the suction rate and at 22° and 30° the operator would have increased the suction rate as over sampling occurred. Table 4-19 from the CFD model revealed that the overall impact of the recirculation zone on the static pressure measurement, translated to the oversampling noted. The same was observed from the actual site tests as shown in Figure 4-15.

4.14 Practical Considerations for PF Sampling

It should be noted that it is possible for the Rotoprobe nozzles to get clogged as a result of moisture and large particles. The Rotoprobe sampling nozzles are smaller in diameter (5mm) (compared to the standard LC-4 PF Sampler (12.5mm)). The clogging as a result of moisture can easily be overcome by ensuring that the Rotoprobe is thoroughly warmed before insertion into the PF pipe. It has a heater facility to pass warm air through the equipment. During this study, it was observed that operator experience can identify when a blockage occurred. In the event of a blockage, it is necessary to clear the blockage, discard the sample and reinitiate the sampling process. The rotating head can also get jammed in the pipe if not adjusted correctly or if the pipe is not concentric. Sampling distances should be correctly calculated and the eccentricity tool (supplied with the sampler) should be utilised to check the adjustments and calculations are correct before inserting the Rotoprobe for sampling. PF leakages on the flanges of the rotating head have been reported on much older sampling systems, this was not observed during this study on the newer system.

Factors affecting PF sampling results would include the negative perception of PF sampling as PF sampling is considered to be a “dirty job”. Depending on the

site conditions after a shift of sampling the operator is unrecognisable, covered from head to toe in PF. In this study a major contributor to this was the limited number of sampling adapters (quick connects) that were available. The quick connects seal off the PF pipe where the sampler is inserted and restricts the amount of PF escaping to the environment. Unavailability of power and air lines at the sampling locations meant carrying long extension leads and air hose lines for the supply of electricity and air required during the sampling process. This meant that time had to be spent with a labour intensive setup before the sampling could be undertaken.

Simple initiatives can be undertaken to improve the sampling process.

- Installation of compressed air lines close to the PF sampling points.
- Installation of electricity points close to PF sampling points
- Installation of sealing quick connects at each PF pipe. These would prevent PF from escaping from the PF pipes when the samplers are attached and limit the PF being expelled onto the operator.
- Installation of a block and tackle or small crane (not essential)
- Prior adjustment of the sampling nozzle (Rotoprobe) or custom sized nozzles for the respective PF pipes.

Chapter 5 **Conclusions and Recommendations**

5.1 Main Conclusions

PF sampling requires some insight into the pneumatic transport of coal dust. For example if a tube mill is not adequately charged with balls, this could affect the grinding process and the PF particle size, which was encountered during this study where little chunks of coal approximately 5mm (diameter) were extracted at the sampling locations. Chunks of this size could result in blockages of the PF samplers and if sampling continues will grossly underestimate the PF mass flow. Fortunately, this was only experienced on one particular day. Another example experienced occurred when the Stations main compressor failed while a sample was being extracted. Again, resulting in an under extraction of PF. In these instances, the samples were discarded. Mere application and operation of PF sampling equipment does not guarantee a representative sample from the pipe. PF sampling requires a willingness to do the activity and a presence of mind to ensure the representativeness of the sample of that in the PF pipe.

The Rizk (1976) and Weber (1981) correlations with a safety factor of 1.5 were found to be suitable for calculation of saltation velocity for PF applications. These correlations were utilised to test if the operating velocity was sufficient to maintain the PF particles in suspension during pneumatic transportation. From the calculations, particles could only fall out of solution close to the pipe walls, however, the bulk of the PF would remain in suspension. This is purely based on the calculated transport velocities.

The developed CFD model predicted a 15.5% increase in the PF mass flow when the target plate sampling was simulated in comparison to an axially orientated sampling nozzle. In the actual sampling at the Power Station, with the target plate on Pipe P1 and Pipe P2, even though the same equipment was utilised for the 3 Axis and target plate sampling, the target plate sampler overestimated the coal mass flow results by 27.17% as shown in Table 4-13. The results were in agreement with that provided by the CFD model.

The study conducted by Crowley et. al., (2013) where pitot tubes were angled and images were captured to visualise the flow around the angled pitot tube, provided valuable insight into the analysis of the CFD results with respect to the overestimation of the PF mass flow obtained by angling the sampling nozzle as well as the overestimation of the PF mass flow results obtained when sampling was conducted with the target plate at the Power Station. The recirculation of the PF/Air mix at the vicinity of the static pressure tapping points on the sampling nozzle had a major impact (net oversampling) on the suction rate applied by the operator during sample extraction.

The plots from the incremental sampling support the importance of location of the sampling ports on the pipe and also illustrates how sampling on 1 Axis could skew the mass flow results which would be highly dependent on the quality of the particle and gas flow distribution in the cross section of the pipe at the sampling location. Ideally sampling should be carried out as far away from flow disturbances as possible, where one is more likely to have a homogeneous PF flow across the cross section of the PF pipe. It is however noted that in Power Stations it is not always possible to have long vertical sections of PF pipes to carry out the sampling as a result of the design restrictions in terms of routeing of the PF pipes.

The 30 tests per method at Pipe P1 and 10 tests at Pipe P2 provided the data for the repeatability and accuracy assessment of the sampling methods.

From the evaluation of the sampling methods on the Pipes P1 and P2, the Rotoprobe sampler was found to have an accuracy of 98.89% and repeatability with a standard deviation of 0.04. The 3 Axis sampler produced an accuracy of 96.71% and a standard deviation of 0.107. The target plate sampler had an accuracy of 72.83% and a standard deviation of 0.164, while the 1 Axis sampler produced an accuracy of 50.93%, accompanied with a standard deviation of 0.317.

The contour plots produced from the incremental sampling illustrated that concentrations of PF (roping) were present and much more predominant in Pipe 2. Based on the results obtained and comparison with the reference flows the

Rotoprobe and the 3 Axis traverse provided accurate PF mass flow results on these pipes. Therefore the rotational movement of the Rotoprobe and the sampling across 3 diameters of the PF pipes with the LC-4 sampler compensated for flow concentrations in the PF pipe at the sampling locations. Reducing the number of diameters to 1 in the case of a 1 Axis traverse did not produce accurate results.

Based on the evaluation considering the accuracy and precision of the sampling methods, it is recommended to utilise the Rotoprobe or alternatively the LC-4 sampler applied to 3 sampling ports (3 Axis traverse) as the preferred methods for PF sampling at power utilities.

The target plate sampler should not be utilised as the results would only yield a 73% accuracy and overestimated the PF mass flow. Additionally, as a result of the variation in results and low accuracy (highly flow dependent) produce by the 1 Axis method this practice should also be discontinued. Both the target plate sampling and the 1 Axis traverse methods produced results that were outside the requirements specified in the Eskom Standard.

Additionally, Isokinetic sampling of the PF in the vertical pipes could be compared to that in the horizontal pipes. For the vertical pipes the recovery rate was calculated to be 100.25% while the horizontal pipe sampling recovery rate was calculated to be 64.75%. Therefore, it is recommended that PF sampling is only carried out on vertical pipes. Additionally, where the PF piping arrangement practically allows for it, sampling locations should be located as far away as practically possible from flow disturbances such as bends, etc.

5.2 Recommendations

Based on the study the following is recommended for consideration;

Learnings from the study to be incorporated into a guideline or the Eskom Standard for PF sampling.

Where the LC-4 sampler is preferred, three sampling Sockets (60° apart) should be installed on the PF pipe to facilitate 3 Axis traverse sampling instead of utilising a target plate from a single socket.

To utilise eight sampling points per diameter for the 3 Axis traverse method. The sample point locations to be calculated utilising equation 1 which was obtained from BS893:1978.

PF sampling to be undertaken in vertical rather than horizontal pipes.

An online PF monitoring system has a number of benefits which include as the name suggests obtaining online PF mass flow measurements, PF mass flows can be obtained for all PF pipes simultaneously as well as an online PF particle size distribution analysis can be obtained utilising a Particle Size Analyser. This could avoid the requirement to physically extract an isokinetic PF sample and have the sample analysed in a laboratory. Therefore, it is recommended to commission the online PF monitoring equipment at Kriel Power Station and to evaluate it against the PF sampling methods that have provided accurate and repeatable results during this study. If the online system proves to provide accurate mass flow and particle size distribution results, this could lead to a reduction in the reliance on PF sampling as PF sampling can be an onerous task.

As the Target Plate method is currently the most commonly utilised sampling method in Eskom, further research into the accuracy of the target plate method should be considered which could include a dedicated CFD analysis to be carried out as part of a post graduate study. Additionally, wind tunnel measurements could be considered to apply a correction factor for the overestimation of the PF mass flows.

References

- Agrawal, V., Panigrahi, B. and Subbarao, P., 2015. *Review of control and fault diagnosis methods applied to coal mills*. Journal of Process Control, 32, pp.138-153.
- Airflowsciencesequipment.com. (2021). Welcome to Airflow Sciences Equipment | Airflow Sciences Equipment. [online] Available at: <<http://www.airflowsciencesequipment.com>> [Accessed 12 November 2021].
- Anantharaman, A., van Ommen, J. and Chew, J. (2015). *Minimum pickup velocity (U_{pu}) of nanoparticles in gas solid pneumatic conveying*. Journal of Nanoparticle Research, 17(12).
- Anantharaman, A., Wu, X., Hadinoto, K. and Chew, J. (2015). *Impact of continuous particle size distribution width and particle sphericity on minimum pickup velocity in gas solid pneumatic conveying*. Chemical Engineering Science, 130, pp.92-100.
- Archary, H., 2014. *Condition monitoring and performance optimisation of pulverised fuel vertical spindle type mills*. Johannesburg, EPPEI
- Bilirgen, H., Levy, E. and Yilmaz, A. (1998). *Prediction of pneumatic conveying flow phenomena using commercial CFD software*. Powder Technology, 95(1), pp.37-41.
- Bilirgen, H. and Levy, E. (2001). *Mixing and dispersion of particle ropes in lean phase pneumatic conveying*. Powder Technology, 119(2-3), pp.134-152.
- Biobaku, A., Schmitz, W. and Naidoo, R., 2019. *Evaluation and comparison of saltation velocity correlations in the context of pulverised fuel transportation*. Energy, 181, pp.694-708.
- British Standards Institute, (1978). *Measurement of the concentration of particulate material in ducts carrying gases*. London: BSI, pp.1-20.

- Cabrejos, F. and Klinzing, G. (1994). *Pickup and saltation mechanisms of solid particles in horizontal pneumatic transport*. Powder Technology, 79(2), pp.173-186.
- Chemicalprocessing.com. (2021). [online] Available at: <<https://www.chemicalprocessing.com/articles/2005/454/>> [Accessed 13 November 2021].
- Crowe, C. (2006). Multiphase flow handbook. Boca Raton, FL: CRC.
- Crowley, C., Shinder, I. and Moldover, M., 2013. *The effect of turbulence on a multi-hole Pitot calibration*. Flow Measurement and Instrumentation, 33, pp.106-109.
- Delprato, U. and Lombardi, V. (1990). *An automatic system for the isokinetic sampling and the PM10 concentration monitoring of industrial stack emissions*. Journal of Aerosol Science, 21, pp.S629-S632.
- Dennis, R., Samples, W., Anderson, D. and Silverman, L. (1957). *Isokinetic Sampling Probes*. Ind. Eng. Chem., 49(2), pp.294-302.
- Dixon, G. (1976). *Particle velocities in vertical pneumatic conveying systems*. International Journal of Multiphase Flow, 2(4), pp.465-470.
- Dpe.gov.za. (2021). [online] Available at: <https://dpe.gov.za/wp-content/uploads/2019/10/ROADMAP-FOR-ESKOM_0015_29102019_FINAL1.pdf> [Accessed 12 November 2021].
- Fan, L., Zhu, C. and Varma, A., 1998. *Principles of Gas-Solid Flows*. Cambridge, GBR: Cambridge University Press.
- Geldart, D. and Ling, S. (1992). *Saltation velocities in high pressure conveying of fine coal*. Powder Technology, 69(2), pp.157-162.
- Gomes, L. and Mesquita, A. (2014). *On the prediction of pickup and saltation velocities in pneumatic conveying*. Brazilian Journal of Chemical Engineering, 31(1), pp.35-46.

- Griebe, R., Winter, E. and Schoenhals, R., 1970. *Choking and shock phenomena in a single component two-phase flow including vibrational effects*. Wärme- und Stoffübertragung, 3(1), pp.7-18.
- Hollis, PC (1985), *Optimisation of the Pulverised Fuel Firing Equipment At Duvha Power Station*.
- Hubert, M. and Kalman, H. (2003). *Experimental determination of length-dependent saltation velocity in dilute flows*. Powder Technology, 134(1-2), pp.156-166.
- Hubert, M. and Kalman, H. (2004). *Measurements and comparison of saltation and pickup velocities in wind tunnel*. GM, 6(2-3), pp.159-165.
- Imperial World Trade Pvt Ltd., 2021. Ball Mills - Manufacturers, Wholesale Suppliers, Dealers, Wholesalers in Rajkot, Gujarat, India. [online] Indiamarketplaces.com. Available at: <<https://www.indiamarketplaces.com/imperial-world-trade/ball-mills.html>> [Accessed 12 November 2021].
- International Standards Organisation, (1991). *Sampling of pulverized coal conveyed by gases in direct fired coal systems*. Switzerland: ISO, pp.1-24.
- ISO. 2021. ISO 9096:2017. [online] Available at: <<https://www.iso.org/standard/70547.html>> [Accessed 13 November 2021].
- Jones, P. and Leung, L. (1978). *A Comparison of Correlations for Saltation Velocity in Horizontal Pneumatic Conveying*. Industrial & Engineering Chemistry Process Design and Development, 17(4), pp.571-575.
- Klinzing, G., Marcus, R., Rizk, F. and Leung, L., 1997. *Flow regimes in vertical and horizontal conveying*.
- Klinzing, G. (2010). *Pneumatic conveying of solids*. Dordrecht: Springer.
- Macawberindia.com. (2016). *Dense Phase Pneumatic Conveying System, Pneumatic Conveying Regimes*, Solid Dense Conveying Systems, Mumbai, India. [online] Available at: <http://www.macawberindia.com/product1.htm>

[Accessed 15 Mar. 2016].

Marcus, R., Reed, A. and Chambers, A. (1986). *Pneumatic conveying of bulk solids*. [Newcastle, N.S.W.]: TUNRA Bulk Solids Handling Research Associates.

Matsumoto, S., Harada, S., Saito, S. and Maeda, S. (1975). *Saltation velocity for horizontal pneumatic conveying*. J. Chem. Eng. Japan / JCEJ, 8(4), pp.331-333.

M&W Asketchnik. (2009). *PFS-A-SL Pulverised Fuel Sampler Automatic – Snap Lock Operation Manual*. Provided by OEN Enterprises.

M&W Asketchnik. (2013). *DAP-RD-SL DIRTY AIR PITOT – Reflecting Disc for SNAP LOCK brochure*. Provided by OEN Enterprises.

Mi, B. and Wypych, P. (1994). *Pressure drop prediction in low-velocity pneumatic conveying*. Powder Technology, 81(2), pp.125-137.

Mills, D. (2004). *Pneumatic conveying design guide*. Oxford: Elsevier/Butterworth-Heinemann.

Molerus, O. (1981). *Prediction of pressure drop with steady state pneumatic conveying of solids in horizontal pipes*. Chemical Engineering Science, 36(12), pp.1977-1984.

Mudry, R., Fleming, M., Brown, R. and Sanchez, J., (2005). *Pulverized Coal Extractive Testing Methods Evaluation at the EPRI Coal Flow Loop*. [online] Airflowsciences.com. Available at: <https://www.airflowsciences.com/sites/default/files/docs/Coal_Loop_Extractive_Presentation_Coal_Gen_2005.pdf> [Accessed 22 April 2015].

Ochi, M. (1993). *Saltation Velocity of the Gas-Solid Two-Phase Flow in a Horizontal Pipe*. Transactions of the Japan Society of Mechanical Engineers Series B, 59(564), pp.2416-2421.

Power Engineering. (2004). [online] Available at: <<https://www.power-eng.com/coal/new-epri-lab-targets-coal-flow-measurement-and-control->

- systems/#gref> [Accessed 22 April 2015].
- Promecon. (2021a). *ME Control Coal Product brochure*. Retrieved from https://www.promecon.com/images/brochures/Mecontrol_coal_2018-3l1_nF_RZ_small.pdf
- Promecon. (2021b). *ME Control PSA brochure*. Retrieved from <https://www.imea.gr/productfiles/coal1.pdf>
- Rabinovich, E. and Kalman, H., 2008. *Boundary saltation and minimum pressure velocities in particle–gas systems*. [online] Academia.edu. Available at: <https://www.academia.edu/21281613/Boundary_saltation_and_minimum_pressure_velocities_in_particle_gas_systems> [Accessed 16 December 2021].
- Ratnayake, C., (2005). *A Comprehensive Scaling up Technique for Pneumatic Transport Systems*. Thesis Dr. Ing. The Norwegian University of Science and Technology.
- RETSCH GmbH. 2019. *Different Sieving Methods for Varying Applications*. AZoM, viewed 05 June 2019, <https://www.azom.com/article.aspx?ArticleID=14339>.
- Rhodes, M., 2008. *Introduction to Particle Technology*. Hoboken, NJ: Wiley.
- Sampling Systems International. (2015). *PF Sampler LC-4 Isokinetic Sampler: manual*. Provided by Sampling Systems
- Scribd. 2021. *Dense Phase Pneumatic Conveying System | PDF | Particle Size Distribution | Valve*. [online] Available at: <<https://www.scribd.com/document/269050777/Dense-Phase-Pneumatic-Conveying-System>> [Accessed 13 November 2021].
- South African Market Insights. (2018). *Eskom amount of coal burnt each year*. [online] Available from: <https://www.southafricanmi.com/eskom-coal-burnt-per-year.html> [Accessed 12 November 2021].

- Steyn, KH. (1999). *Pulverised Fuel Sampling Procedure*, Eskom Standard GGP 0855. Johannesburg:Eskom, pp.1-32
- Stoess, H. (1983). *Pneumatic conveying*. New York: Wiley.
- Tharun Kanth Ventrapati et al. (2019). *Efficiency and Cost Benefit Assessments on a Typical 600mw Coal Fired Boiler Power Plant*. International Journal of Mechanical and Production Engineering Research and Development, 9(1), pp.201-216.
- van Den Boorn, J. (1989). *Development and Operating Instructions for Pulverised Fuel Isokinetic Sampler*. Johannesburg: Eskom, pp.1-19.
- Van Der Merwe, J., 2013. *Pulverised fuel transport and balancing using 2-phase flow modelling and testing*. MSc Dissertation, Johannesburg, South Africa: University of the Witwatersrand.
- WhatIs.com. (2020). *What is computational fluid dynamics (CFD)?* - Definition from WhatIs.com. [online] Available at: <<http://whatIs.techtarget.com/definition/computational-fluid-dynamics-CFD>> [Accessed 13 June 2020].
- Zwiegelhaar, J. (2015). *Pulverised Fuel Sample Collection and Size Grading, Eskom Standard 240-7640331*. Johannesburg: Eskom, pp.1-14.
- Yang, Y. and Telionis, D., (2011). *Design and Testing of Instrumentation for Multi-Phase Flow Sampling and Local Void Fraction Measurement*.
- Yi, J., 2001. *Transport boundaries for pneumatic conveying*. [online] Research Online. Available at: <<https://ro.uow.edu.au/theses/1840/>> [Accessed 4 December 2021].

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Appendix A Interview Transcript

1. How often is PF sampling carried out at this Power Station?
2. What equipment is available to conduct PF sampling?
3. What size sockets and how many are available on the PF pipes for sampling?
4. What sampling method is utilised, ie Rotoprobe, 3 Axis traverse, 1 Axis traverse or target plate?
5. What standards and or procedures are utilised to carry out PF sampling?
6. Is PF sampling carried out by Performance and Testing Staff or is it contracted out?
7. What type of mills do the units have?
8. How many mills are there per unit?
9. How many PF pipes are there per mill?
10. What type of feeders do the mills have?
11. How is the raw coal mass flow determined and how is this verified?
12. What can be done with the results?
13. What factors affect PF sampling?
14. Are there any other comments regarding PF sampling?

Appendix B Interview Responses

Table A-1: Survey and Directed Interview Results

Power Station	A	E	C	B	D
Sampling Frequency	As and when required due to staff constraints	As and when required.	Once in three months	18 mills per month, once every 2 months	Determined by mill cycling. When mill comes back from service. 2 sets of samples between 0-5000hrs.
Equipment	Standard Isokinetic PF sampler + Rotoprobe	Standard Isokinetic PF sampler + additional cyclone.	Standard Isokinetic PF sampler + Rotoprobe	Standard Isokinetic PF sampler	Standard Isokinetic PF sampler
Sampling points	1x50mm socket + 1xdustless connector		U9 B 3x50mm ports	3x50mm ports	2x50mm ports
Application	Target plate or dustless connector		Utilize target plate or dustless connector	3 Axis traverse	Utilise 1 to do a 1 Axis traverse. Target plate on the bottom mills.
Standards / Procedures	ISO 9931:1999	BS893 Matimba procedures (PWD/206/011 rev 1, PWD/206/013 rev 1,	ISO 9931:1999	PTP0007 (Sampling) PTP0023 (Sieving)	EBP0367

Power Station	A	E	C	B	D
		PWD/206/012 rev 2) being on GGP 0855			
In house vs contracted out	In house	Contracted out	In house	Contracted out	In house
Mill type	Tube mills - 1 Vertical spindle - 2,3,4,5,6	tube mills	Vertical spindle - 1,2,3,8,9 Tube mills - 4,5,6,7	Vertical spindle	Vertical spindle - small(10.8m diameter) - 1-3 -larger(12.8 diameter) 4-6
Number of mills				6 per unit	
Number of pipes per mill	1 to 4 to 8 (riffle boxes)		4 pipes out of classifier	1 to 4	6
Feed type	Gravimetric (U1) Volumetric (U2-5)		Gravimetric	Volumetric	
Raw Mass Flow determination	Gravimetric Feeders Ball Drop Test Truck Test		load line check, gravimetric feeders	Use a profile bar & feeder speed to calculate volume and mass flow. load line check.	Use a profile bar & feeder speed to calculate volume and mass flow. load line check Truck test.

Power Station	A	E	C	B	D
What can be done with the results			Classifier setting and ramp pressure can be adjusted on vertical spindle mills.	Classifier setting, grinding pressure, rotating speeds (gearbox), check profiles of grinding balls, throat gaps.	
Factors Affecting Sampling			Mill must be on manual, 90% MCR, orientation of the probe, controlling of the machine, clogging of the tubes, sample point location i.e. after bends.	Cleanliness of the tubes. Boiler conditions Nozzle shape, size, condition. Moisture. Timing. Orientation of the probe.	Factors Affecting Sampling

Power Station	A	E	C	B	D
Comment	Would like to do a unit per week, lost 4 staff recently. Don't stop timer / equipment while moving from points on the target plate. Sampling points are installed after the first riffle box, i.e testing is done on 4 pipes. There is a split further up, ie 8 pipes in total. Pf sampler nozzle is long and goes almost into the riffle box.	Additional cyclone improves sampling efficiency. German SMG 10 sampler, used at unit 6 (all burner corners) initially but discontinued its use due to under recovery of sample.	Sampling points in horizontal sections. Performance and testing do the sampling and make adjustments to the classifiers. Sampling done at night when utilising the standard sampler as a result of the heat. EtaPro used for mill load lines	Had an M&W rotary sampler about 10 years ago, discarded because of blockages and leaking of sampler. All sampling points are on vertical except for mill F - Space constraints. Fixed classifier vanes.	Instruments can have issues. Mill load line set by C&I, it is a straight line equation. Operator operating manually. Over or under sample. Leaks on the system. Probe nozzle diameter. Calibration - annually. Fluid on manometer not balancing.

Appendix C Experimental Sampling Scope

Table A-2: Experimental Sampling Scope

Station	Unit	Mill	Method	Pipes	Pipe ID (mm)	Samples per pipe	Points	Note	Total # of samples
Arnot	1	B	1 Axis traverse	1	356	30	8	single pipe 1	30
Arnot	1	B	Target plate	1	356	30	32	single pipe 1	30
Arnot	1	B	3 Axis traverse	1	356	30	24	single pipe 1	30
Arnot	1	B	Rotoprobe	1	356	30	4	single pipe 1	30
Arnot	1	B	1 Axis traverse	1	356	10	8	single pipe 2	10
Arnot	1	B	Target plate	1	356	10	32	single pipe 2	10
Arnot	1	B	3 Axis traverse	1	356	10	24	single pipe 2	10
Arnot	1	B	Rotoprobe	1	356	10	1	single pipe 2	10
Arnot	1	Mill A	1 Axis traverse	4	508	3	8	mill x 8 pipes	12
Arnot	1	Mill A	Target plate	4	508	3	32	mill x 8 pipes	12
Arnot	1	Mill A	Rotoprobe	4	508	3		mill x 8 pipes	12
Arnot	1	Mill B	1 Axis traverse	4	508	3	8	mill x 8 pipes	12
Arnot	1	Mill B	Target plate	4	508	3	32	mill x 8 pipes	12
Arnot	1	Mill B	Rotoprobe	4	508	3	4	mill x 8 pipes	12
Arnot	5	Mill D	1 Axis traverse	4	508	3	8	mill x 4pipes	12
Arnot	5	Mill D	Target plate	4	508	3	32	mill x 4pipes	12
Arnot	5	Mill D	Rotoprobe	4	508	3	4	mill x 4pipes	12

Station	Unit	Mill	Method	Pipes	Pipe ID (mm)	Samples per pipe	Points	Note	Total # of samples
Arnot	1	Mill B, Pipe 1	Incremental (3 Axis)	1	356	3	24	single pipe 1, separate sample per point	72
Arnot	1	Mill B, Pipe 2	Incremental (3 Axis)	1	356	3	24	single pipe 2, separate sample per point	72
Arnot	1	Mill B, Pipe B2	Incremental (target plate)	1	508	3	32	single pipe 3, seprate sample per point, vertical	96
Arnot	5	Mill D, Pipe D3	Incremental (target plate)	1	508	3	32	single pipe 4, separate sample per point	96
Arnot	1	Mill B, Pipe B2, H	Incremental (target plate)	1	508	3	32	single pipe B2, seprate sample per point, horizontal	96
Arnot	1	Mill B, Pipe B1, V	Incremental (target plate)	1	508	3	32	single pipe B1, seprate sample per point, vertical	96
Arnot	1	Mill A	1 Axis traverse	4	508	3	8	mill x 4 horizontal pipes	12
Arnot	1	Mill A	2 Axis traverse	4	508	3	16	mill x 4 horizontal pipes	12
Arnot	1	Mill A	Target plate	4	508	3	32	mill x 4 horizontal pipes	12
Arnot	1	Mill A	Rotoprobe	4	508	3	8	mill x 4 horizontal pipes	12
Arnot	1	Mill B	1 Axis traverse	4	508	3	8	mill x 4 horizontal pipes	12
Arnot	1	Mill B	2 Axis traverse	4	508	3	16	mill x 4 horizontal pipes	12
Arnot	1	Mill B	Target plate	4	508	3	32	mill x 4 horizontal pipes	12
Arnot	1	Mill B	Rotoprobe	4	508	3	8	mill x 4 horizontal pipes	12
Arnot	1	Mill A	Rotoprobe	1	508	7	4	Test to evaluate the effect of changing the velocity 16, 20, 24 m/s	7

Station	Unit	Mill	Method	Pipes	Pipe ID (mm)	Samples per pipe	Points	Note	Total # of samples
Arnot	1	Mill A	Rotoprobe	1	508	25	8	Test to evaluate the effect of changing the g factor 1.12, 1.11, 1.10, 1.08, 1.06, 1.04, 1.03, 1.02	25
Total Samples									924

Appendix D Sample Identification

Table A-3: Unit 1 AB Mill 356 mm Pipe Sample Identification

Pipe	Method	Sample ID	# of Samples	Date Sampled
P1	1 Axis	SA-1-T1 to T5	5	30-Jul
P1	1 Axis	SA-1-T6 to T10	5	05-Aug
P1	1 Axis	SA-1-T11 to T15	5	06-Aug
P1	1 Axis	SA-1-T16 to T20	5	11-Aug
P1	1 Axis	SA-1-T21 to T30	5	17-Aug
P1	3 Axis	3A-1-T1 to T10	10	05-Aug
P1	3 Axis	3A-1-T11 to T15	5	06-Aug
P1	3 Axis	3A-1-T16 to T20	5	11-Aug
P1	3 Axis	3A-1-T21 to T30	10	17-Aug
P1	Target Plate	TP-1-T1 to T10	10	04-Aug
P1	Target Plate	TP-1-T11 to T15	5	06-Aug
P1	Target Plate	TP-1-T16 to T20	5	11-Aug
P1	Target Plate	TP-1-T21 to T30	10	17-Aug
P1	Rotoprobe	RTP1-31 to 60	30	06-Aug
P1	3 Axis (Incremental)	I-3A-1-T1	24	18-Aug
P1	3 Axis (Incremental)	I-3A-1-T2	24	19-Aug
P1	3 Axis (Incremental)	I-3A-1-T3	24	20-Aug
P2	1 Axis	SA-2-T1 to T5	5	30-Jul
P2	1 Axis	SA-2-T6 to T10	5	05-Aug
P2	3 Axis	3A-2-T1 to T5	5	30-Jul
P2	3 Axis	3A-2-T6 to T10	5	05-Aug
P2	Target Plate	TP-2-T1 to T5	5	30-Jul
P2	Target Plate	TP-2-T6 to T10	5	05-Aug
P2	Rotoprobe	RTP2-9 to 20	10	06-Aug
P2	3 Axis (Incremental)	I-3A-2-T1	24	18-Aug
P2	3 Axis (Incremental)	I-3A-2-T2	24	19-Aug
P2	3 Axis (Incremental)	I-3A-2-T3	24	20-Aug

Table A-4: Unit 1 AB Mill 508 mm Vertical Pipes Sample Identification

Pipe	Method	Sample ID	# of Samples	Date Sampled
A1 -A4	1 Axis	SA-A1 to A4-T1	4	18-Aug
A1 -A4	1 Axis	SA-A1 to A4-T2	4	19-Aug
A1 -A4	1 Axis	SA-A1 to A4-T3	4	19-Aug
A1 -A4	Target Plate	TP-A1 to A4-T1	4	13-Aug
A1 -A4	Target Plate	TP-A1 to A4-T2	4	13-Aug
A1 -A4	Target Plate	TP-A1 to A4-T3	4	13-Aug
A1	Rotoprobe	A1P1-T14 to T16	3	17-Aug
A2	Rotoprobe	A2P2-T4, T5, T7	3	17-Aug
A3	Rotoprobe	A3P3-T7, T9, T10	3	17-Aug
A4	Rotoprobe	A4P4-T7, T9, T10	3	17-Aug
B1-B4	1 Axis	SA-B1 to B4-T1	4	18-Aug
B1-B4	1 Axis	SA-B1 to B4-T2	4	19-Aug
B1-B4	1 Axis	SA-B1 to B4-T3	4	19-Aug
B1-B4	Target Plate	TP-B1 to B4-T1	4	13-Aug
B1-B4	Target Plate	TP-B1 to B4-T2	4	13-Aug
B1-B4	Target Plate	TP-B1 to B4-T3	4	13-Aug
B1	Rotoprobe	B1P1-T1 to T3	3	17-Aug
B2	Rotoprobe	B2P2-T1 to T3	3	17-Aug
B3	Rotoprobe	B3P3-T1 to T3	3	17-Aug
B4	Rotoprobe	B4P4-T1 to T3	3	17-Aug
B1	Target Plate (Incremental)	I-TP-B1-T1	32	02-Sep
B1	Target Plate (Incremental)	I-TP-B1-T2	32	02-Sep
B1	Target Plate (Incremental)	I-TP-B1-T3	32	03-Sep
B2	Target Plate (Incremental)	I-TP-B2-T1	32	19-Aug
B2	Target Plate (Incremental)	I-TP-B2-T2	32	20-Aug
B2	Target Plate (Incremental)	I-TP-B2-T3	32	20-Aug

Table A-5: Unit 5 D Mill 508 mm Pipes Sample Identification

Pipe	Method	Sample ID	# of Samples	Date Sampled
D1-D4	1 Axis	SA-D1 to D4-T1	4	24-Aug
D1-D4	1 Axis	SA-D1 to D4-T2	4	24-Aug
D1-D4	1 Axis	SA-D1 to D4-T3	4	24-Aug
D1-D4	Target Plate	TP-D1 to D4-T1	4	17-Aug
D1-D4	Target Plate	TP-D1 to D4-T2	4	18-Aug
D1-D4	Target Plate	TP-D1 to D4-T3	4	18-Aug
D1	Rotoprobe	DP1-T1 to T3	3	13-Aug
D2	Rotoprobe	DP2-T2 to T4	3	13-Aug
D3	Rotoprobe	DP3-T1 to T3	3	13-Aug
D4	Rotoprobe	DP4-T1 to T3	3	13-Aug
D3	Target Plate (Incremental)	I-TP-D3-T1	32	24-Aug
D3	Target Plate (Incremental)	I-TP-D3-T2	32	25-Aug
D3	Target Plate (Incremental)	I-TP-D3-T3	32	25-Aug

Table A-6: Unit 1 AB Mill 508 mm Horizontal Pipes Sample Identification

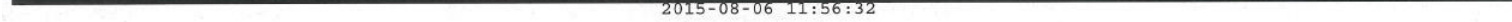
Pipe	Method	Sample ID	# of Samples	Date Sampled
A1-A4	1 Axis	H-SA-A1 to A4-T1	4	27-Aug
A1-A4	1 Axis	H-SA-A1 to A4-T2	4	27-Aug
A1-A4	1 Axis	H-SA-A1 to A4-T3	4	27-Aug
A1-A4	2 Axis	H-2A-A1 to A4-T1	4	27-Aug
A1-A4	2 Axis	H-2A-A1 to A4-T2	4	27-Aug
A1-A4	2 Axis	H-2A-A1 to A4-T3	4	27-Aug
A1-A4	Target Plate	H-TP-A1 to A4-T1	4	01-Sep
A1-A4	Target Plate	H-TP-A1 to A4-T2	4	01-Sep
A1-A4	Target Plate	H-TP-A1 to A4-T3	4	01-Sep
A1	Rotoprobe	A1H1-T4, T6, T8	3	17-Aug
A2	Rotoprobe	A2H2-T2, T3, T4	3	17-Aug
A3	Rotoprobe	A3H3-T1, T2, T3	3	17-Aug
A4	Rotoprobe	A4H4-T1, T2, T3	3	17-Aug
B1-B4	1 Axis	H-SA-B1 to B4-T1	4	26-Aug
B1-B4	1 Axis	H-SA-B1 to B4-T2	4	26-Aug
B1-B4	1 Axis	H-SA-B1 to B4-T3	4	26-Aug
B1-B4	2 Axis	H-2A-B1 to B4-T1	4	27-Aug
B1-B4	2 Axis	H-2A-B1 to B4-T2	4	27-Aug
B1-B4	2 Axis	H-2A-B1 to B4-T3	4	27-Aug
B1-B4	Target Plate	H-TP-B1 to B4-T1	4	01-Sep
B1-B4	Target Plate	H-TP-B1 to B4-T2	4	01-Sep
B1-B4	Target Plate	H-TP-B1 to B4-T3	4	01-Sep
B1	Rotoprobe	B1H1-T1, T3, T4	3	17-Aug
B2	Rotoprobe	B2H2-T1 to T3	3	17-Aug
B3	Rotoprobe	B3H3-T1 to T3	3	17-Aug
B4	Rotoprobe	B4H4-T1 to T3	3	17-Aug
B2	Target Plate (Incremental)	HI-TP-B2-T1	32	02-Sep
B2	Target Plate (Incremental)	HI-TP-B2-T2	32	02-Sep
B2	Target Plate (Incremental)	HI-TP-B2-T3	32	03-Sep

Appendix E **Raw Coal Analysis**

Table A-7: Unit 1 AB Mill Raw Coal Analysis

Lab. No	Sample Name	Sample Mass	Air dried								BULK DENSITY
			IM	TM	Ash	C.V.	Vol	A.I	TS	HGI	
			SWP 025	SWP 018	SWP 024	SWP 020	SWP 023	SWP 018	SWP 021	%	
			Based on	Based on	Based on	Based on	Based on	Based on	Based on	Eskom	
			SABS 5925	ISO 589	ISO 1997	ISO 1928	ISO 562	Eskom	ASTM D4239		
		Kg	% ^m / _m	% ^m / _m	% ^m / _m	MJ/kg	% ^m / _m	mg/Fe	% ^m / _m		
17574	ARNOT UNIT 1 MILL A 04/09/15	20.15	3.1	8.6	25.7	22.90	22.8	160	1.02	53.5	0.95
17581	ARNOT UNIT 1 MILL B 17/8/15	19.60	1.9	8.5	28.2	21.87	21.7	247	0.87	56.7	1.02
17582	ARNOT UNIT 1 MILL A 25/08/15	31.40	1.5	7.7	27.6	22.15	21.6	167	0.98	68.7	1.00
17583	ARNOT UNIT 1 MILL A 26/08/2015	11.85	2.4	5.5	26.6	22.55	21.1	233	1.13	47.8	0.96
17584	ARNOT UNIT 1 MILL B 20/08/15	19.70	3.0	8.8	24.5	23.35	22.6	273	1.22	54.7	0.90
17593	ARNOT UNIT 1 MILL A 11/08/15	35.15	3.2	8.4	27.8	21.60	21.0	275	1.22	64.4	1.27
17818	ARNOT U1 MILL B 2/9/15	18.20	1.9	6.7	31.0	20.79	21.4	331	0.53	49.2	0.93
17820	ARNOT U1 MILL B 25/8/15	16.45	2.4	5.1	27.9	22.05	21.7	390	0.50	50.8	1.06
17821	ARNOT PS U1 MILL B 11/8/15	23.80	2.2	6.2	29.3	21.50	21.5	332	0.90	44.6	1.06
17822	ARNOT US MILL D 25/8/15	22.05	2.2	5.9	28.6	21.68	21.5	330	0.77	54.5	1.07
17823	ARNOT U1 MILL A 2/9/15	20.10	1.9	6.6	25.9	22.82	22.6	366	0.88	55.2	1.04
17995	ARNOT U1 MILL B 18/08/15	22.40	2.1	8.1	28.6	20.93	21.4	202	0.92	55.4	1.01
17996	ARNOT U1 MILL B 05/08/15	26.80	2.7	8.0	26.5	21.47	22.2	200	1.03	54.7	1.12
17997	ARNOT U1 MILL B 31/08/15	16.20	3.0	7.7	29.5	20.78	20.2	174	0.67	62.8	0.96
17998	ARNOT U1 MILL B 11/08/15	25.25	3.9	7.7	28.7	19.96	19.2	191	0.58	54.8	0.97
18011	ARNOT U1 MILL B 03/09/15	18.40	2.8	6.4	26.7	22.00	23.3	213	0.78	56.8	1.05
18012	ARNOT U1 MILL B 24/08/15	19.75	3.0	5.5	28.6	21.26	21.6	160	1.22	48.2	0.98
18013	ARNOT PS U1 MILL A 18/08/15	32.95	3.2	7.5	28.1	21.16	21.1	195	0.47	45.4	1.22
18014	ARNOT U1 MILL A 24/08/15	29.15	3.8	7.4	27.0	22.40	21.2	171	1.05	50.5	0.88
18015	ARNOT U1 MILL B 4/09/15	16.25	3.1	7.6	27.6	22.09	22.6	204	0.99	49.8	1.08
18094	ARNOT U1 MILL A 5/08/15	22.25	1.4	7.7	29.7	21.15	20.9	212	0.72	51.2	0.91
18095	ARNOT U1 MILL A 3/09/15	14.95	1.2	7.7	26.3	22.49	22.1	167	0.66	48.4	1.12
18096	ARNOT U1 MILL A 1/09/15	24.25	1.5	2.6	27.8	21.95	21.7	126	0.57	57.9	0.96
18097	ARNOT U5 MILL D 24/08/15	25.35	1.8	7.7	27.7	22.01	21.8	187	1.11	64.3	1.06
18098	ARNOT U1 MILL A 19/08/15	22.90	1.5	6.5	28.7	21.59	22.3	260	1.15	46.7	1.14
18099	ARNOT U1 MILL A 31/08/15	16.15	1.5	6.2	25.1	23.15	22.3	172	0.85	68.1	1.02
18111	ARNOT P/S UNIT 5 MILL D 18/8/15	17.55	3.6	6.5	27.5	22.02	23.1	150	0.76	66.2	0.93
18112	ARNOT UNIT 1 MILL A 20/8/15	27.20	2.5	6.5	28.1	21.89	22.8	283	0.80	55.2	1.00
18117	ARNOT UNIT 1 MILL B 26/8/15	12.50	3.4	6.0	27.8	22.85	21.5	193	1.10	60.5	0.91
18118	ARNOT UNIT 1 MILL A 17/8/15	20.15	3.4	6.6	26.8	21.82	23.2	200	1.16	51.2	0.98
18119	ARNOT UNIT 5 DMILL 13/8/15	21.15	3.7	6.4	29.1	21.25	21.8	325	0.55	56.9	1.06

Sample	Dry basis				As received				Ash Fusion Temperatures				C	H	N
Name	Ash	C.V.	Vol	TS	Ash	C.V.	Vol	TS	Def*	Soft*	Hem*	Flow*	Carbon	Hydrogen	Nitrogen
	SWP 024	SWP 020	SWP 023	SWP 021	SWP 024	SWP 020	SWP 023	SWP 021	SWP 026	SWP 026	SWP 026	SWP 026			
	Based on	Based on	Based on	Based on	Based on	Based on	Based on	Based on	Based on	Based on	Based on	Based on			
	ISO	ISO	ISO	ASTM	ISO	ISO	ISO	ASTM	ISO	ISO	ISO	ISO			
	1997	1928	562	D4239	1997	1928	562	D4239	540	540	540	540	ASTM	ASTM	ASTM
	% ^m /m	MJ/kg	% ^m /m	% ^m /m	% ^m /m	MJ/kg	% ^m /m	% ^m /m	°C	°C	°C	°C	5373	5373	5373
ARNOT UNIT 1 MILL A 04/09/15	26.5	23.63	23.5	1.05	25.7	21.60	21.5	0.96	1330	1350	1370	1400			
ARNOT UNIT 1 MILL B 17/8/15	28.7	22.29	22.1	0.89	28.2	20.40	20.2	0.81	1340	1360	1380	1400	59.60	3.04	1.42
ARNOT UNIT 1 MILL A 25/08/15	28.0	22.49	21.9	0.99	27.6	20.76	20.2	0.92	1380	1390	1410	1440			
ARNOT UNIT 1 MILL A 26/08/2015	27.3	23.10	21.6	1.16	26.6	21.83	20.4	1.09	1430	1450	1470	1480			
ARNOT UNIT 1 MILL B 20/08/15	25.3	24.07	23.3	1.26	24.5	21.95	21.2	1.15	1410	1420	1430	1440	61.50	3.46	1.46
ARNOT UNIT 1 MILL A 11/08/15	28.7	22.31	21.7	1.26	27.8	20.44	19.9	1.15	1340	1360	1380	1400	58.20	3.23	1.36
ARNOT U1 MILL B 2/9/15	31.6	21.19	21.8	0.54	31.0	19.79	20.4	0.50	1380	1400	1420	1440	34.80	1.76	0.79
ARNOT U1 MILL B 25/8/15	28.5	22.59	22.2	0.51	27.9	21.44	21.1	0.49	1420	1440	1460	1490			
ARNOT PS U1 MILL B 11/8/15	30.0	21.98	22.0	0.92	29.3	20.62	20.7	0.86	1460	1480	1490	1500			
ARNOT US MILL D 25/8/15	29.3	22.17	22.0	0.79	28.6	20.87	20.7	0.74	1380	1390	1410	1430			
ARNOT U1 MILL A 2/9/15	26.4	23.26	23.1	0.90	25.9	21.73	21.6	0.84	1360	1370	1390	1410			
ARNOT U1 MILL B 18/08/15	29.2	21.38	21.9	0.94	28.6	19.65	20.1	0.86	1400	1410	1430	1450	57.90	3.13	1.36
ARNOT U1 MILL B 05/08/15	27.2	22.07	22.8	1.06	26.5	20.30	21.0	0.97	1370	1390	1410	1430	59.60	3.17	1.34
ARNOT U1 MILL B 31/08/15	30.4	21.42	20.8	0.69	29.5	19.77	19.2	0.64	1430	1450	1470	1490	59.60	3.34	1.39
ARNOT U1 MILL B 11/08/15	29.9	20.77	20.0	0.60	28.7	19.17	18.4	0.56	1410	1430	1460	1480	57.90	3.19	1.43
ARNOT U1 MILL B 03/09/15	27.5	22.63	24.0	0.80	26.7	21.19	22.4	0.75	1410	1420	1440	1460			
ARNOT U1 MILL B 24/08/15	29.5	21.92	22.3	1.26	28.6	20.71	21.0	1.19	1380	1490	1460	1500			
ARNOT PS U1 MILL A 18/08/15	29.0	21.86	21.8	0.49	28.1	20.22	20.2	0.45	1440	1450	1470	1490			
ARNOT U1 MILL A 24/08/15	28.1	23.28	22.0	1.09	27.0	21.56	20.4	1.01	1340	1360	1380	1410			
ARNOT U1 MILL B 4/09/15	28.5	22.80	23.3	1.02	27.6	21.06	21.6	0.94	1350	1370	1390	1400			
ARNOT U1 MILL A 5/08/15	30.1	21.45	21.2	0.73	29.7	19.80	19.6	0.67	1420	1440	1470	1500			
ARNOT U1 MILL A 3/09/15	26.6	22.76	22.4	0.67	26.3	21.01	20.6	0.62	1390	1410	1430	1450			
ARNOT U1 MILL A 1/09/15	28.2	22.28	22.0	0.58	27.8	21.70	21.5	0.56	1360	1380	1400	1420			
ARNOT U5 MILL D 24/08/15	28.2	22.41	22.2	1.13	27.7	20.69	20.5	1.04	1350	1380	1400	1430			
ARNOT U1 MILL A 19/08/15	29.1	21.92	22.6	1.17	28.7	20.49	21.2	1.09	1390	1410	1430	1450			
ARNOT U1 MILL A 31/08/15	25.5	23.50	22.6	0.86	25.1	22.05	21.2	0.81	1410	1420	1450	1490			
ARNOT P/S UNIT 5 MILL D 18/8/15	28.5	22.84	24.0	0.79	27.5	21.36	22.4	0.74	1380	1400	1420	1430			
ARNOT UNIT 1 MILL A 20/8/15	28.8	22.45	23.4	0.82	28.1	20.99	21.9	0.77	1500	1500	1500	1500			
ARNOT UNIT 1 MILL B 26/8/15	28.8	23.65	22.3	1.14	27.8	22.23	20.9	1.07	1430	1450	1470	1480			
ARNOT UNIT 1 MILL A 17/8/15	27.7	22.59	24.0	1.20	26.8	21.10	22.4	1.12	1410	1440	1460	1500			
ARNOT UNIT 5 DMILL 13/8/15	30.2	22.07	22.6	0.57	29.1	20.65	21.2	0.53	1420	1450	1480	1500			



Appendix G Mill A & Mill B Mass flow Trend (extract)

Table A-9: Unit 1 Mill A & Mill B Raw Coal Mass Flow (kg/s)

DATE & TIME	MILL A FEEDER MASS FLOW (kg/s)	MILL B FEEDER MASS FLOW (kg/s)
2015/08/17 07:00:00 PM	8,69	8,78
2015/08/17 07:02:00 PM	8,68	8,82
2015/08/17 07:04:00 PM	8,99	9,08
2015/08/17 07:06:00 PM	8,70	8,75
2015/08/17 07:08:00 PM	8,70	8,78
2015/08/17 07:10:00 PM	8,93	8,98
2015/08/17 07:12:00 PM	8,98	9,04
2015/08/17 07:14:00 PM	8,78	8,74
2015/08/17 07:16:00 PM	8,64	8,68
2015/08/17 07:18:00 PM	8,91	8,98
2015/08/17 07:20:00 PM	9,11	9,15
2015/08/17 07:22:00 PM	8,81	8,84
2015/08/17 07:24:00 PM	8,76	8,75
2015/08/17 07:26:00 PM	8,87	8,91
2015/08/17 07:28:00 PM	8,77	8,84
2015/08/17 07:30:00 PM	8,84	8,96
2015/08/17 07:32:00 PM	8,97	9,23
2015/08/17 07:34:00 PM	9,20	9,22
2015/08/17 07:36:00 PM	9,05	9,07
2015/08/17 07:38:00 PM	8,81	8,92
2015/08/17 07:40:00 PM	8,87	9,01
2015/08/17 07:42:00 PM	8,51	8,64
2015/08/17 07:44:00 PM	8,36	8,43
2015/08/17 07:46:00 PM	8,75	8,83
2015/08/17 07:48:00 PM	8,94	8,95
2015/08/17 07:50:00 PM	8,76	8,86
2015/08/17 07:52:00 PM	8,91	9,03
2015/08/17 07:54:00 PM	8,99	8,99
2015/08/17 07:56:00 PM	8,61	8,68
2015/08/17 07:58:00 PM	8,64	8,70
2015/08/17 08:00:00 PM	8,92	8,97
2015/08/17 08:02:00 PM	9,02	9,06
2015/08/17 08:04:00 PM	8,83	8,78
2015/08/17 08:06:00 PM	8,61	8,62
2015/08/17 08:08:00 PM	9,04	9,07
2015/08/17 08:10:00 PM	9,08	9,14

DATE & TIME	MILL A FEEDER MASS FLOW (kg/s)	MILL B FEEDER MASS FLOW (kg/s)
2015/08/17 08:12:00 PM	8,57	8,70
2015/08/17 08:14:00 PM	8,70	8,80
2015/08/17 08:16:00 PM	9,02	9,07
2015/08/17 08:18:00 PM	8,78	8,86
2015/08/17 08:20:00 PM	8,45	8,57
2015/08/17 08:22:00 PM	8,76	8,82
2015/08/17 08:24:00 PM	8,96	8,98
2015/08/17 08:26:00 PM	8,46	8,50
2015/08/17 08:28:00 PM	8,55	8,63
2015/08/17 08:30:00 PM	9,04	9,16
2015/08/17 08:32:00 PM	9,06	9,15
2015/08/17 08:34:00 PM	8,52	8,61
2015/08/17 08:36:00 PM	8,40	8,53
2015/08/17 08:38:00 PM	9,08	9,17
2015/08/17 08:40:00 PM	9,11	9,25
2015/08/17 08:42:00 PM	8,94	9,07
2015/08/17 08:44:00 PM	8,72	8,78
2015/08/17 08:46:00 PM	8,94	9,04
2015/08/17 08:48:00 PM	8,97	9,07
2015/08/17 08:50:00 PM	8,74	8,84
2015/08/17 08:52:00 PM	8,82	8,97
2015/08/17 08:54:00 PM	8,94	9,08
2015/08/17 08:56:00 PM	8,96	9,07
2015/08/17 08:58:00 PM	8,85	8,97
2015/08/17 09:00:00 PM	8,76	8,90
2015/08/17 09:02:00 PM	8,81	8,81
2015/08/17 09:04:00 PM	8,46	8,45
2015/08/17 09:06:00 PM	8,58	8,62
2015/08/17 09:08:00 PM	8,96	9,01
2015/08/17 09:10:00 PM	8,99	9,06
2015/08/17 09:12:00 PM	9,01	9,10
2015/08/17 09:14:00 PM	9,03	9,03
2015/08/17 09:16:00 PM	9,02	8,97
2015/08/17 09:18:00 PM	8,99	8,97
2015/08/17 09:20:00 PM	9,05	8,95
2015/08/17 09:22:00 PM	9,05	8,98
2015/08/17 09:24:00 PM	9,18	9,05
2015/08/17 09:26:00 PM	9,16	8,96
2015/08/17 09:28:00 PM	9,05	8,88
2015/08/17 09:30:00 PM	9,15	8,94
2015/08/17 09:32:00 PM	9,14	8,94
2015/08/17 09:34:00 PM	8,77	8,63
2015/08/17 09:36:00 PM	7,92	7,80

DATE & TIME	MILL A FEEDER MASS FLOW (kg/s)	MILL B FEEDER MASS FLOW (kg/s)
2015/08/17 09:38:00 PM	8,01	7,87
2015/08/17 09:40:00 PM	8,51	8,27
2015/08/17 09:42:00 PM	9,01	8,81
2015/08/17 09:44:00 PM	9,07	8,90
2015/08/17 09:46:00 PM	9,02	8,87
2015/08/17 09:48:00 PM	8,26	8,10
2015/08/17 09:50:00 PM	8,25	8,13
2015/08/17 09:52:00 PM	8,92	8,90
2015/08/17 09:54:00 PM	9,14	9,24
2015/08/17 09:56:00 PM	8,91	9,05
2015/08/17 09:58:00 PM	8,90	8,89
2015/08/17 10:00:00 PM	8,79	8,76
Average	8,83	8,86

Appendix H AB Mill Demand % (extract)

Table A-10: Unit 1 AB Mill Demand Set Point

	GEN LOAD	MILL A/B LOAD DEMAND SP	MILL C/D LOAD DEMAND SP	MILL E/F LOAD DEMAND SP
Timestamp	MW	(%)	(%)	(%)
2015/08/17 09:30:00 AM	329.99	89.99	85.35	82.76
2015/08/17 09:31:00 AM	329.72	89.99	85.35	82.76
2015/08/17 09:32:00 AM	328.29	89.99	85.35	82.76
2015/08/17 09:33:00 AM	329.20	89.99	85.35	82.76
2015/08/17 09:34:00 AM	330.53	89.99	85.35	82.76
2015/08/17 09:35:00 AM	331.47	89.99	85.35	82.76
2015/08/17 09:36:00 AM	332.00	89.99	85.35	82.76
2015/08/17 09:37:00 AM	332.37	89.99	85.35	82.76
2015/08/17 09:38:00 AM	331.35	89.99	85.35	82.76
2015/08/17 09:39:00 AM	330.23	89.99	85.35	82.76
2015/08/17 09:40:00 AM	329.03	89.99	85.35	82.76
2015/08/17 09:41:00 AM	328.70	89.99	85.35	82.76
2015/08/17 09:42:00 AM	329.51	89.99	85.35	82.76
2015/08/17 09:43:00 AM	329.19	89.99	85.35	82.76
2015/08/17 09:44:00 AM	328.80	89.99	85.35	82.76
2015/08/17 09:45:00 AM	326.04	89.99	85.35	82.76
2015/08/17 09:46:00 AM	327.11	89.99	85.35	82.76
2015/08/17 09:47:00 AM	329.51	89.99	85.35	82.76
2015/08/17 09:48:00 AM	332.03	89.99	85.35	82.76
2015/08/17 09:49:00 AM	334.29	89.99	85.35	82.76
2015/08/17 09:50:00 AM	332.22	89.99	85.35	82.76
2015/08/17 09:51:00 AM	333.10	89.99	85.35	82.76
2015/08/17 09:52:00 AM	334.62	89.99	85.35	82.76
2015/08/17 09:53:00 AM	335.09	89.99	85.35	82.76
2015/08/17 09:54:00 AM	333.75	89.99	85.35	82.76
2015/08/17 09:55:00 AM	330.73	89.99	85.35	82.76
2015/08/17 09:56:00 AM	333.50	89.99	85.35	82.76
2015/08/17 09:57:00 AM	337.54	89.99	85.35	82.76
2015/08/17 09:58:00 AM	338.06	89.99	85.35	82.76
2015/08/17 09:59:00 AM	330.14	89.99	85.35	82.76
2015/08/17 10:00:00 AM	320.22	89.99	85.35	82.76
2015/08/17 10:01:00 AM	317.91	89.99	85.35	82.76
2015/08/17 10:02:00 AM	323.78	89.99	85.35	82.76
2015/08/17 10:03:00 AM	332.31	89.99	85.35	82.76
2015/08/17 10:04:00 AM	338.42	89.99	85.35	82.76
2015/08/17 10:05:00 AM	334.19	89.99	85.35	82.76

Appendix I **Mill AB Feeder Truck Test**

	POWER STATION A MEMORANDUM	Doc No :ARNF 598
		Rev: 0
		Pages :2

Date: 20th October 2014

From: (Information removed)

Performance & Testing

To: P&T Manager

Tel : (Information removed)

Fax : (Information removed)

Background

Truck test was conducted performance and testing department on Saturday the 04th October 2014 between 20h00 and 00h00 to verify the unit 1 A and B mill feeders weight meters accuracy against the coal stockyard weighbridge scale.

Methodology

The method followed to conduct the truck test was as follows:

1. Raw coal pipes above A & B mill classifiers were removed and raw coal transfer chutes were installed by milling plant mechanical maintenance department (CMP).

2. Mill feeder side covers in the vicinity of the loadcell were open by mechanical maintenance department in preparation for control and instrumentation department to conduct feeder belt span and loadcell calibration at A & B mill feeders.
3. Control and instrumentation effected simulations that allowed A & B feeders to be operated from the unit control room whilst the mill was out of commission.
4. Feeder belt scale span and loadcell calibration was conducted by control and instrumentation department at A & B mill feeders.
5. Mill feeder side covers in the vicinity of loadcell were reinstated by mechanical maintenance department
6. Profile plate height adjustment bolts height measurements were recorded by performance and testing department.
7. Belt tension adjustment bolts length measurements were recorded by performance and testing
8. Coal stockyard tipper trucks (2 off) were weighed empty at weighbridge before they were loaded with coal from mill feeders.
9. Mill B & A feeders were run at 20%, 40%, 60%, 80% and 100% of feeder speed control to load coal on tipper trucks respectively. After each load the tipper trucks were weighed with coal load, offloaded coal then weighed empty before collecting the next load.
10. During each run the average ton per hour and feeder speed were recorded from the field display.
11. Weighbridge scale slips for each truck weighing were brought by each tipper truck after offloading coal.
12. Raw coal transfer chutes were removed and raw coal pipe were reinstated by milling plant mechanical maintenance department (CMP).

Results

Unit 1A Feeder

Feeder Speed Control Setpoint (%)	Unit Control Room Beltspeed (rpm)	Unit Control Room Massflow (kg/s) / [t/hr]	Feeder Display Average Beltspeed (rpm)	Feeder Display Average Massflow (t/hr)	Feeder Display Totaliser Mass (kg)	Weighbridge Laden Truck Nett Mass (kg)	Weighbridge vs Feeder Scales Difference (kg)	Error (%) $\frac{\{\text{Weighbridge} - \text{Feeder}\}}{\{\text{Weighbridge}\}} \times 100$
20	6.0	(5.7) / [20.5]	5.17	20.3	9992.9	10080	87.1	0.86
40	12.2	(11.5) / [41.4]	10.5	40.5	8855.9	8820	-35.9	-0.41
60	18.4	(14.9) / [53.6]	15.8	63.5	11447.6	11300	-147.6	-1.31

80	24.5	(14.9) / [53.6]	21.2	84.0	9157.3	8920	-237.3	-2.66
100	25.7	(14.9) / [53.6]	26.4	110.0	12460.4	12120	-340.4	-2.81

Unit 1B Feeder

Feeder Speed Control Setpoint (%)	Unit Control Room Beltspeed (rpm)	Unit Control Room Massflow (kg/s) / [t/hr]	Feeder Display Average Beltspeed (rpm)	Feeder Display Average Massflow (t/hr)	Feeder Totaliser Load Mass (kg)	Weighbridge Laden Truck Load Nett Mass (kg)	Weighbridge vs Feeder Scales Difference (kg)	Error (%) {Weighbridge – Feeder} / {Weighbridge} x 100
20	6.2	(6.3) / [22.7]	5.32	22.3	11457.3	9680	-1777.3	-18.36
40	12.5	(12.7) / [45.7]	10.8	45.5	11699.8	9680	-2019.8	-20.87
60	18.5	(14.9) / [53.6]	16.0	67.2	10899.6	9080	-1819.6	-20.04
80	25.0	(14.9) / [53.6]	21.46	91.2	11039.3	9180	-1859.3	-20.25
100	25.6	(14.9) / [53.6]	27.0	115.0	13487.5	11140	-2347.5	-21.07

Observations

- Field display and unit control room belt speed indication are different at respective feeder speed control limit.
- Unit control room massflow indication is limited to 14.9kg/s from 60% to 100% feeder speed control limit setpoint whereas the field display rises progressively.
- Unit 1A feeder weightometer totaliser has less than 3% error against weighbridge scale.
- Unit 1B feeder weightometer totaliser average 20% error against weighbridge scale.

Conclusion

Unit 1B feeder weightometer has a 20% error which is also visible on unit 1AB mill measured fuel indication that is always 20% higher than mill demand setpoint. The effects of this offset have been seen where unit 1AB mill chokes due to drop in air to fuel

ratio when the mill fuel control pulls back the mill inlet dampers whereas mill feeders continue feeding raw coal at a higher rate in an effort to equal the measured fuel to mill demand setpoint. This has caused unit controllers to put mill fuel control on manual in order to prevent the mill inlet dampers from pulling back to prevent the mill to get into the choking mode.

Recommendation

- a) A correction factor of 98.8% (input 988 on display) shall be effected on unit 1A feeder. CID notification number - 22944264
- b) A correction factor of 83.3% (input 833 on display) shall be effected on unit 1B feeder. CID notification number - 22944266
- c) Establish and address the cause of the discrepancy between field and control room feederbelt speed indication on unit 1A feeder. CID notification number – 22944268
- d) Establish and address the cause of the discrepancy between field and control room feederbelt speed indication on unit 1B feeder. CID notification number – 22944269
- e) Establish and address the cause discrepancy between field and control room massflow indication from 60% to 100% on unit 1A feeder. CID notification number – 22944270
- f) Establish and address the cause discrepancy between field and control room massflow indication from 60% to 100% on unit 1B feeder. CID notification number – 22944301

Appendix J Results – Rotoprobe on P1 and P2

**Table A-11: Method Accuracy & Repeatability – Rotoprobe Results
(calculated and read off from control unit) (PF Mass Flow) from Pipe 1**

Date	R Probe	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw Calc. (kg/s)	MFw Roto (kg/s)
6/8/2015		T1	P1	3.75	64	5	356	156	0.16	0.92	0.88
		T2	P1	3.75	64	5	356	130	0.13	0.76	0.74
		T3	P1	3.75	64	5	356	148	0.15	0.87	0.84
		T4	P1	3.75	64	5	356	149	0.15	0.87	0.84
		T5	P1	3.75	64	5	356	152	0.15	0.89	0.87
6/08/2016		T6	P1	3.75	64	5	356	156	0.16	0.92	0.88
		T7	P1	3.75	64	5	356	150	0.15	0.88	0.85
		T8	P1	3.75	64	5	356	154	0.15	0.90	0.88
		T9	P1	3.75	64	5	356	155	0.16	0.91	0.88
		T10	P1	3.75	64	5	356	144	0.14	0.84	0.82
6/08/2015		T11	P1	3.75	64	5	356	161	0.16	0.94	0.91
		T12	P1	3.75	64	5	356	154	0.15	0.90	0.87
		T13	P1	3.75	64	5	356	157	0.16	0.92	0.88
		T14	P1	3.75	64	5	356	152	0.15	0.89	0.87
		T15	P1	3.75	64	5	356	153	0.15	0.90	0.90
6/08/2015		T16	P1	3.75	64	5	356	138	0.14	0.81	0.80
		T17	P1	3.75	64	5	356	151	0.15	0.89	0.88
		T18	P1	3.75	64	5	356	150	0.15	0.88	0.88
		T19	P1	3.75	64	5	356	148	0.15	0.87	0.87
		T20	P1	3.75	64	5	356	152	0.15	0.89	0.89
6/08/2015		T21	P1	3.75	64	5	356	154	0.15	0.90	0.89
		T22	P1	3.75	64	5	356	152	0.15	0.89	0.89
		T23	P1	3.75	64	5	356	152	0.15	0.89	0.89
		T24	P1	3.75	64	5	356	153	0.15	0.90	0.89
		T25	P1	3.75	64	5	356	157	0.16	0.92	0.92
6/08/2015		T26	P1	3.75	64	5	356	152	0.15	0.89	0.89
		T27	P1	3.75	64	5	356	154	0.15	0.90	0.90
		T28	P1	3.75	64	5	356	121	0.12	0.71	0.71
		T29	P1	3.75	64	5	356	150	0.15	0.88	0.88
		T30	P1	3.75	64	5	356	147	0.15	0.86	0.86

**Table A-12: Method Accuracy & Repeatability – Rotoprobe Results
(calculated and read off from control unit) (PF Mass Flow) from Pipe 2**

Date	R Probe	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw Calc. (kg/s)	MFw Roto (kg/s)
6/8/2015		T1	P2	3.75	64	5	356	175	0.18	1.03	1.03
		T2	P2	3.75	64	5	356	183	0.18	1.07	1.08
		T3	P2	3.75	64	5	356	179	0.18	1.05	1.04
		T4	P2	3.75	64	5	356	189	0.19	1.11	1.10
		T5	P2	3.75	64	5	356	180	0.18	1.06	1.04
6/8/2015		T6	P2	3.75	64	5	356	182	0.18	1.07	1.06
		T7	P2	3.75	64	5	356	179	0.18	1.05	1.04
		T8	P2	3.75	64	5	356	180	0.18	1.06	1.05
		T9	P2	3.75	64	5	356	177	0.18	1.04	1.03
		T10	P2	3.75	64	5	356	185	0.19	1.09	1.08

Appendix K Results – Target Plate on P1 and P2

Table A-13: Method Accuracy & Repeatability – Target Plate Results (PF Mass Flow) from Pipe 1

Date	T Plate	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)
4/8/2015		T1	P1	15	32	12.50	356	822.4	0.82	1.39
		T2	P1	15	32	12.50	356	806.6	0.81	1.36
		T3	P1	15	32	12.50	356	826.5	0.83	1.40
		T4	P1	15	32	12.50	356	798.3	0.80	1.35
		T5	P1	15	32	12.50	356	676.4	0.68	1.14
4/08/2016		T6	P1	15	32	12.50	356	819.40	0.82	1.38
		T7	P1	15	32	12.50	356	767.30	0.77	1.30
		T8	P1	15	32	12.50	356	789.60	0.79	1.33
		T9	P1	15	32	12.50	356	803.40	0.80	1.36
		T10	P1	15	32	12.50	356	693.30	0.69	1.17
6/08/2015		T11	P1	15	32	12.50	356	724.30	0.72	1.22
		T12	P1	15	32	12.50	356	749.10	0.75	1.27
		T13	P1	15	32	12.50	356	717.70	0.72	1.21
		T14	P1	15	32	12.50	356	747.60	0.75	1.26
		T15	P1	15	32	12.50	356	694.20	0.69	1.17
11/08/2015		T16	P1	15	32	12.50	356	671.70	0.67	1.14
		T17	P1	15	32	12.50	356	542.10	0.54	0.92
		T18	P1	15	32	12.50	356	501.50	0.50	0.85
		T19	P1	15	32	12.50	356	439.40	0.44	0.74
		T20	P1	15	32	12.50	356	459.00	0.46	0.78
11/08/2015		T21	P1	15	32	12.50	356	681.30	0.68	1.15
		T22	P1	15	32	12.50	356	665.70	0.67	1.12
		T23	P1	15	32	12.50	356	656.80	0.66	1.11
		T24	P1	15	32	12.50	356	619.00	0.62	1.05
		T25	P1	15	32	12.50	356	639.90	0.64	1.08
17/08/2015		T26	P1	15	32	12.50	356	772.60	0.77	1.31
		T27	P1	15	32	12.50	356	830.30	0.83	1.40
		T28	P1	15	32	12.50	356	760.10	0.76	1.28
		T29	P1	15	32	12.50	356	633.40	0.63	1.07
		T30	P1	15	32	12.50	356	686.90	0.69	1.16

Table A-14: Method Accuracy & Repeatability – Target Plate Results (PF Mass Flow) from Pipe 2

Date	T Plate	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)
5/8/2015		T1	P1	15	32	12.50	356	877.4	0.88	1.48
		T2	P1	15	32	12.50	356	844.6	0.84	1.43
		T3	P1	15	32	12.50	356	812.1	0.81	1.37
		T4	P1	15	32	12.50	356	761.2	0.76	1.29
		T5	P1	15	32	12.50	356	751.3	0.75	1.27
5/08/2015		T6	P1	15	32	12.50	356	705.30	0.71	1.19
		T7	P1	15	32	12.50	356	720.30	0.72	1.22
		T8	P1	15	32	12.50	356	737.30	0.74	1.25
		T9	P1	15	32	12.50	356	659.70	0.66	1.11
		T10	P1	15	32	12.50	356	666.70	0.67	1.13

Appendix L Results – 3 Axis Traverse on P1 & P2

Table A-15: Method Accuracy & Repeatability - 3 Axis Traverse Results (PF Mass Flow) from Pipe 1

Date	T Plate	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)
5/8/2015		T1	P1	30	24	12.50	356	781.3	0.78	0.88
		T2	P1	30	24	12.50	356	631.4	0.63	0.71
		T3	P1	30	24	12.50	356	738	0.74	0.83
		T4	P1	30	24	12.50	356	715.8	0.72	0.81
		T5	P1	30	24	12.50	356	768.8	0.77	0.87
5/8/2015		T6	P1	30	24	12.50	356	814.90	0.81	0.92
		T7	P1	30	24	12.50	356	765.90	0.77	0.86
		T8	P1	30	24	12.50	356	707.40	0.71	0.80
		T9	P1	30	24	12.50	356	670.10	0.67	0.75
		T10	P1	30	24	12.50	356	773.80	0.77	0.87
6/8/2015		T11	P1	30	24	12.50	356	777.50	0.78	0.88
		T12	P1	30	24	12.50	356	776.60	0.78	0.87
		T13	P1	30	24	12.50	356	737.60	0.74	0.83
		T14	P1	30	24	12.50	356	762.80	0.76	0.86
		T15	P1	30	24	12.50	356	812.30	0.81	0.92
11/8/2015		T16	P1	30	24	12.50	356	793.60	0.79	0.89
		T17	P1	30	24	12.50	356	733.90	0.73	0.83
		T18	P1	30	24	12.50	356	782.80	0.78	0.88
		T19	P1	30	24	12.50	356	799.60	0.80	0.90
		T20	P1	30	24	12.50	356	751.70	0.75	0.85
17/8/2015		T21	P1	30	24	12.50	356	812.30	0.81	0.92
		T22	P1	30	24	12.50	356	778.00	0.78	0.88
		T23	P1	30	24	12.50	356	731.70	0.73	0.82
		T24	P1	30	24	12.50	356	681.20	0.68	0.77
		T25	P1	30	24	12.50	356	757.60	0.76	0.85
17/8/2015		T26	P1	30	24	12.50	356	777.60	0.78	0.88
		T27	P1	30	24	12.50	356	881.30	0.88	0.99
		T28	P1	30	24	12.50	356	724.70	0.72	0.82
		T29	P1	30	24	12.50	356	658.80	0.66	0.74
		T30	P1	30	24	12.50	356	676.30	0.68	0.76

Table A-16: Method Accuracy & Repeatability - 3 Axis Traverse Results (PF Mass Flow) from Pipe 2

Date	T Plate	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)
30/7/2015		T1	P1	30	24	12.50	356	1332	1.33	1.50
		T2	P1	30	24	12.50	356	1146.9	1.15	1.29
		T3	P1	30	24	12.50	356	1377.5	1.38	1.55
		T4	P1	30	24	12.50	356	1046.4	1.05	1.18
		T5	P1	30	24	12.50	356	1144	1.14	1.29
5/8/2015		T6	P1	30	24	12.50	356	862.70	0.86	0.97
		T7	P1	30	24	12.50	356	798.20	0.80	0.90
		T8	P1	30	24	12.50	356	702.90	0.70	0.79
		T9	P1	30	24	12.50	356	875.00	0.88	0.99
		T10	P1	30	24	12.50	356	953.60	0.95	1.07

Appendix M Results – 1 Axis Traverse on P1 & P2

Table A-17: Method Accuracy & Repeatability - 1 Axis Traverse Results (PF Mass Flow) from Pipe 1

Date	T Plate	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)
30/7/2015		T1	P1	30	8	12.50	356	298.9	0.30	1.01
		T2	P1	30	8	12.50	356	420.9	0.42	1.42
		T3	P1	30	8	12.50	356	660.6	0.66	2.23
		T4	P1	30	8	12.50	356	589.8	0.59	1.99
		T5	P1	30	8	12.50	356	780	0.78	2.64
5/8/2015		T6	P1	30	8	12.50	356	274.2	0.27	0.93
		T7	P1	30	8	12.50	356	273.7	0.27	0.93
		T8	P1	30	8	12.50	356	263.3	0.26	0.89
		T9	P1	30	8	12.50	356	251.6	0.25	0.85
		T10	P1	30	8	12.50	356	260.3	0.26	0.88
6/8/2015		T11	P1	30	8	12.50	356	256.9	0.26	0.87
		T12	P1	30	8	12.50	356	254	0.25	0.86
		T13	P1	30	8	12.50	356	254.7	0.25	0.86
		T14	P1	30	8	12.50	356	239.7	0.24	0.81
		T15	P1	30	8	12.50	356	237.1	0.24	0.80
11/8/2015		T16	P1	30	8	12.50	356	266.80	0.27	0.90
		T17	P1	30	8	12.50	356	253.10	0.25	0.86
		T18	P1	30	8	12.50	356	254.60	0.25	0.86
		T19	P1	30	8	12.50	356	249.00	0.25	0.84
		T20	P1	30	8	12.50	356	243.10	0.24	0.82
17/08/2015		T21	P1	30	8	12.50	356	277.10	0.28	0.94
		T22	P1	30	8	12.50	356	303.60	0.30	1.03
		T23	P1	30	8	12.50	356	304.50	0.30	1.03
		T24	P1	30	8	12.50	356	294.00	0.29	0.99
		T25	P1	30	8	12.50	356	242.60	0.24	0.82
17/08/2015		T26	P1	30	8	12.50	356	258.10	0.26	0.87
		T27	P1	30	8	12.50	356	271.70	0.27	0.92
		T28	P1	30	8	12.50	356	287.70	0.29	0.97
		T29	P1	30	8	12.50	356	308.50	0.31	1.04
		T30	P1	30	8	12.50	356	235.30	0.24	0.80

Table A-18: Method Accuracy & Repeatability - 1 Axis Traverse Results (PF Mass Flow) from Pipe 2

Date	T Plate	Test	Pipe	t (s)	n	d (mm)	D (mm)	mass (g)	Mw (kg)	MFw (kg/s)
30/7/2015		T1	P1	30	8	12.50	356	670.3	0.67	2.27
		T2	P1	30	8	12.50	356	501.3	0.50	1.69
		T3	P1	30	8	12.50	356	495	0.50	1.67
		T4	P1	30	8	12.50	356	458.3	0.46	1.55
		T5	P1	30	8	12.50	356	570.1	0.57	1.93
30/7/2015		T6	P1	30	8	12.50	356	413.2	0.41	1.40
		T7	P1	30	8	12.50	356	532.2	0.53	1.80
		T8	P1	30	8	12.50	356	638.3	0.64	2.16
		T9	P1	30	8	12.50	356	689.8	0.69	2.33
		T10	P1	30	8	12.50	356	640.2	0.64	2.16

Appendix N Results – All Sampling Methods on P1 & P2

Table A-19: Summary of Method Accuracy & Repeatability Results (PF Mass Flow) from Pipe 1

Test	Pipe	Roto probe (kg/s)	Target Plate (kg/s)	3 Axis (kg/s)	1 Axis (kg/s)
T1	P1	0.88	1.39	0.88	1.01
T2	P1	0.74	1.36	0.71	1.42
T3	P1	0.84	1.40	0.83	2.23
T4	P1	0.84	1.35	0.81	1.99
T5	P1	0.87	1.14	0.87	2.64
T6	P1	0.88	1.38	0.92	0.93
T7	P1	0.85	1.30	0.86	0.93
T8	P1	0.88	1.33	0.80	0.89
T9	P1	0.88	1.36	0.75	0.85
T10	P1	0.82	1.17	0.87	0.88
T11	P1	0.91	1.22	0.88	0.87
T12	P1	0.87	1.27	0.87	0.86
T13	P1	0.88	1.21	0.83	0.86
T14	P1	0.87	1.26	0.86	0.81
T15	P1	0.90	1.17	0.92	0.80
T16	P1	0.80	1.14	0.89	0.90
T17	P1	0.88	0.92	0.83	0.86
T18	P1	0.88	0.85	0.88	0.86
T19	P1	0.87	0.74	0.90	0.84
T20	P1	0.89	0.78	0.85	0.82
T21	P1	0.89	1.15	0.92	0.94
T22	P1	0.89	1.12	0.88	1.03
T23	P1	0.89	1.11	0.82	1.03
T24	P1	0.89	1.05	0.77	0.99
T25	P1	0.92	1.08	0.85	0.82
T26	P1	0.89	1.31	0.88	0.87
T27	P1	0.90	1.40	0.99	0.92
T28	P1	0.71	1.28	0.82	0.97
T29	P1	0.88	1.07	0.74	1.04
T30	P1	0.86	1.16	0.76	0.80

Table A-20: Summary of Method Accuracy & Repeatability Results (PF Mass Flow) from Pipe 2

Test	Pipe	Roto probe (kg/s)	Target Plate (kg/s)	3 Axis (kg/s)	1 Axis (kg/s)
1	P2	1.03	1.48	1.50	2.27
2	P2	1.03	1.43	1.29	1.69
3	P2	1.08	1.37	1.55	1.67
4	P2	1.08	1.29	1.18	1.55
5	P2	1.04	1.27	1.29	1.93
6	P2	1.10	1.19	0.97	1.40
7	P2	1.04	1.22	0.90	1.80
8	P2	1.06	1.25	0.79	2.16
9	P2	1.04	1.11	0.99	2.33
10	P2	1.05	1.13	1.07	2.16

Appendix O Results from Pipe B1 to B4

Table A-21: PF Mass Flow Results from Pipe B1

Date	Test Method	Test #	Pipe	t (s)	n	d (mm)	D (mm)	mass (g) wet	Moisture (%) PF	Md (kg)	MFd (kg/s)	mass (g) dry	MFw (kg/s)	ave per test set (kg/s)
18/08/2015	1 Axis	T1 - V	B1	30	8	12.5	508	352.20	2.67	0.34	2.36	342.81	2.42	
19/08/2015	1 Axis	T2 - V	B1	30	8	12.5	508	340.50	2.83	0.33	2.28	330.85	2.34	
19/08/2015	1 Axis	T3 - V	B1	30	8	12.5	508	304.60	3.00	0.30	2.03	295.46	2.10	2.22
26/08/2015	1 Axis	T1 - H	B1	30	8	12.5	508	206.10	1.83	0.20	1.39	202.32	1.42	
26/08/2015	1 Axis	T2 - H	B1	30	8	12.5	508	209.20	1.83	0.21	1.41	205.36	1.44	
26/08/2015	1 Axis	T3 - H	B1	30	8	12.5	508	218.70	1.83	0.21	1.48	214.69	1.51	1.43
13/08/2015	T Plate	T1 - V	B1	15	32	12.5	508	805.00	2.17	0.79	2.71	787.56	2.77	
13/08/2015	T Plate	T2 - V	B1	15	32	12.5	508	542.40	1.83	0.53	1.83	532.46	1.87	
13/08/2015	T Plate	T3 - V	B1	15	32	12.5	508	792.90	2.00	0.78	2.67	777.04	2.73	2.41
01/09/2015	T Plate	T1 - H	B1	15	32	12.5	508	413.50	2.50	0.40	1.39	403.16	1.42	
01/09/2015	T Plate	T2 - H	B1	15	32	12.5	508	421.60	2.33	0.41	1.42	411.76	1.45	
01/09/2015	T Plate	T3 - H	B1	15	32	12.5	508	432.60	2.17	0.42	1.46	423.23	1.49	1.42
27/08/2015	2 Axis H	T1 - H	B1	30	16	12.5	508	408.40	2.33	0.40	1.37	398.87	1.41	
27/08/2015	2 Axis H	T2 - H	B1	30	16	12.5	508	404.80	2.33	0.40	1.36	395.35	1.39	
27/08/2015	2 Axis H	T3 - H	B1	30	16	12.5	508	420.40	2.17	0.41	1.42	411.29	1.45	1.38
17/8/2015	Roto	T1 - V	B1P1	15	64	5.0	508	199.41	1.85	0.20	2.10	195.72	2.14	
17/8/2015	Roto	T2 - V	B1P1	15	64	5.0	508	205.31	1.72	0.20	2.17	201.79	2.21	
17/8/2015	Roto	T3 - V	B1P1	15	64	5.0	508	210.16	1.23	0.21	2.23	207.57	2.26	2.17
21/8/2015	Roto	T1 - H	B1H1	15	64	5.0	508	119.90	1.68	0.12	1.27	117.89	1.29	
21/8/2015	Roto	T2 - H	B1H1	15	64	5.0	508	124.63	1.68	0.12	1.32	122.54	1.34	
21/8/2015	Roto	T3 - H	B1H1	15	64	5.0	508	130.70	1.68	0.13	1.38	128.50	1.41	1.32

Table A-22: PF Mass Flow Results from Pipe B2

Date	Test Method	Test #	Pipe	t (s)	n	d (mm)	D (mm)	mass (g) wet	Moisture (%) PF	Md (kg)	MFd (kg/s)	mass (g) dry	MFw (kg/s)	ave per test set (kg/s)
18/08/2015	1 Axis	T1 - V	B2	30	8	12.5	508	266.70	2.33	0.26	1.79	260.48	1.84	
19/08/2015	1 Axis	T2 - V	B2	30	8	12.5	508	313.00	2.83	0.30	2.09	304.13	2.15	
19/08/2015	1 Axis	T3 - V	B2	30	8	12.5	508	304.60	2.67	0.30	2.04	296.48	2.10	1.98
26/08/2015	1 Axis	T1 - H	B2	30	8	12.5	508	230.70	2.17	0.23	1.55	225.70	1.59	
26/08/2015	1 Axis	T2 - H	B2	30	8	12.5	508	202.40	2.33	0.20	1.36	197.68	1.39	
26/08/2015	1 Axis	T3 - H	B2	30	8	12.5	508	211.00	2.17	0.21	1.42	206.43	1.45	1.44
13/08/2015	T Plate	T1 - V	B2	15	32	12.5	508	742.90	2.00	0.73	2.51	728.04	2.56	
13/08/2015	T Plate	T2 - V	B2	15	32	12.5	508	684.50	1.83	0.67	2.31	671.95	2.36	
13/08/2015	T Plate	T3 - V	B2	15	32	12.5	508	518.80	1.83	0.51	1.75	509.29	1.79	2.19
01/09/2015	T Plate	T1 - H	B2	15	32	12.5	508	499.30	2.67	0.49	1.67	485.99	1.72	
01/09/2015	T Plate	T2 - H	B2	15	32	12.5	508	397.80	2.50	0.39	1.33	387.86	1.37	
01/09/2015	T Plate	T3 - H	B2	15	32	12.5	508	553.90	2.50	0.54	1.86	540.05	1.91	1.62
27/08/2015	2 Axis H	T1 - H	B2	30	16	12.5	508	411.80	2.50	0.40	1.38	401.51	1.42	
27/08/2015	2 Axis H	T2 - H	B2	30	16	12.5	508	404.90	2.50	0.39	1.36	394.78	1.39	
27/08/2015	2 Axis H	T3 - H	B2	30	16	12.5	508	425.30	2.33	0.42	1.43	415.38	1.46	1.39
17/8/2015	Roto	T1 - V	B2P2	15	64	5.0	508	177.88	1.75	0.17	1.88	174.77	1.91	
17/8/2015	Roto	T2 - V	B2P2	15	64	5.0	508	178.07	1.60	0.18	1.88	175.22	1.91	
17/8/2015	Roto	T3 - V	B2P2	15	64	5.0	508	176.48	1.82	0.17	1.86	173.27	1.90	1.88
21/8/2015	Roto	T1 - H	B2H2	15	64	5.0	508	194.57	1.68	0.19	2.06	191.30	2.09	
21/8/2015	Roto	T2 - H	B2H2	15	64	5.0	508	197.01	1.68	0.19	2.08	193.70	2.12	
21/8/2015	Roto	T3 - H	B2H2	15	64	5.0	508	204.41	1.68	0.20	2.16	200.98	2.20	2.10

Table A-23: PF Mass Flow Results from Pipe B3

Date	Test Method	Test #	Pipe	t (s)	n	d (mm)	D (mm)	mass (g) wet	Moisture (%) PF	Md (kg)	MFd (kg/s)	mass (g) dry	MFw (kg/s)	ave per test set (kg/s)
18/08/2015	1 Axis	T1 - V	B3	30	8	12.5	508	280.20	2.50	0.27	1.88	273.20	1.93	
19/08/2015	1 Axis	T2 - V	B3	30	8	12.5	508	288.70	2.83	0.28	1.93	280.52	1.99	
19/08/2015	1 Axis	T3 - V	B3	30	8	12.5	508	256.20	2.67	0.25	1.72	249.37	1.76	1.84
26/08/2015	1 Axis	T1 - H	B3	30	8	12.5	508	253.70	2.17	0.25	1.71	248.20	1.75	
26/08/2015	1 Axis	T2 - H	B3	30	8	12.5	508	237.70	2.17	0.23	1.60	232.55	1.64	
26/08/2015	1 Axis	T3 - H	B3	30	8	12.5	508	221.70	2.17	0.22	1.49	216.90	1.53	1.60
13/08/2015	T Plate	T1 - V	B3	15	32	12.5	508	633.50	2.17	0.62	2.13	619.77	2.18	
13/08/2015	T Plate	T2 - V	B3	15	32	12.5	508	653.70	1.83	0.64	2.21	641.72	2.25	
13/08/2015	T Plate	T3 - V	B3	15	32	12.5	508	672.00	2.00	0.66	2.27	658.56	2.31	2.20
01/09/2015	T Plate	T1 - H	B3	15	32	12.5	508	587.50	2.50	0.57	1.97	572.81	2.02	
01/09/2015	T Plate	T2 - H	B3	15	32	12.5	508	686.50	2.00	0.67	2.31	672.77	2.36	
01/09/2015	T Plate	T3 - H	B3	15	32	12.5	508	662.10	2.17	0.65	2.23	647.75	2.28	2.17
27/08/2015	2 Axis H	T1 - H	B3	30	16	12.5	508	597.30	2.50	0.58	2.00	582.37	2.06	
27/08/2015	2 Axis H	T2 - H	B3	30	16	12.5	508	625.70	2.17	0.61	2.11	612.14	2.15	
27/08/2015	2 Axis H	T3 - H	B3	30	16	12.5	508	673.90	2.17	0.66	2.27	659.30	2.32	2.13
17/8/2015	Roto	T1 - V	B3P3	15	64	5.0	508	177.58	1.50	0.17	1.88	174.92	1.91	
17/8/2015	Roto	T2 - V	B3P3	15	64	5.0	508	180.24	1.52	0.18	1.91	177.51	1.94	
17/8/2015	Roto	T3 - V	B3P3	15	64	5.0	508	182.17	1.78	0.18	1.92	178.92	1.96	1.90
21/8/2015	Roto	T1 - H	B3H3	15	64	5.0	508	47.41	1.68	0.05	0.50	46.61	0.51	
21/8/2015	Roto	T2 - H	B3H3	15	64	5.0	508	49.18	1.68	0.05	0.52	48.35	0.53	
21/8/2015	Roto	T3 - H	B3H3	15	64	5.0	508	35.98	1.68	0.04	0.38	35.38	0.39	0.47

Table A-24: PF Mass Flow Results from Pipe B4

Date	Test Method	Test #	Pipe	t (s)	n	d (mm)	D (mm)	mass (g) wet	Moisture (%) PF	Md (kg)	MFd (kg/s)	mass (g) dry	MFw (kg/s)	ave per test set (kg/s)
18/08/2015	1 Axis	T1 - V	B4	30	8	12.5	508	313.20	2.33	0.31	2.11	305.89	2.16	
19/08/2015	1 Axis	T2 - V	B4	30	8	12.5	508	275.20	2.50	0.27	1.85	268.32	1.89	
19/08/2015	1 Axis	T3 - V	B4	30	8	12.5	508	293.70	2.67	0.29	1.97	285.87	2.02	1.97
26/08/2015	1 Axis	T1 - H	B4	30	8	12.5	508	308.40	2.00	0.30	2.08	302.23	2.12	
26/08/2015	1 Axis	T2 - H	B4	30	8	12.5	508	356.40	2.00	0.35	2.40	349.27	2.45	
26/08/2015	1 Axis	T3 - H	B4	30	8	12.5	508	350.70	2.00	0.34	2.37	343.69	2.41	2.28
13/08/2015	T Plate	T1 - V	B4	15	32	12.5	508	806.70	2.00	0.79	2.72	790.57	2.78	
13/08/2015	T Plate	T2 - V	B4	15	32	12.5	508	743.00	2.00	0.73	2.51	728.14	2.56	
13/08/2015	T Plate	T3 - V	B4	15	32	12.5	508	815.90	2.00	0.80	2.75	799.58	2.81	2.66
01/09/2015	T Plate	T1 - H	B4	15	32	12.5	508	499.30	2.17	0.49	1.68	488.48	1.72	
01/09/2015	T Plate	T2 - H	B4	15	32	12.5	508	658.60	2.00	0.65	2.22	645.43	2.27	
01/09/2015	T Plate	T3 - H	B4	15	32	12.5	508	607.40	2.17	0.59	2.04	594.24	2.09	1.98
27/08/2015	2 Axis H	T1 - H	B4	30	16	12.5	508	487.40	2.00	0.48	1.64	477.65	1.68	
27/08/2015	2 Axis H	T2 - H	B4	30	16	12.5	508	437.70	2.33	0.43	1.47	427.49	1.51	
27/08/2015	2 Axis H	T3 - H	B4	30	16	12.5	508	406.50	2.33	0.40	1.37	397.02	1.40	1.49
17/8/2015	Roto	T1 - V	B4P4	15	64	5.0	508	204.09	1.63	0.20	2.16	200.76	2.19	
17/8/2015	Roto	T2 - V	B4P4	15	64	5.0	508	206.10	1.75	0.20	2.18	202.49	2.22	
17/8/2015	Roto	T3 - V	B4P4	15	64	5.0	508	210.07	2.05	0.21	2.21	205.76	2.26	2.18
21/8/2015	Roto	T1 - H	B4H4	15	64	5.0	508	132.14	1.68	0.13	1.40	129.92	1.42	
21/8/2015	Roto	T2 - H	B4P4	15	64	5.0	508	134.28	1.68	0.13	1.42	132.02	1.44	
24/8/2015	Roto	T3 - H	B4H4	15	64	5.0	508	131.34	1.68	0.13	1.39	129.13	1.41	1.40

Table A-25: Total Dry PF Flow in Vertical Pipes vs Dry Raw Coal Flow from Feeder

Date	Test Method	Test #	Pipe	ave Md per test set (kg/s)	Raw coal Flow (kg/s)	Raw coal Moisture Content (%)	MRCd (kg/s)
19/08/2015	1 Axis	T1-T3 - V	B1	2.22	8.10	6.97	7.54
19/08/2015	1 Axis	T1-T3 - V	B2	1.98	8.10	6.97	7.54
19/08/2015	1 Axis	T1-T3 - V	B3	1.84	8.10	6.97	7.54
19/08/2015	1 Axis	T1-T3 - V	B4	1.97	8.10	6.97	7.54
19/08/2016	1 Axis	T1-T3 - V	B1-B4	8.01	8.10	6.97	7.54
13/08/2015	T Plate	T1-T3 - V	B1	2.41	8.30	5.40	7.85
13/08/2015	T Plate	T1-T3 - V	B2	2.19	8.30	5.40	7.85
13/08/2015	T Plate	T1-T3 - V	B3	2.20	8.30	5.40	7.85
13/08/2015	T Plate	T1-T3 - V	B4	2.66	8.30	5.40	7.85
13/08/2015	T Plate	T1-T3 - V	B1-B4	9.46	8.30	5.40	7.85
17/8/2015	Roto	T1-T3 - V	B1P1	2.17	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B2P2	1.88	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B3P3	1.90	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B4P4	2.18	8.86	8.50	8.11
17/8/2015	Roto	T1-T3 - V	B1P1-B4P4	8.13	8.86	8.50	8.11

Table A-26: Total Dry PF Flow in Horizontal Pipes vs Dry Raw Coal Flow from Feeder

Date	Test Method	Test #	Pipe	ave Md per test set (kg/s)	Raw coal Flow (kg/s)	Raw coal Moisture Content (%)	MRCd (kg/s)
26/08/2015	1 Axis	T1-T3 - H	B1	1.43	8.10	6.00	7.61
26/08/2015	1 Axis	T1-T3 - H	B2	1.44	8.10	6.00	7.61
26/08/2015	1 Axis	T1-T3 - H	B3	1.60	8.10	6.00	7.61
26/08/2015	1 Axis	T1-T3 - H	B4	2.28	8.10	6.00	7.61
26/08/2015	1 Axis	T1-T3 - H	B1-B4	6.76	8.10	6.00	7.61
01/09/2015	T Plate	T1-T3 - H	B1	1.42	9.20	5.40	8.70
01/09/2015	T Plate	T1-T3 - H	B2	1.62	9.20	5.40	8.70
01/09/2015	T Plate	T1-T3 - H	B3	2.17	9.20	5.40	8.70
01/09/2015	T Plate	T1-T3 - H	B4	1.98	9.20	5.40	8.70
01/09/2015	T Plate	T1-T3 - H	B1-B4	7.20	9.20	5.40	8.70
27/08/2015	2 Axis H	T1-T3 - H	B1	1.38	8.10	5.10	7.69
27/08/2015	2 Axis H	T1-T3 - H	B2	1.39	8.10	5.10	7.69
27/08/2015	2 Axis H	T1-T3 - H	B3	2.13	8.10	5.10	7.69
27/08/2015	2 Axis H	T1-T3 - H	B4	1.49	8.10	5.10	7.69
27/08/2015	2 Axis H	T1-T3 - H	B1-B4	6.39	8.10	5.10	7.69
21/8/2015	Roto	T1-T3 - H	B1H1	1.32	8.84	7.60	8.17
21/8/2015	Roto	T1-T3 - H	B2H2	2.10	8.84	7.60	8.17
21/8/2015	Roto	T1-T3 - H	B3H3	0.47	8.84	7.60	8.17
24/8/2015	Roto	T1-T3 - H	B4H4	1.40	8.83	7.60	8.16
21&24/8/2015	Roto	T1-T3 - H	B1H1-B4H4	5.29	8.84	7.60	8.17

Appendix P PF Sampling Results on P1 T1 to T30

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.9
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1098.7
MILL OUTLET TEMP.	(°C)	91.0
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	1
TEST No.	1 to 05
DATE	30-07-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-1-T01	1A-1-T02	1A-1-T03	1A-1-T04	1A-1-T05
Masses in grams					
TEST No.	1	2	3	4	5
container + sample	302.6	424.6	664.3	593.5	783.7
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	298.9	420.9	660.6	589.8	780.0
Average	264.6				
% deviation from mean	13.0	59.1	149.7	122.9	194.8

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.6	58.6	58.8	58.8	58.9
% PF MOISTURE	2.3	2.3	2.0	2.0	1.8

SIEVING

50 grams sieved

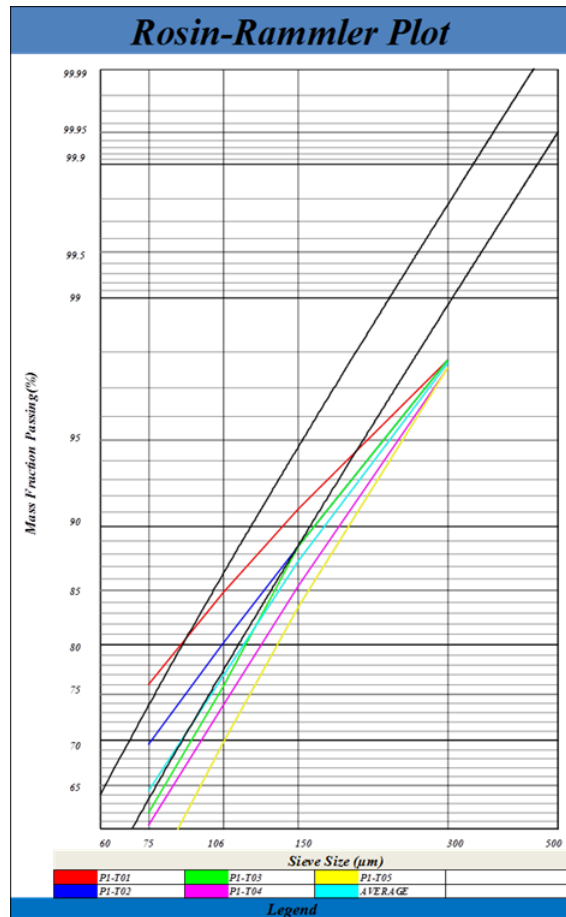
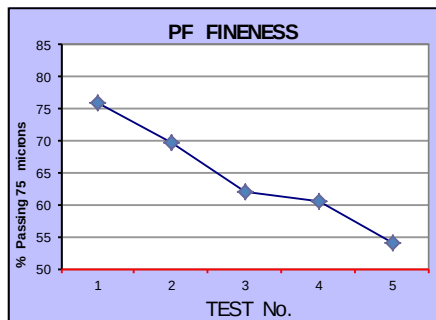
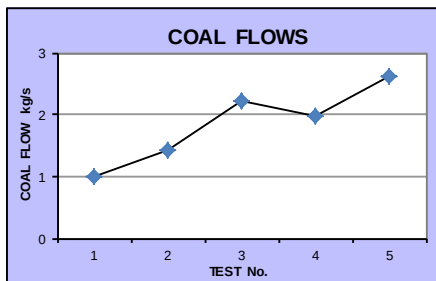
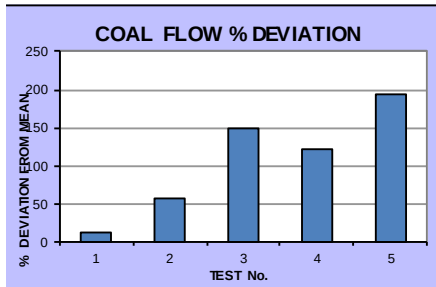
TEST No.	1	2	3	4	5
Retained PF mass > 300 um	1.1	1.1	1.1	1.2	1.2
Retained PF mass > 150 um	3.3	4.6	4.6	6.1	7.0
Retained PF mass > 106 um	3.2	4.2	6.4	5.8	6.9
Retained PF mass > 75 um	4.4	5.3	6.9	6.6	7.9
Collected in the receiver	38.3	35.0	31.2	30.6	27.2
Sum totals	50.3	50.2	50.2	50.3	50.2

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.34	1.1	91	84.0	0.8137
2	0.38	1.1	91		0.8143
3	0.32	1.0	91		0.8129
4	0.34	0.9	91		0.8120
5	0.32	0.9	91		0.8125

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	1 to 05
PA FLOW (kg/s)	13.9	PF Pipe Diameter = 356 mm		DATE	30-07-15
Sampling time : 30 sec x 8 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.01	13.0	1.80	91	22.1	97.8	91.2	84.8	76.0
2	1.42	59.1	1.90	91	23.4	97.8	88.6	80.2	69.6
3	2.23	149.7	1.74	91	21.5	97.8	88.6	75.8	62.0
4	1.99	122.9	1.80	91	22.1	97.6	85.4	73.8	60.6
5	2.64	194.8	1.74	91	21.5	97.6	83.6	69.8	54.0
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.7	86.2	74.2	60.4



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1104.9
MILL OUTLET TEMP.	(°C)	91.0
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	1
TEST No.	6 to 10
DATE	05-08-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-1-T06	1A-1-T07	1A-1-T08	1A-1-T09	1A-1-T10
Masses in grams					
TEST No.	6	7	8	9	10
container + sample	277.9	277.4	267.0	255.3	264.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	274.2	273.7	263.3	251.6	260.3
Average	264.6				
% deviation from mean	3.6	3.4	-0.5	-4.9	-1.6

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.6	58.6	58.8	58.8	58.9
% PF MOISTURE	2.3	2.3	2.0	2.0	1.8

SIEVING

50 grams sieved

TEST No.	6	7	8	9	10
Retained PF mass > 300 um	1.2	1.0	1.0	1.1	1.0
Retained PF mass > 150 um	3.9	3.5	3.8	3.2	3.3
Retained PF mass > 106 um	3.4	3.4	3.6	3.4	3.3
Retained PF mass > 75 um	4.5	5.0	4.6	4.9	4.3
Collected in the receiver	37.3	37.4	37.3	37.7	38.4
Sum totals	50.3	50.3	50.3	50.3	50.3

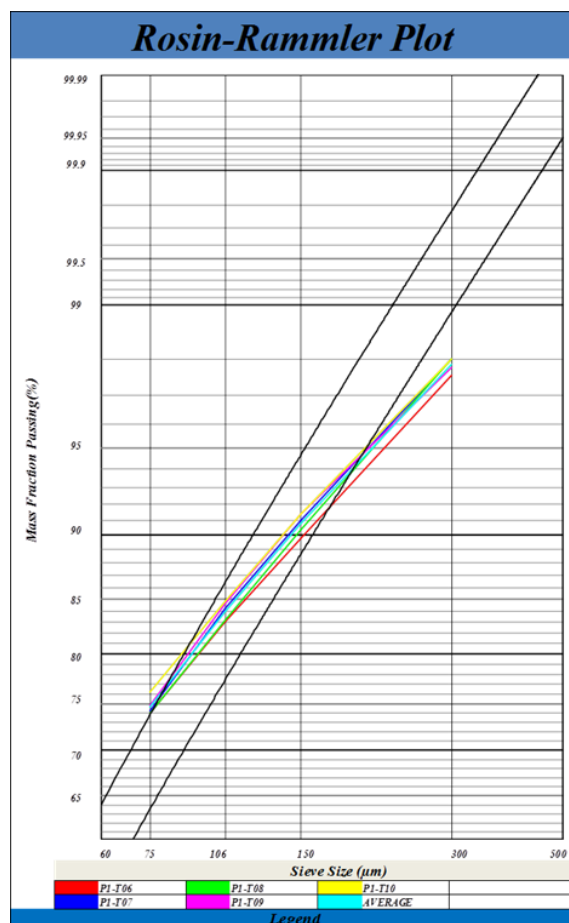
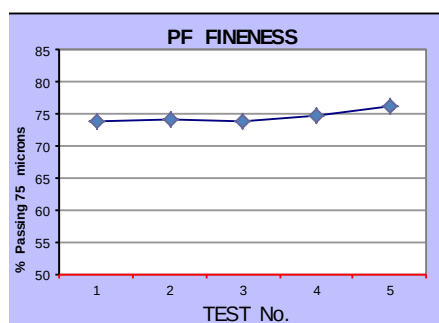
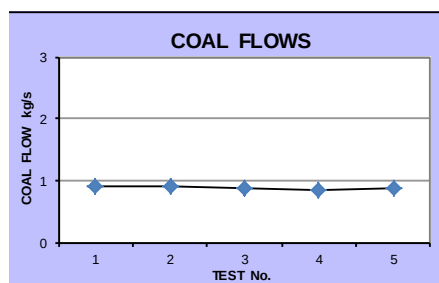
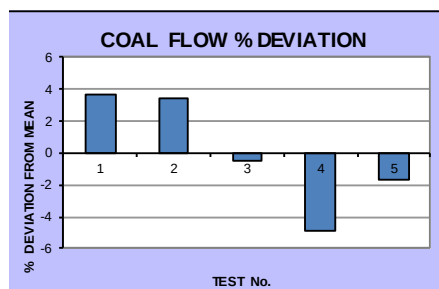
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
6	0.32	0.8	91	84.0	0.8108
7	0.32	0.7	91		0.8106
8	0.32	0.8	91		0.8110
9	0.32	0.7	91		0.8104
10	0.34	0.7	91		0.8103

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	6 to 10
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 356 mm		DATE	05-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	0.93	3.6	1.74	91	21.5	97.6	89.8	83.0	74.0
7	0.93	3.4	1.74	91	21.5	98.0	91.0	84.2	74.2
8	0.89	-0.5	1.74	91	21.5	98.0	90.4	83.2	74.0
9	0.85	-4.9	1.74	91	21.5	97.8	91.4	84.6	74.8
10	0.88	-1.6	1.80	91	22.2	98.0	91.4	84.8	76.2
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.9	91.0	84.2	74.8



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1108.1
MILL OUTLET TEMP.	(°C)	72.1
COAL FLOW A	(kg/s)	8.4
COAL FLOW B	(kg/s)	8.3

MILL	1B
PF PIPE	1
TEST No.	11 to 15
DATE	06-08-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-1-T11	1A-1-T12	1A-1-T13	1A-1-T14	1A-1-T15
Masses in grams					
TEST No.	11	12	13	14	15
container + sample	260.6	257.7	258.4	243.4	240.8
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	256.9	254.0	254.7	239.7	237.1
Average	264.6				
% deviation from mean	-2.9	-4.0	-3.7	-9.4	-10.4

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.2	58.2	58.3	58.2	58.1
% PF MOISTURE	3.0	3.0	2.8	3.0	3.2

SIEVING

50 grams sieved

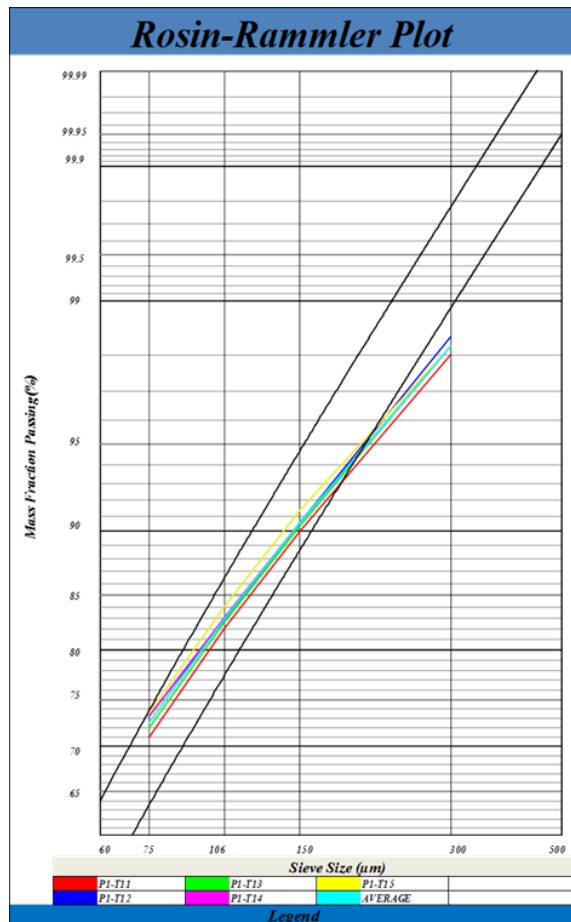
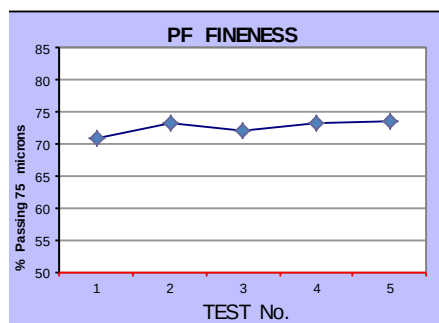
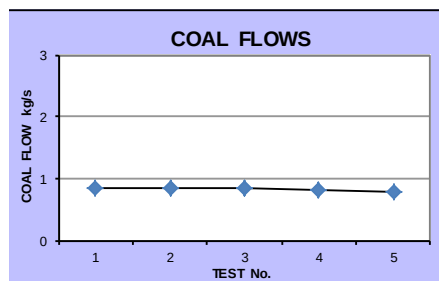
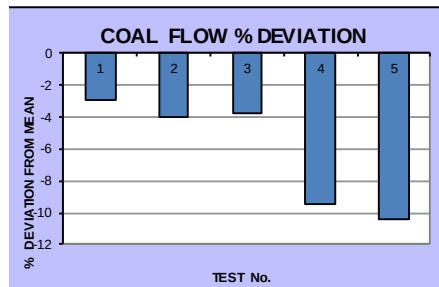
TEST No.	11	12	13	14	15
Retained PF mass > 300 um	1.0	0.8	0.9	0.9	0.9
Retained PF mass > 150 um	4.0	3.9	3.9	3.8	3.4
Retained PF mass > 106 um	4.0	3.9	3.9	3.8	3.7
Retained PF mass > 75 um	5.5	4.8	5.3	4.9	5.2
Collected in the receiver	35.7	36.9	36.3	36.9	37.1
Sum totals	50.2	50.3	50.3	50.3	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
11	0.28	0.6	71	84.0	0.8567
12	0.28	0.6	71		0.8565
13	0.28	0.7	71		0.8575
14	0.28	0.7	71		0.8571
15	0.28	0.7	71		0.8571

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	11 to 15
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 356 mm		DATE	06-08-15
Sampling time : 30 sec x 8 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
11	0.87	-2.9	1.68	71	19.6	98.0	90.0	82.0	71.0
12	0.86	-4.0	1.68	71	19.6	98.4	90.6	82.8	73.2
13	0.86	-3.7	1.68	71	19.5	98.2	90.4	82.6	72.0
14	0.81	-9.4	1.68	71	19.6	98.2	90.6	83.0	73.2
15	0.80	-10.4	1.68	71	19.6	98.2	91.4	84.0	73.6
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.2	90.7	83.1	73.0



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.6
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1119.2
MILL OUTLET TEMP.	(°C)	83.0
COAL FLOW A	(kg/s)	8.9
COAL FLOW B	(kg/s)	8.6

MILL	1B
PF PIPE	1
TEST No.	16 to 20
DATE	11-08-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-1-T16	1A-1-T17	1A-1-T18	1A-1-T19	1A-1-T20
Masses in grams					
TEST No.	16	17	18	19	20
container + sample	270.5	256.8	258.3	252.7	246.8
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	266.8	253.1	254.6	249.0	243.1
Average	264.6				
% deviation from mean	0.8	-4.3	-3.8	-5.9	-8.1

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.7	58.6	58.8	58.7
% PF MOISTURE	2.2	2.2	2.3	2.0	2.2

SIEVING

50 grams sieved

TEST No.	16	17	18	19	20
Retained PF mass > 300 um	0.9	0.7	0.9	0.9	0.9
Retained PF mass > 150 um	4.2	2.8	3.8	4.0	3.3
Retained PF mass > 106 um	4.0	3.0	3.5	3.5	3.1
Retained PF mass > 75 um	5.1	4.5	4.8	4.8	4.5
Collected in the receiver	36.1	39.3	37.2	36.9	38.4
Sum totals	50.3	50.3	50.2	50.1	50.2

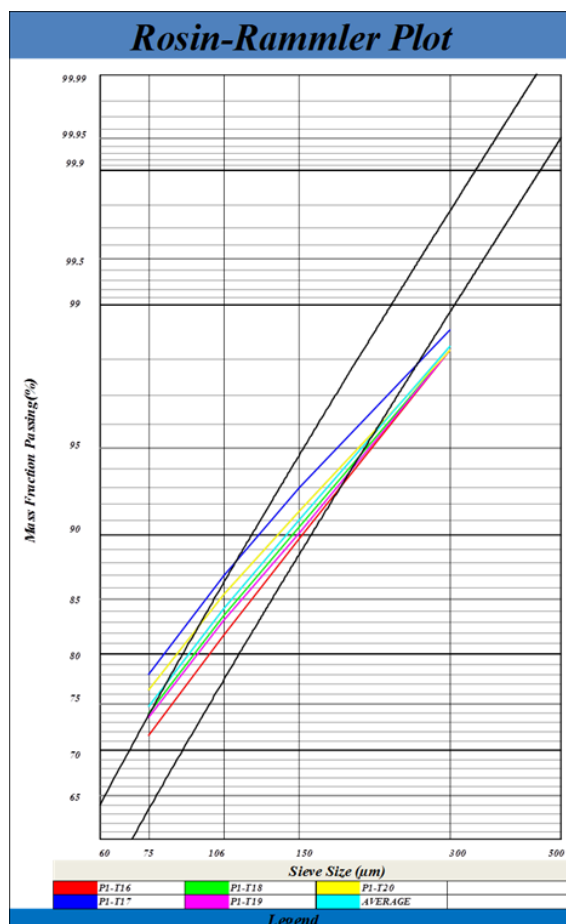
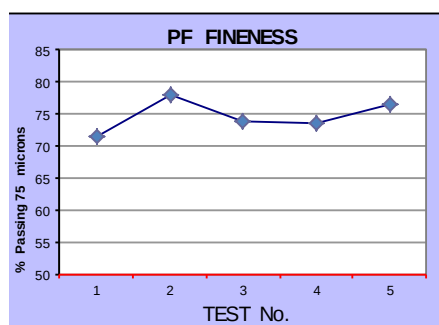
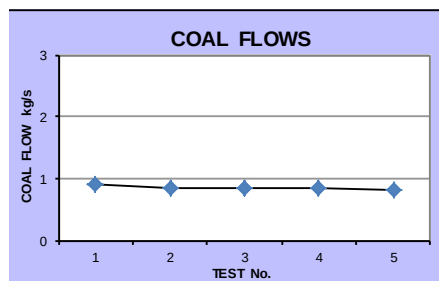
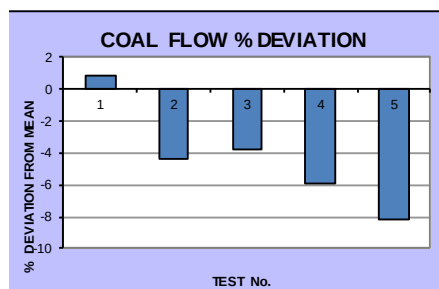
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
16	0.28	0.6	80	84.0	0.8349
17	0.32	0.6	80		0.8349
18	0.28	0.6	80		0.8349
19	0.32	0.6	80		0.8349
20	0.28	0.6	80		0.8341

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	16 to 20
PA FLOW (kg/s)	13.6	PF Pipe Diameter = 356 mm		DATE	11-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
16	0.90	0.8	1.65	80	19.8	98.2	89.8	81.8	71.6
17	0.86	-4.3	1.77	80	21.2	98.6	93.0	87.0	78.0
18	0.86	-3.8	1.65	80	19.8	98.2	90.6	83.6	74.0
19	0.84	-5.9	1.77	80	21.2	98.2	90.2	83.2	73.6
20	0.82	-8.1	1.65	80	19.8	98.2	91.6	85.4	76.4
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.3	91.4	84.8	75.5



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.6
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1119.2
MILL OUTLET TEMP.	(°C)	83.0
COAL FLOW A	(kg/s)	8.9
COAL FLOW B	(kg/s)	8.6

MILL	1B
PF PIPE	1
TEST No.	21 to 25
DATE	17-08-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-1-T21	1A-1-T22	1A-1-T23	1A-1-T24	1A-1-T25
Masses in grams					
TEST No.	21	22	23	24	25
container + sample	280.8	307.3	308.2	297.7	246.3
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	277.1	303.6	304.5	294.0	242.6
Average	264.6				
% deviation from mean	4.7	14.7	15.1	11.1	-8.3

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.6	58.6	59.1	58.8	58.5
% PF MOISTURE	2.3	2.3	1.5	2.0	2.5

SIEVING

50 grams sieved

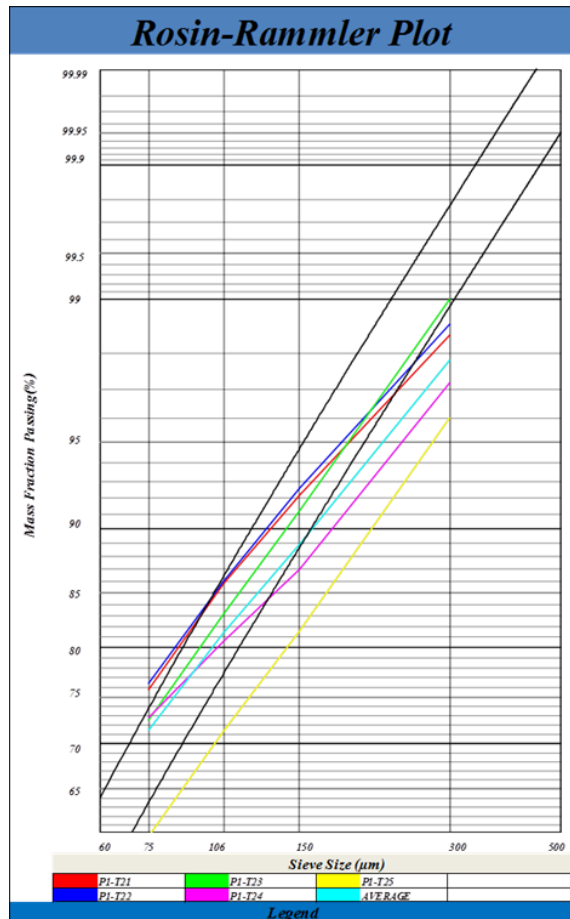
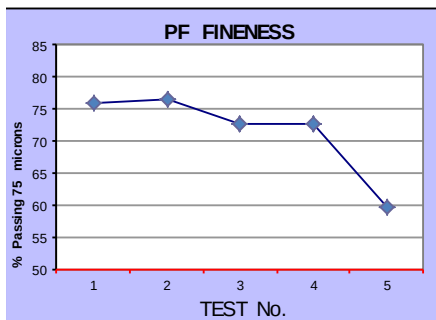
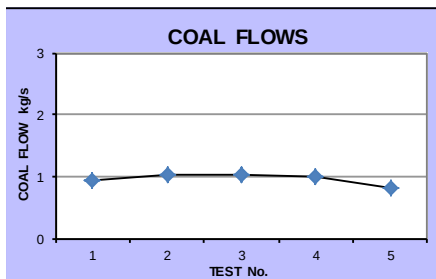
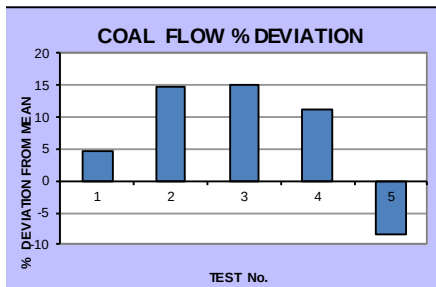
TEST No.	21	22	23	24	25
Retained PF mass > 300 um	0.8	0.7	0.5	1.4	2.0
Retained PF mass > 150 um	3.1	3.0	3.9	5.1	7.2
Retained PF mass > 106 um	3.2	3.3	4.0	3.2	5.1
Retained PF mass > 75 um	5.0	4.8	5.3	3.9	5.8
Collected in the receiver	38.2	38.4	36.6	36.6	30.2
Sum totals	50.3	50.2	50.3	50.2	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
21	0.28	0.6	80	84.0	0.8349
22	0.28	0.6	80		0.8341
23	0.34	0.9	80		0.8377
24	0.32	1.0	80		0.8388
25	0.34	1.1	80		0.8396

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	21 to 25
PA FLOW (kg/s)	13.6	PF Pipe Diameter = 356 mm		DATE	17-08-15
Sampling time : 30 sec x 8 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
21	0.94	4.7	1.65	80	19.8	98.4	92.2	85.8	75.8
22	1.03	14.7	1.65	80	19.8	98.6	92.6	86.0	76.4
23	1.03	15.1	1.83	80	21.8	99.0	91.2	83.2	72.6
24	0.99	11.1	1.77	80	21.1	97.2	87.0	80.6	72.8
25	0.82	-8.3	1.83	80	21.8	96.0	81.6	71.4	59.8
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.9	88.5	80.8	70.9



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.5
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1121.6
MILL OUTLET TEMP.	(°C)	102.4
COAL FLOW A	(kg/s)	14.1
COAL FLOW B	(kg/s)	14.8

MILL	1B
PF PIPE	1
TEST No.	26 to 30
DATE	17-08-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-1-T26	1A-1-T27	1A-1-T28	1A-1-T29	1A-1-T30
Masses in grams					
TEST No.	26	27	28	29	30
container + sample	261.8	275.4	291.4	312.2	239.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	258.1	271.7	287.7	308.5	235.3
Average	264.6				
% deviation from mean	-2.5	2.7	8.7	16.6	-11.1

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.5	58.7	58.7	58.9	58.8
% PF MOISTURE	2.5	2.2	2.2	1.8	2.0

SIEVING

50 grams sieved

TEST No.	26	27	28	29	30
Retained PF mass > 300 um	1.1	1.2	0.8	0.9	0.9
Retained PF mass > 150 um	4.7	5.0	4.0	5.2	4.3
Retained PF mass > 106 um	3.5	3.8	3.0	4.2	3.3
Retained PF mass > 75 um	4.5	5.0	3.8	5.0	4.1
Collected in the receiver	36.5	35.3	38.5	35.0	37.7
Sum totals	50.3	50.3	50.1	50.3	50.3

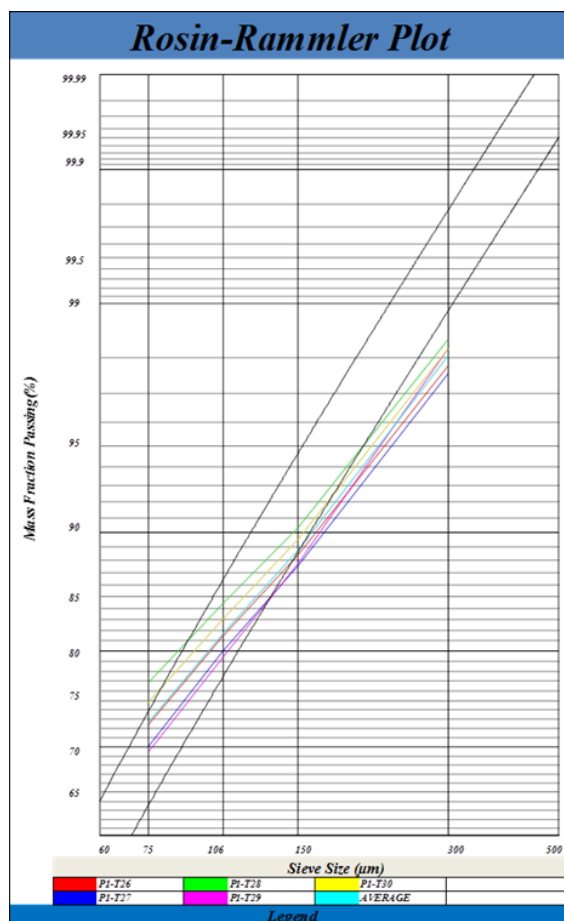
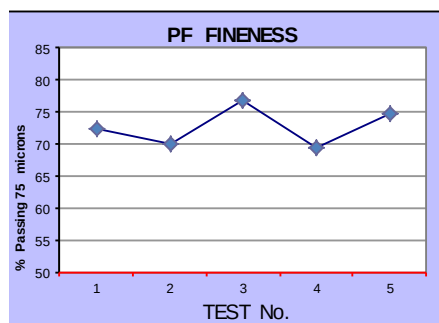
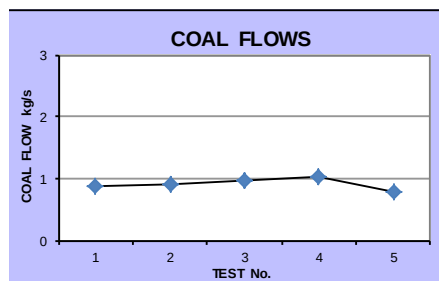
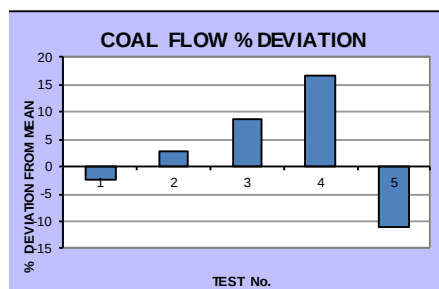
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
26	0.32	1.0	81	84.0	0.8365
27	0.32	1.0	81		0.8363
28	0.32	1.0	81		0.8365
29	0.32	1.0	81		0.8365
30	0.34	1.0	81		0.8363

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		SINGLE PIPE, SINGLE AXIS		TEST No.	26 to 30
PA FLOW (kg/s) 13.5		PF Pipe Diameter = 356 mm		DATE	17-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
26	0.87	-2.5	1.77	81	21.1	97.8	88.4	81.4	72.4
27	0.92	2.7	1.77	81	21.2	97.6	87.6	80.0	70.0
28	0.97	8.7	1.77	81	21.2	98.4	90.4	84.4	76.8
29	1.04	16.6	1.77	81	21.2	98.2	87.8	79.4	69.4
30	0.80	-11.1	1.82	81	21.8	98.2	89.6	83.0	74.8
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.0	88.8	81.6	72.6



Appendix Q PF Sampling Results on P2 T1 to T10

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1098.7
MILL OUTLET TEMP.	(°C)	84.4
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	2
TEST No.	1 to 05
DATE	30-07-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-2-T01	1A-2-T02	1A-2-T03	1A-2-T04	1A-2-T05
Masses in grams					
TEST No.	1	2	3	4	5
container + sample	674.0	505.0	498.7	462.0	573.8
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	670.3	501.3	495.0	458.3	570.1
Average	1023.9				
% deviation from mean	-34.5	-51.0	-51.7	-55.2	-44.3

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.7	58.7	58.7	58.8	58.8
% PF MOISTURE	2.2	2.2	2.2	2.0	2.0

SIEVING

50 grams sieved

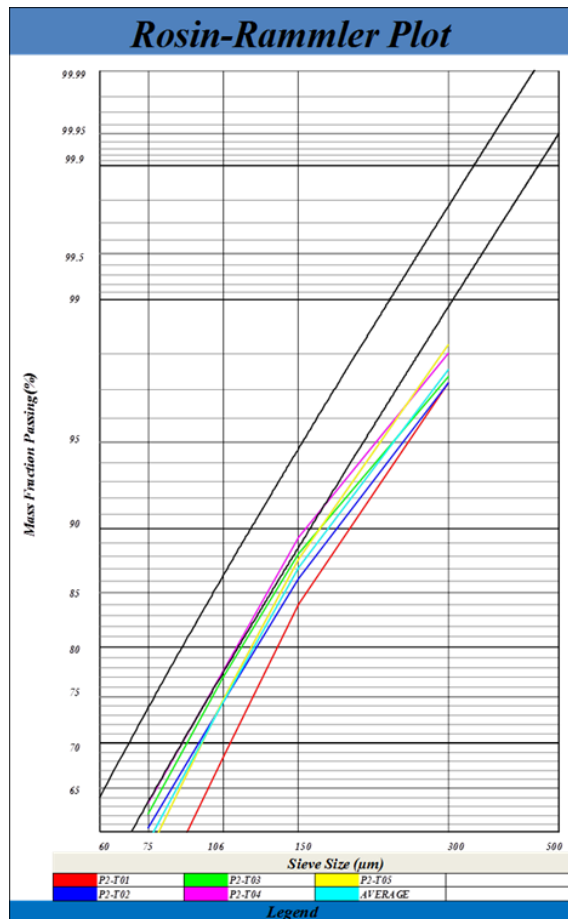
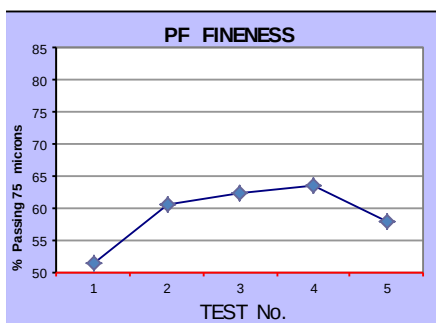
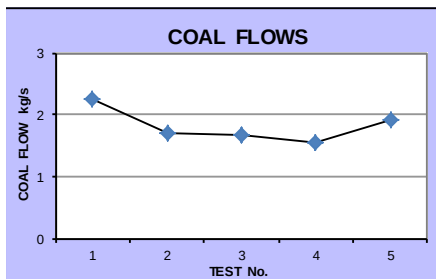
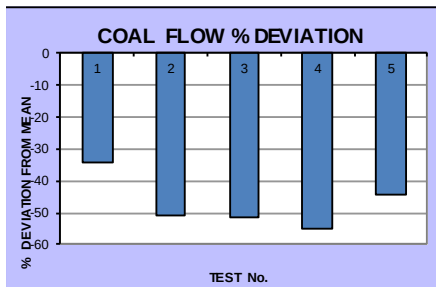
TEST No.	1	2	3	4	5
Retained PF mass > 300 um	1.4	1.4	1.3	1.0	0.9
Retained PF mass > 150 um	6.6	5.5	4.6	4.3	5.2
Retained PF mass > 106 um	7.8	5.9	5.6	5.9	6.6
Retained PF mass > 75 um	8.5	6.9	7.4	7.1	8.4
Collected in the receiver	26.0	30.5	31.4	32.3	29.2
Sum totals	50.3	50.2	50.3	50.6	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.46	1.0	93	84.0	0.8084
2	0.46	1.1	93		0.8094
3	0.48	1.1	93		0.8098
4	0.46	1.1	93		0.8098
5	0.48	1.1	93		0.8092

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	2
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	1 to 05
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 356 mm		DATE	30-07-15
Sampling time : 30 sec x 8 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	2.27	-34.5	2.12	93	25.4	97.2	84.0	68.4	51.4
2	1.69	-51.0	2.09	93	25.8	97.2	86.2	74.4	60.6
3	1.67	-51.7	2.13	93	26.3	97.4	88.2	77.0	62.2
4	1.55	-55.5	2.09	93	25.8	98.0	89.4	77.6	63.4
5	1.93	-44.3	2.13	93	26.3	98.2	87.8	74.6	57.8
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.6	87.9	75.8	60.8



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1098.7
MILL OUTLET TEMP.	(°C)	84.4
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	2
TEST No.	6 to 10
DATE	30-07-15

SINGLE PIPE, SINGLE AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	1A-2-T06	1A-2-T07	1A-2-T08	1A-2-T09	1A-2-T10
Masses in grams					
TEST No.	6	7	8	9	10
container + sample	423.6	542.6	648.7	700.2	650.6
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	419.9	538.9	645.0	696.5	646.9
Average	560.9				
% deviation from mean	-25.1	-3.9	15.0	24.2	15.3

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.8	58.9	59.1	58.6
% PF MOISTURE	1.8	2.0	1.8	1.5	2.3

SIEVING

50 grams sieved

TEST No.	6	7	8	9	10
Retained PF mass > 300 um	1.2	1.3	1.3	1.1	1.0
Retained PF mass > 150 um	6.3	5.5	4.7	4.4	5.2
Retained PF mass > 106 um	7.5	6.0	5.5	5.9	6.5
Retained PF mass > 75 um	8.3	7.0	7.3	7.1	8.3
Collected in the receiver	27.0	30.5	31.5	31.8	29.2
Sum totals	50.3	50.3	50.3	50.3	50.2

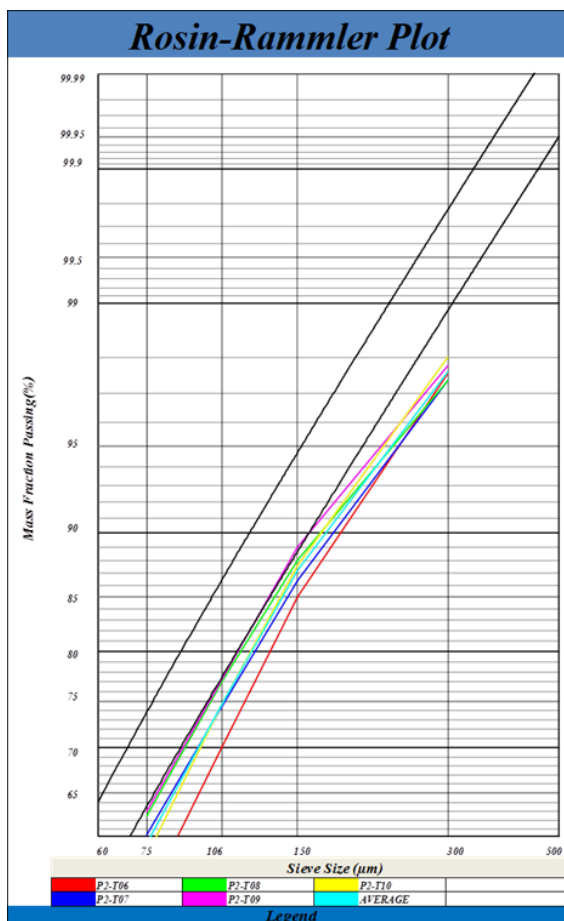
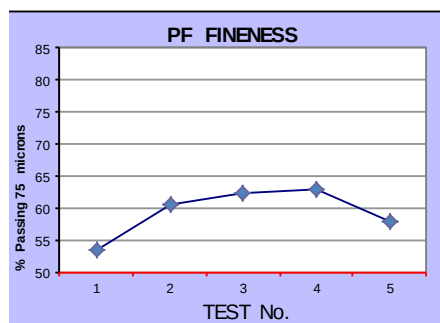
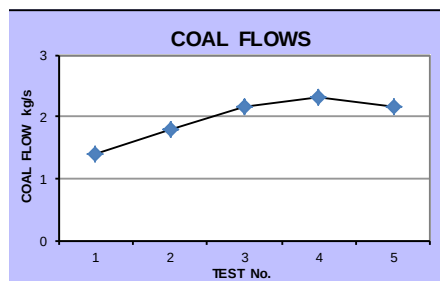
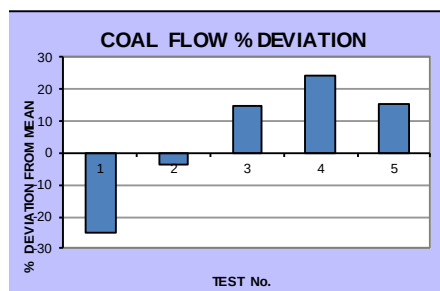
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
6	0.44	1.1	83	84.0	0.8324
7	0.46	1.2	82		0.8353
8	0.48	1.1	81		0.8369
9	0.45	1.1	83		0.8320
10	0.48	1.0	82		0.8339

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	2
TEST CONDITIONS :		<u>SINGLE PIPE, SINGLE AXIS</u>		TEST No.	6 to 10
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 356 mm		DATE	30-07-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	1.40	-25.1	2.08	83	24.8	97.6	85.0	70.0	53.4
7	1.80	-3.9	2.12	82	25.4	97.4	86.4	74.4	60.4
8	2.16	15.0	2.17	81	25.9	97.4	88.0	77.0	62.4
9	2.33	24.2	2.09	83	25.2	97.8	89.0	77.2	63.0
10	2.16	15.3	2.16	82	26.0	98.0	87.6	74.6	58.0
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.7	87.8	75.9	61.0



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1104.9
MILL OUTLET TEMP.	(°C)	73.6
COAL FLOW A	(kg/s)	8.8
COAL FLOW B	(kg/s)	8.7

MILL	1B
PF PIPE	1
TEST No.	1 to 5
DATE	05-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-1-T1	3A-1-T2	3A-1-T3	3A-1-T4	3A-1-T5
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Masses in grams

TEST No.	1	2	3	4	5
container + sample	785.0	635.1	741.7	719.5	772.5
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	781.3	631.4	738.0	715.8	768.8
Average	752.5				
% deviation from mean	3.8	-16.1	-1.9	-4.9	2.2

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.2	58.4	58.4	58.5
% PF MOISTURE	2.2	3.0	2.7	2.7	2.5

SIEVING

50 grams sieved

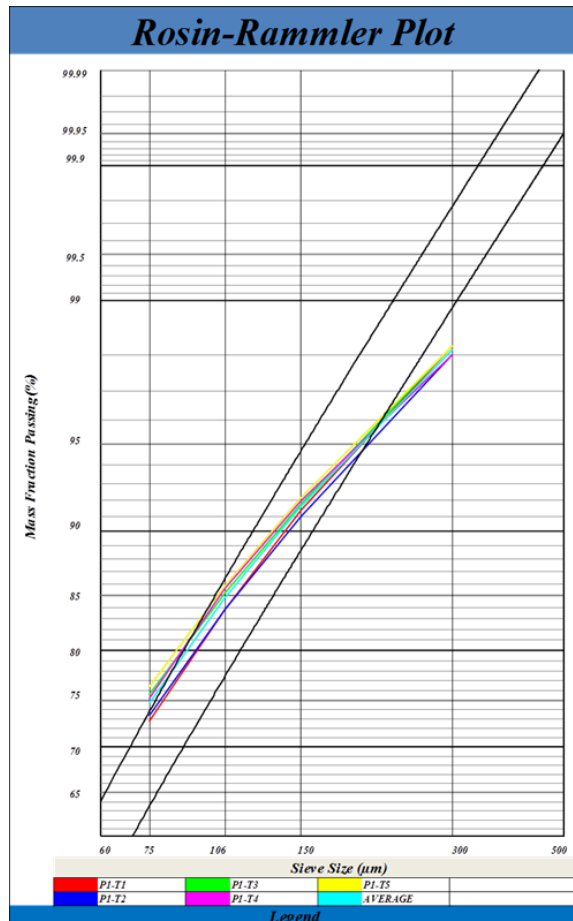
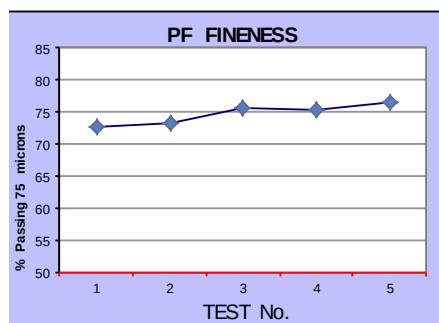
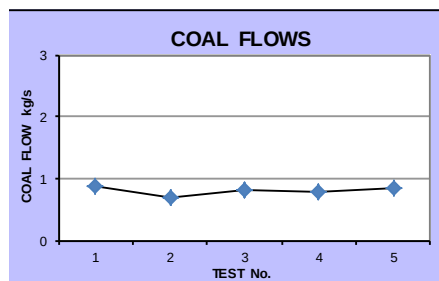
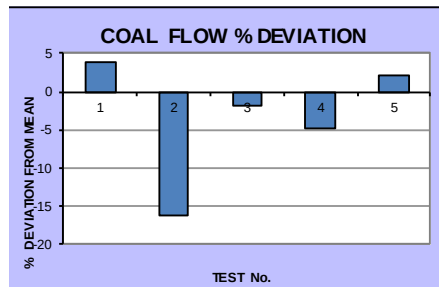
TEST No.	1	2	3	4	5
Retained PF mass > 300 um	0.9	1.0	0.9	1.0	0.9
Retained PF mass > 150 um	3.4	3.5	3.2	3.0	3.0
Retained PF mass > 106 um	3.8	3.6	3.3	3.2	3.2
Retained PF mass > 75 um	5.5	5.2	4.8	5.2	4.7
Collected in the receiver	36.6	37.0	38.0	37.9	38.4
Sum totals	50.2	50.3	50.2	50.3	50.2

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.32	0.7	74	84.0	0.8513
2	0.34	0.8	74		0.8517
3	0.32	0.7	74		0.8513
4	0.28	0.7	74		0.8511
5	0.38	0.8	74		0.8515

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, 3 AXIS</u>		TEST No.	1 to 5
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 356 mm		DATE	05-08-15
Sampling time : 30 sec x 24 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	0.88	3.8	1.77	74	21.1	98.2	91.4	83.8	72.8
2	0.71	-16.1	1.84	74	21.6	98.0	91.0	83.8	73.4
3	0.83	-1.9	1.79	74	21.0	98.2	91.8	85.2	75.6
4	0.81	-4.9	1.67	74	19.6	98.0	92.0	85.6	75.2
5	0.87	2.2	1.95	74	22.9	98.2	92.2	85.8	76.4
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.1	91.8	85.2	75.2



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1104.9
MILL OUTLET TEMP.	(°C)	73.6
COAL FLOW A	(kg/s)	8.8
COAL FLOW B	(kg/s)	8.7

MILL	1B
PF PIPE	1
TEST No.	6 to 10
DATE	05-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-1-T6	3A-1-T7	3A-1-T8	3A-1-T9	3A-1-T10
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Masses in grams

TEST No.	6	7	8	9	10
container + sample	818.6	769.6	711.1	673.8	777.5
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	814.9	765.9	707.4	670.1	773.8
Average	752.5				
% deviation from mean	8.3	1.8	-6.0	-11.0	2.8

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.5	58.7	58.7	58.6	58.6
% PF MOISTURE	2.5	2.2	2.2	2.3	2.3

SIEVING

50 grams sieved

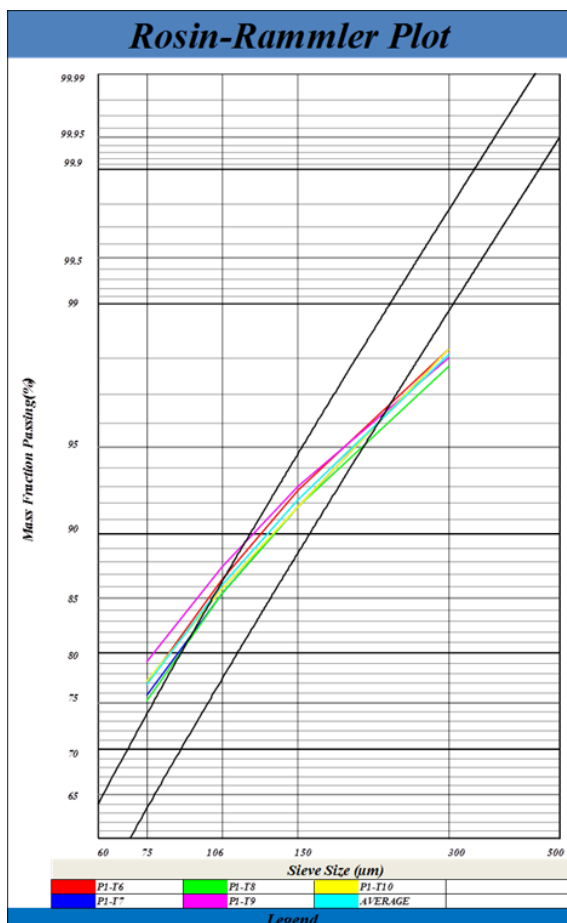
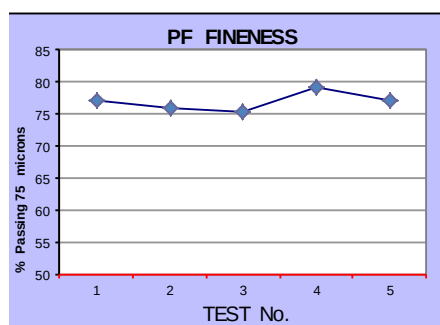
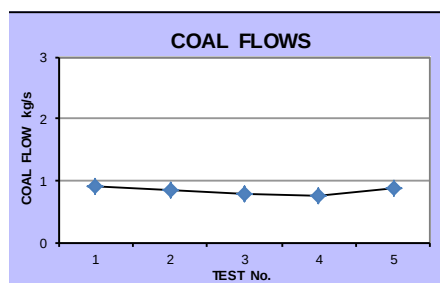
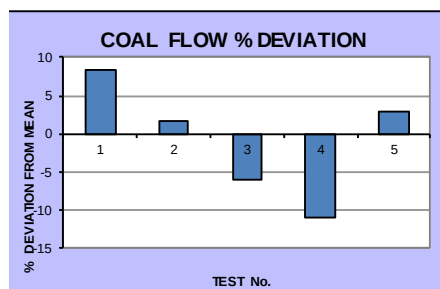
TEST No.	6	7	8	9	10
Retained PF mass > 300 um	0.9	0.9	1.1	1.0	0.9
Retained PF mass > 150 um	2.7	3.2	3.0	2.5	3.2
Retained PF mass > 106 um	3.1	3.2	3.2	2.7	3.0
Retained PF mass > 75 um	4.8	4.8	5.1	4.2	4.3
Collected in the receiver	38.7	38.0	37.7	39.8	38.9
Sum totals	50.2	50.1	50.1	50.2	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
6	0.28	0.7	74	84.0	0.8511
7	0.28	0.7	74		0.8511
8	0.28	0.7	74		0.8511
9	0.32	0.7	74		0.8513
10	0.28	0.7	74		0.8513

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, 3 AXIS</u>		TEST No.	6 to 10
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 356 mm		DATE	05-08-15
Sampling time : 30 sec x 24 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	0.92	8.3	1.66	74	19.8	98.2	92.8	86.6	77.0
7	0.86	1.8	1.67	74	19.6	98.2	91.8	85.4	75.8
8	0.80	-6.0	1.67	74	19.6	97.8	91.8	85.4	75.2
9	0.75	-11.0	1.79	74	21.0	98.0	93.0	87.6	79.2
10	0.87	2.8	1.67	74	19.6	98.2	91.8	85.8	77.2
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.1	92.1	86.0	76.8



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1106.3
MILL OUTLET TEMP.	(°C)	72.0
COAL FLOW A	(kg/s)	8.5
COAL FLOW B	(kg/s)	8.4

MILL	1B
PF PIPE	1
TEST No.	11 to 15
DATE	06-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-1-T11	3A-1-T12	3A-1-T13	3A-1-T14	3A-1-T15
Masses in grams					
TEST No.	11	12	13	14	15
container + sample	781.2	780.3	741.3	766.5	816.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	777.5	776.6	737.6	762.8	812.3
Average	752.5				
% deviation from mean	3.3	3.2	-2.0	1.4	7.9

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.3	58.3	58.2	58.3	58.2
% PF MOISTURE	2.8	2.8	3.0	2.8	3.0

SIEVING

50 grams sieved

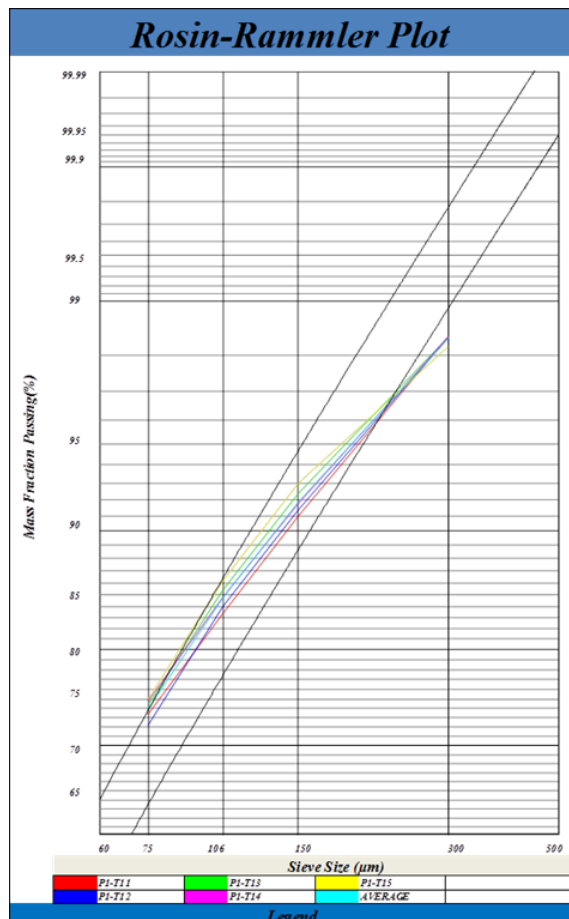
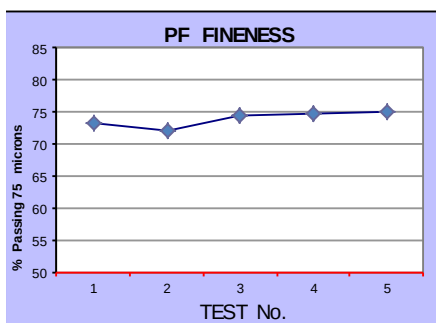
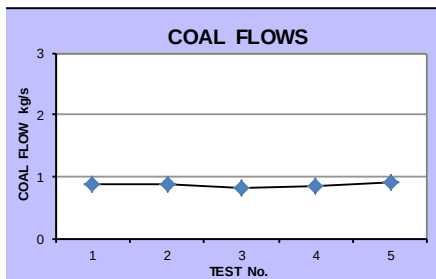
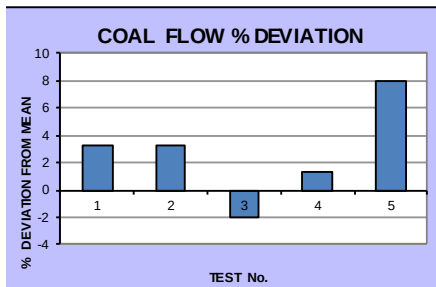
TEST No.	11	12	13	14	15
Retained PF mass > 300 um	0.8	0.8	0.8	0.8	0.9
Retained PF mass > 150 um	3.7	3.5	3.0	3.3	2.6
Retained PF mass > 106 um	3.8	3.7	3.5	3.5	3.4
Retained PF mass > 75 um	5.0	5.9	5.5	5.0	5.6
Collected in the receiver	36.8	36.3	37.3	37.6	37.9
Sum totals	50.1	50.2	50.1	50.2	50.4

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
11	0.32	0.7	71	84.0	0.8575
12	0.32	0.7	71		0.8577
13	0.28	0.7	71		0.8571
14	0.34	0.7	71		0.8571
15	0.32	0.7	71		0.8571

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, 3 AXIS</u>		TEST No.	11 to 15
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 356 mm		DATE	06-08-15
Sampling time : 30 sec x 24 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
11	0.88	3.3	1.77	71	21.1	98.4	91.0	83.4	73.4
12	0.87	3.2	1.79	71	20.9	98.4	91.4	84.0	72.2
13	0.83	-2.0	1.68	71	19.6	98.4	92.4	85.4	74.4
14	0.86	1.4	1.85	71	21.5	98.4	91.8	84.8	74.8
15	0.92	7.9	1.79	71	20.9	98.2	93.0	86.2	75.0
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.4	92.2	85.1	74.1



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.6
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1119.2
MILL OUTLET TEMP.	(°C)	83.0
COAL FLOW A	(kg/s)	8.9
COAL FLOW B	(kg/s)	8.6

MILL	1B
PF PIPE	1
TEST No.	16 to 20
DATE	11-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-1-T16	3A-1-T17	3A-1-T18	3A-1-T19	3A-1-T20
Masses in grams					
TEST No.	16	17	18	19	20
container + sample	797.3	737.6	786.5	803.3	755.4
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	793.6	733.9	782.8	799.6	751.7
Average	752.5				
% deviation from mean	5.5	-2.5	4.0	6.3	-0.1

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.7	58.6	58.8	58.7
% PF MOISTURE	2.2	2.2	2.3	2.0	2.2

SIEVING

50 grams sieved

TEST No.	16	17	18	19	20
Retained PF mass > 300 um	0.9	0.7	0.9	0.9	0.9
Retained PF mass > 150 um	4.2	2.8	3.8	4.0	3.3
Retained PF mass > 106 um	4.0	3.0	3.5	3.5	3.1
Retained PF mass > 75 um	5.1	4.5	4.8	4.8	4.5
Collected in the receiver	36.1	39.3	37.2	36.9	38.4
Sum totals	50.3	50.3	50.2	50.1	50.2

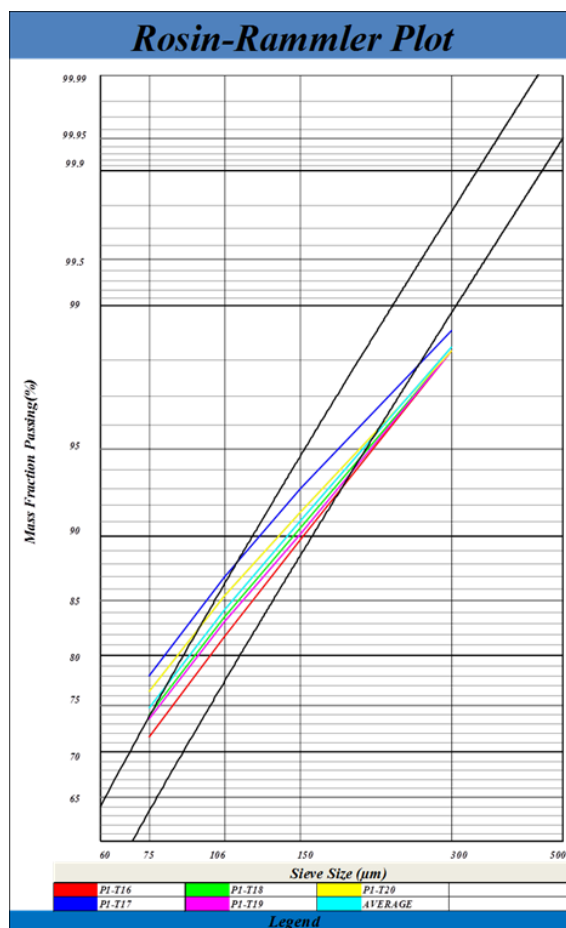
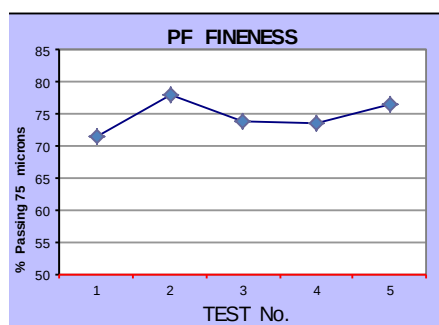
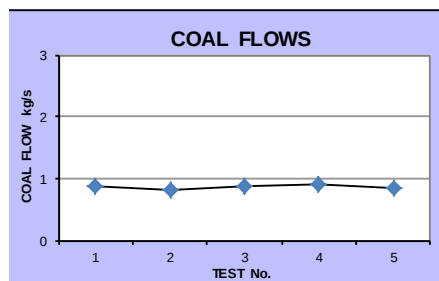
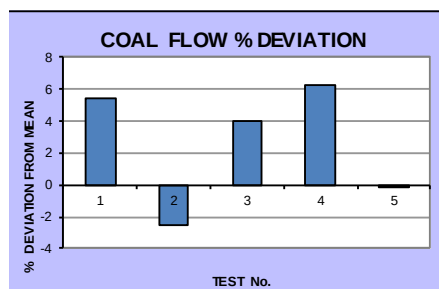
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
16	0.28	0.6	80	84.0	0.8349
17	0.32	0.6	80		0.8349
18	0.28	0.6	80		0.8349
19	0.32	0.6	80		0.8349
20	0.28	0.6	80		0.8341

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		SINGLE PIPE, 3 AXIS		TEST No.	16 to 20
PA FLOW (kg/s)	13.6	PF Pipe Diameter = 356 mm		DATE	11-08-15

Sampling time : 30 sec x 24 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
16	0.89	5.5	1.66	80	19.8	98.2	89.8	81.8	71.6
17	0.83	-2.5	1.77	80	21.2	98.6	93.0	87.0	78.0
18	0.88	4.0	1.65	80	19.8	98.2	90.6	83.6	74.0
19	0.90	6.3	1.77	80	21.2	98.2	90.2	83.2	73.6
20	0.85	-0.1	1.65	80	19.8	98.2	91.6	85.4	76.4
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.3	91.3	84.8	75.4



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.6
MILL DEMAND	(%)	89.1
MILL POWER	(kW)	1056.0
MILL OUTLET TEMP.	(°C)	91.7
COAL FLOW A	(kg/s)	9.0
COAL FLOW B	(kg/s)	8.6

MILL	1B
PF PIPE	1
TEST No.	21 to 25
DATE	17-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-1-T21	3A-1-T22	3A-1-T23	3A-1-T24	3A-1-T25
Masses in grams					
TEST No.	21	22	23	24	25
container + sample	816.0	781.7	735.4	684.9	761.3
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	812.3	778.0	731.7	681.2	757.6
Average	752.5				
% deviation from mean	7.9	3.4	-2.8	-9.5	0.7

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.5	58.4	58.7	58.7	58.9
% PF MOISTURE	2.5	2.7	2.2	2.2	1.8

SIEVING

50 grams sieved

TEST No.	21	22	23	24	25
Retained PF mass > 300 um	1.0	0.8	0.7	0.6	0.6
Retained PF mass > 150 um	3.4	2.4	2.6	1.6	1.7
Retained PF mass > 106 um	3.4	2.8	2.7	1.9	2.3
Retained PF mass > 75 um	4.8	4.3	4.1	3.7	4.2
Collected in the receiver	37.7	40.0	40.2	42.5	41.4
Sum totals	50.3	50.3	50.3	50.3	50.2

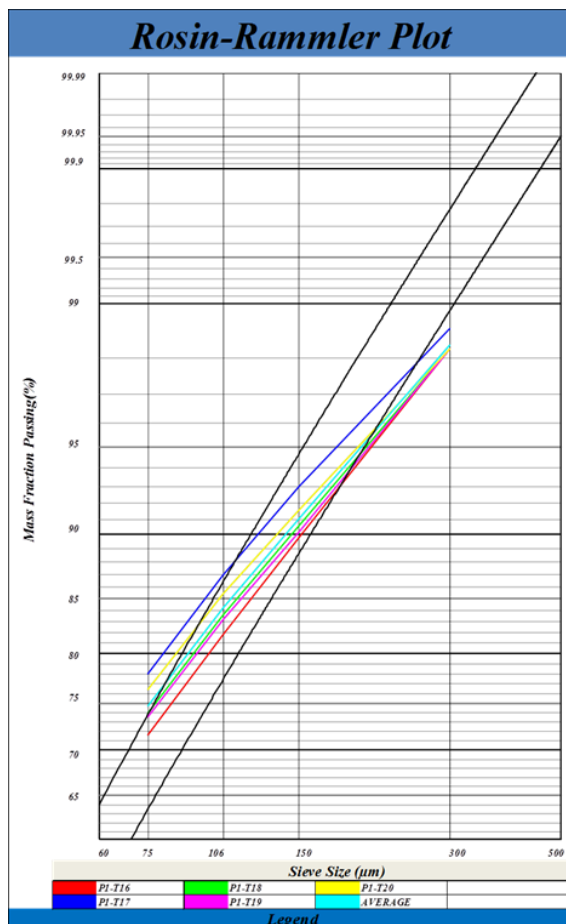
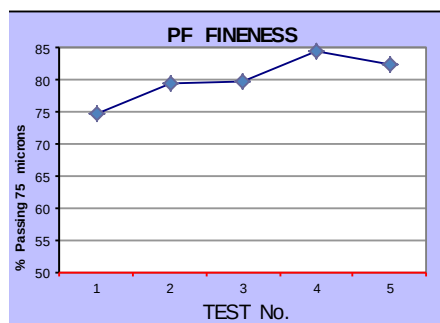
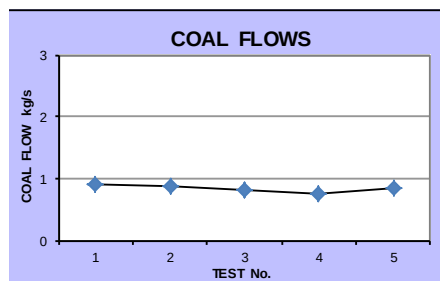
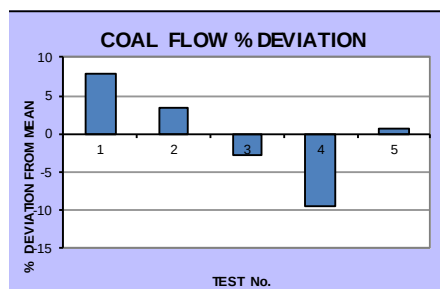
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
21	0.32	0.6	81	84.0	0.8317
22	0.28	0.6	81		0.8325
23	0.34	0.9	81		0.8353
24	0.38	1.0	81		0.8359
25	0.38	1.0	81		0.8365

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		SINGLE PIPE, 3 AXIS		TEST No.	21 to 25
PA FLOW (kg/s)	13.6	PF Pipe Diameter = 356 mm		DATE	17-08-15

Sampling time : 30 sec x 24 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
21	0.92	7.9	1.77	81	21.1	98.0	91.2	84.4	74.8
22	0.88	3.4	1.65	81	19.8	98.4	93.6	88.0	79.4
23	0.82	-2.8	1.82	81	21.8	98.6	93.4	88.0	79.8
24	0.77	-9.5	1.93	81	23.1	98.8	95.6	91.8	84.4
25	0.85	0.7	1.93	81	23.1	98.8	95.4	90.8	82.4
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.5	94.5	89.6	81.4



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.6
MILL DEMAND	(%)	89.1
MILL POWER	(kW)	1056.0
MILL OUTLET TEMP.	(°C)	91.7
COAL FLOW A	(kg/s)	9.0
COAL FLOW B	(kg/s)	8.6

MILL	1B
PF PIPE	1
TEST No.	26 to 30
DATE	17-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-1-T26	3A-1-T27	3A-1-T28	3A-1-T29	3A-1-T30
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Masses in grams

TEST No.	26	27	28	29	30
container + sample	781.3	885.0	728.4	662.5	680.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	777.6	881.3	724.7	658.8	676.3
Average	752.5				
% deviation from mean	3.3	17.1	-3.7	-12.5	-10.1

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.8	58.9	58.8	58.9	58.9
% PF MOISTURE	2.0	1.8	2.0	1.8	1.8

SIEVING

50 grams sieved

TEST No.	26	27	28	29	30
Retained PF mass > 300 um	0.7	0.8	0.7	0.6	0.8
Retained PF mass > 150 um	3.5	4.0	1.5	1.1	2.6
Retained PF mass > 106 um	3.1	5.2	1.9	1.6	2.5
Retained PF mass > 75 um	4.2	6.9	4.0	3.6	3.8
Collected in the receiver	38.8	33.5	42.2	43.4	40.6
Sum totals	50.3	50.4	50.3	50.3	50.3

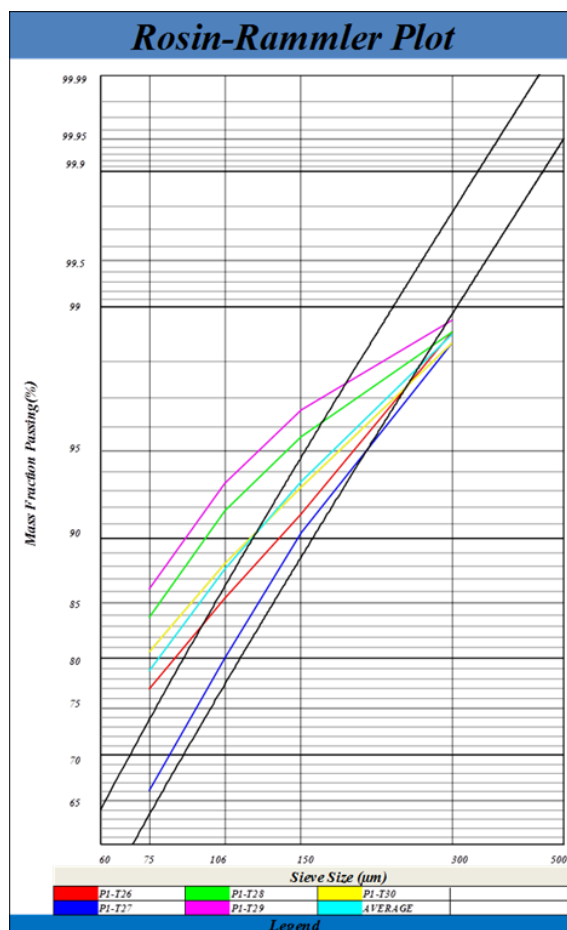
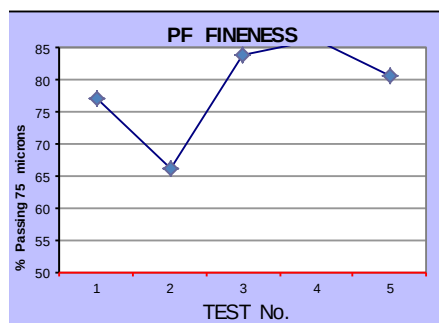
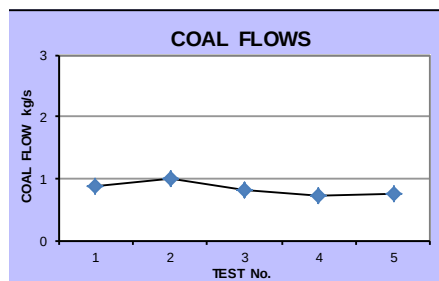
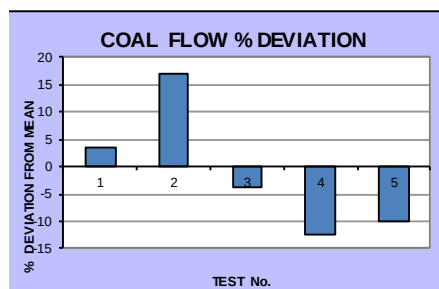
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
26	0.38	0.9	92	84.0	0.8110
27	0.32	1.0	92		0.8119
28	0.32	1.0	92		0.8119
29	0.38	1.0	92		0.8117
30	0.32	1.0	92		0.8119

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		SINGLE PIPE, 3 AXIS		TEST No.	26 to 30
PA FLOW (kg/s)	13.6	PF Pipe Diameter = 356 mm		DATE	17-08-15

Sampling time : 30 sec x 24 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
26	0.88	3.3	1.93	92	23.0	98.6	91.6	85.4	77.0
27	0.99	17.1	1.74	92	21.5	98.4	90.4	80.0	66.2
28	0.82	-3.7	1.74	92	21.5	98.6	95.6	91.8	83.8
29	0.74	-12.5	1.90	92	23.4	98.8	96.6	93.4	86.2
30	0.76	-10.1	1.74	92	21.5	98.4	93.2	88.2	80.6
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.6	93.7	87.8	78.3



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.9
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1098.7
MILL OUTLET TEMP.	(°C)	91.0
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	2
TEST No.	1 to 5
DATE	30-07-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-2-T01	3A-2-T02	3A-2-T03	3A-2-T04	3A-2-T05
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Masses in grams

TEST No.	1	2	3	4	5
container + sample	1332.0	1146.9	1377.5	1046.4	1144.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	1328.3	1143.2	1373.8	1042.7	1140.3
Average	1023.9				
% deviation from mean	29.7	11.6	34.2	1.8	11.4

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.8	58.8	58.9	58.7	59.0
% PF MOISTURE	2.0	2.0	1.8	2.2	1.7

SIEVING

50 grams sieved

TEST No.	1	2	3	4	5
Retained PF mass > 300 um	0.9	0.9	0.9	0.6	0.6
Retained PF mass > 150 um	4.2	3.2	3.3	3.0	3.6
Retained PF mass > 106 um	4.5	3.6	4.4	3.8	4.8
Retained PF mass > 75 um	6.0	5.0	6.3	5.5	6.4
Collected in the receiver	34.7	37.6	35.2	37.8	34.9
Sum totals	50.3	50.3	50.1	50.7	50.3

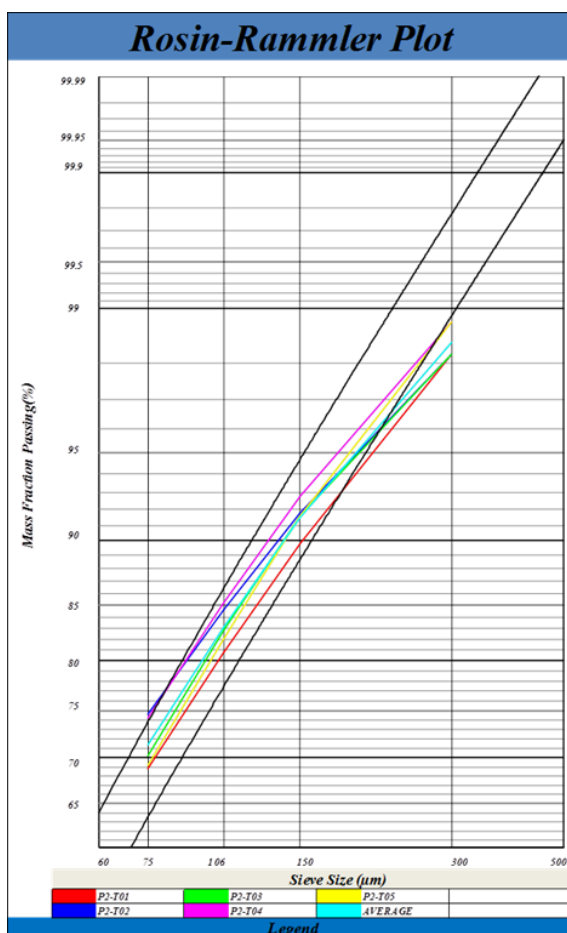
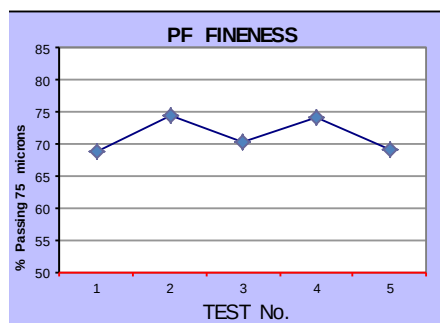
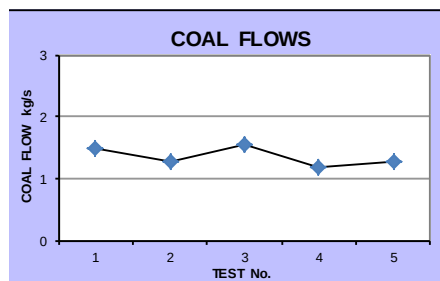
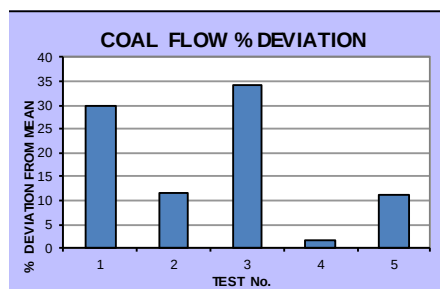
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.44	1.1	91	84.0	0.8144
2	0.48	1.2	91		0.8146
3	0.48	1.1	91		0.8139
4	0.44	1.1	91		0.8137
5	0.48	1.0	91		0.8133

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	2
TEST CONDITIONS : SINGLE PIPE, 3 AXIS				TEST No.	1 to 5
PA FLOW (kg/s)	13.9	PF Pipe Diameter = 356 mm		DATE	30-07-15

Sampling time : 30 sec x 24 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.50	29.7	2.08	91	24.8	98.2	89.8	80.8	68.8
2	1.29	11.6	2.14	91	26.3	98.2	91.8	84.6	74.6
3	1.55	34.2	2.14	91	26.3	98.2	91.6	82.8	70.2
4	1.18	1.8	2.05	91	25.2	98.8	92.8	85.2	74.2
5	1.29	11.4	2.14	91	26.3	98.8	91.6	82.0	69.2
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.4	91.9	83.6	71.9



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1104.9
MILL OUTLET TEMP.	(°C)	73.6
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	2
TEST No.	6 to 10
DATE	05-08-15

SINGLE PIPE, 3 AXIS

PF Pipe Diameter = 356 mm

Sampling time : 30 sec x 24 points

SAMPLE ID	3A-2-T06	3A-2-T07	3A-2-T08	3A-2-T09	3A-2-T10
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Masses in grams

TEST No.	6	7	8	9	10
container + sample	866.4	801.9	706.6	878.7	957.3
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	862.7	798.2	702.9	875.0	953.6
Average	1023.9				
% deviation from mean	-15.7	-22.0	-31.4	-14.5	-6.9

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.6	58.7	58.7	58.7	58.8
% PF MOISTURE	2.3	2.2	2.2	2.2	2.0

SIEVING

50 grams sieved

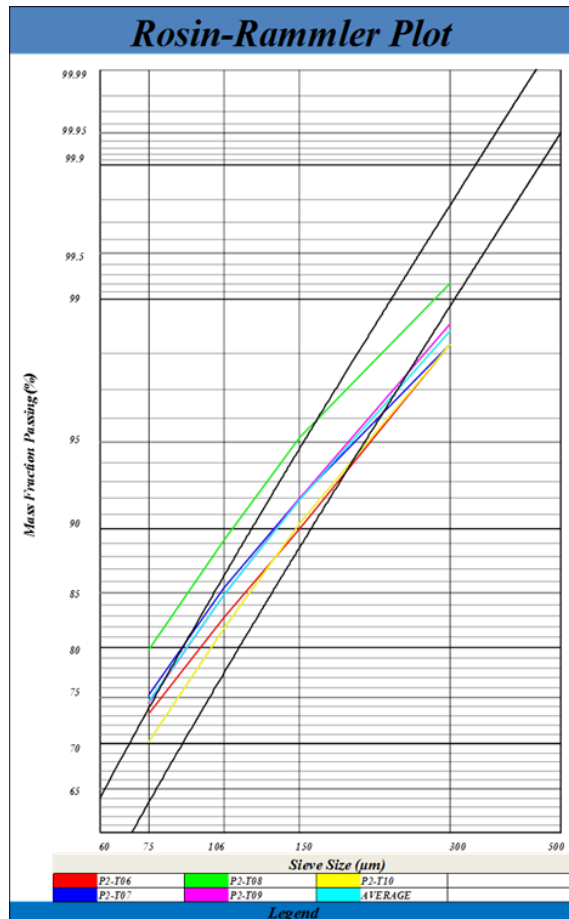
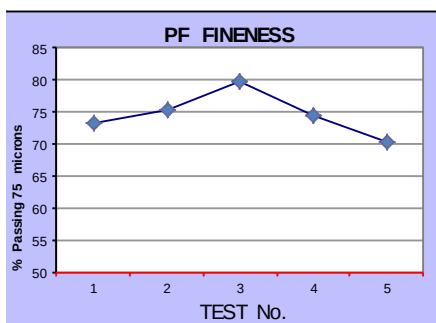
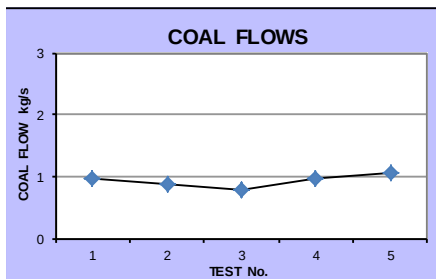
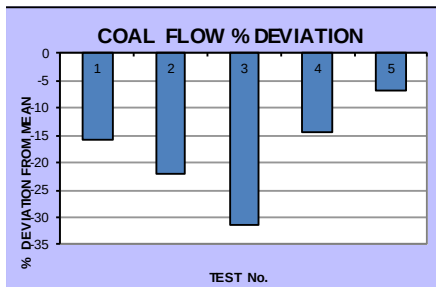
TEST No.	6	7	8	9	10
Retained PF mass > 300 um	0.9	0.9	0.4	0.7	0.9
Retained PF mass > 150 um	4.1	3.1	2.0	3.3	3.9
Retained PF mass > 106 um	3.6	3.3	3.0	3.6	4.3
Retained PF mass > 75 um	4.8	5.1	4.7	5.2	5.8
Collected in the receiver	36.9	37.9	40.5	37.5	35.1
Sum totals	50.3	50.3	50.6	50.3	50.0

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
6	0.36	0.8	90	84.0	0.8132
7	0.38	0.8	90		0.8132
8	0.38	0.8	90		0.8130
9	0.38	0.8	90		0.8132
10	0.38	0.8	90		0.8132

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	2
TEST CONDITIONS :		<u>SINGLE PIPE, 3 AXIS</u>		TEST No.	6 to 10
PA FLOW (kg/s) 13.7		PF Pipe Diameter = 356 mm		DATE	05-08-15
Sampling time : 30 sec x 24 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	0.97	-15.7	1.88	90	22.4	98.2	90.0	82.8	73.2
7	0.90	-22.0	1.90	90	23.4	98.2	92.0	85.4	75.2
8	0.79	-31.4	1.90	90	23.4	99.2	95.2	89.2	79.8
9	0.99	-14.5	1.90	90	23.4	98.6	92.0	84.8	74.4
10	1.07	-6.9	1.90	90	23.4	98.2	90.4	81.8	70.2
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.5	92.2	85.0	74.5



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	1
TEST No.	1 to 5
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
 Sampling time : 4 minutes

SAMPLE ID	RTP1-31	RTP1-32	RTP1-33	RTP1-34	RTP1-35
Masses in grams					
TEST No.	1	2	3	4	5
Container + sample	158.00	132.00	150.00	151.00	154.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	156.00	130.00	148.00	149.00	152.00
Average	150.07				
% deviation from mean	3.95	-13.37	-1.38	-0.71	1.29

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.42	58.41	58.50	58.53	58.54
% PF MOISTURE	2.64	2.65	2.51	2.46	2.44

SIEVING

50 grams sieved

TEST No.	1	2	3	4	5
Retained PF mass > 300 um	1.13	1.17	1.12	1.01	1.20
Retained PF mass > 150 um	4.24	4.95	4.30	4.16	4.51
Retained PF mass > 106 um	9.92	5.75	4.96	5.08	6.90
Retained PF mass > 75 um	5.98	7.44	6.56	9.84	6.87
Collected in the receiver	28.29	30.49	32.59	29.62	30.35
Sum totals	49.56	49.80	49.53	49.71	49.83

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
1	20.00	1.08	74.80	1.10	
2	20.00	1.08	74.80	1.10	nozzle blocked
3	20.00	1.08	74.80	1.10	
4	20.00	1.08	74.80	1.10	
5	20.00	1.08	74.80	1.10	

Power Station A PF SAMPLING TEST RESULTS

MILL **1B**

PF PIPE **1**

TEST CONDITIONS : **SINGLE PIPE, Rotoprobe**

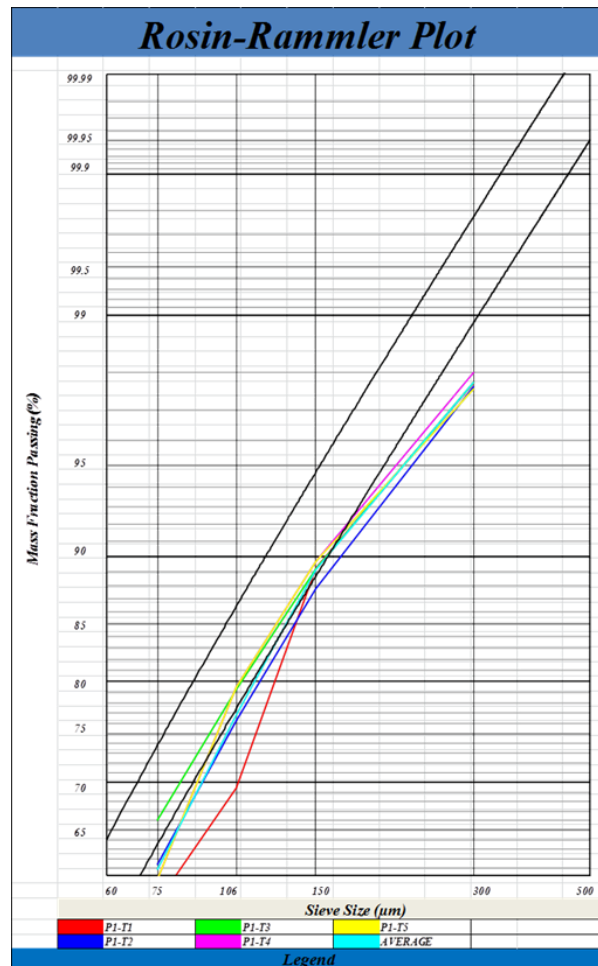
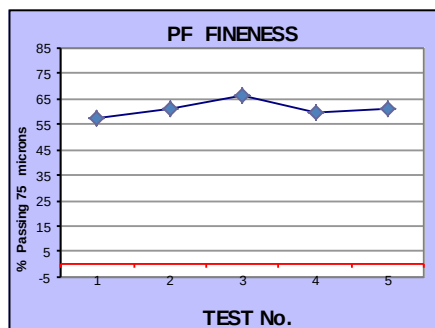
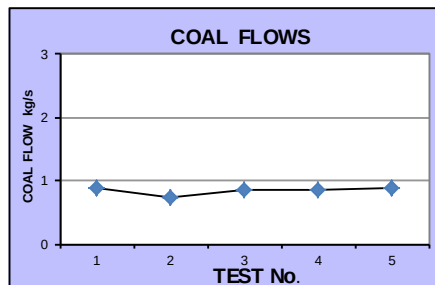
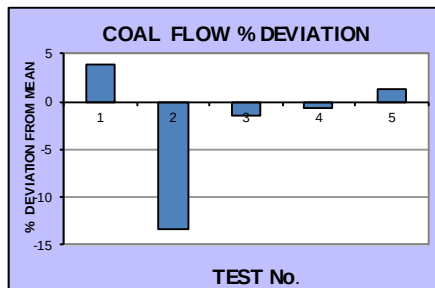
TEST No. **1 to 5**

PA FLOW (kg/s) **13.80** PF Pipe Diameter = **356 mm**

DATE **06-08-15**

Sampling time : 4 minutes

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	0.88	3.95	1.10	74.80	20.00	97.74	89.26	69.42	57.46
2	0.74	-13.37	1.10	74.80	20.00	97.66	87.76	76.26	61.38
3	0.84	-1.38	1.10	74.80	20.00	97.76	89.16	79.24	66.12
4	0.84	-0.71	1.10	74.80	20.00	97.98	89.66	79.50	59.82
5	0.87	1.29	1.10	74.80	20.00	97.60	88.58	74.78	61.04
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.75	88.82	77.46	62.11



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	1
TEST No.	6 to 10
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
 Sampling time : 4 minutes

SAMPLE ID	RTP1-36	RTP1-37	RTP1-38	RTP1-39	RTP1-40
Masses in grams					
TEST No.	6	7	8	9	10
Container + sample	158.00	152.00	156.00	157.00	146.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	156.00	150.00	154.00	155.00	144.00
Average	150.07				
% deviation from mean	3.95	-0.05	2.62	3.29	-4.04

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.54	58.53	58.52	58.46	58.44
% PF MOISTURE	2.44	2.46	2.47	2.58	2.60

SIEVING

50 grams sieved

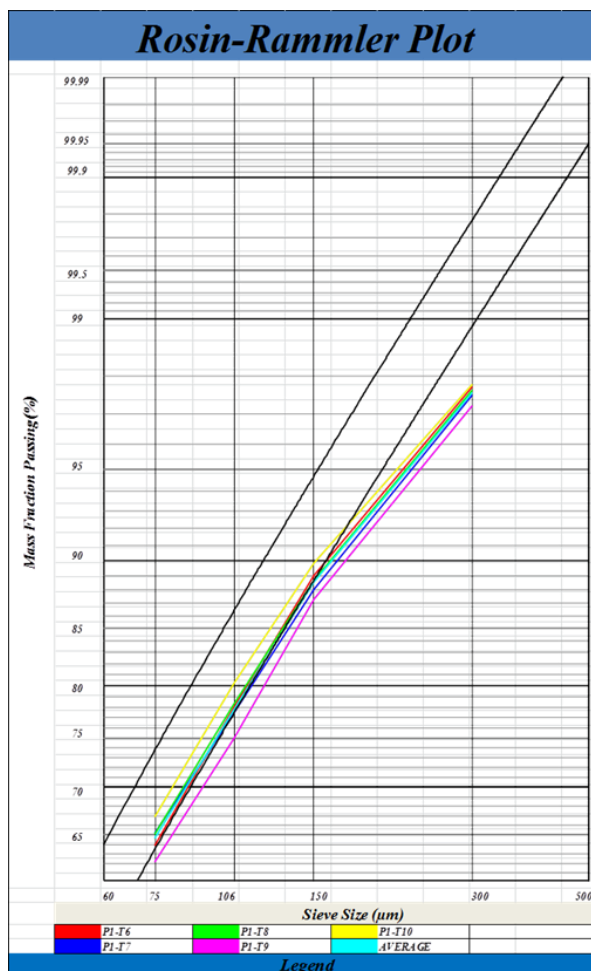
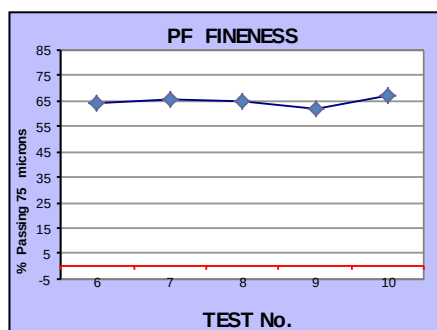
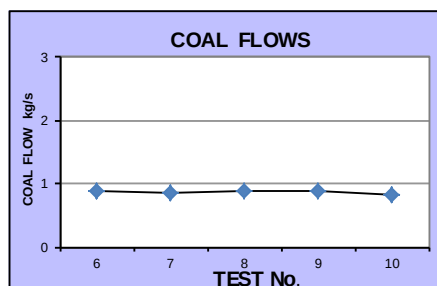
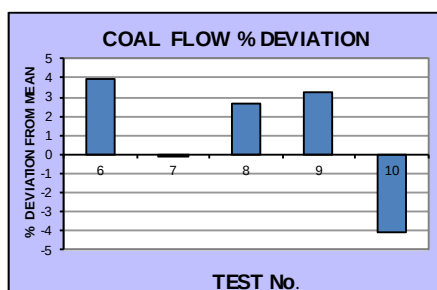
TEST No.	6	7	8	9	10
Retained PF mass > 300 um	1.13	1.24	1.17	1.38	1.10
Retained PF mass > 150 um	4.38	4.74	4.51	4.97	3.98
Retained PF mass > 106 um	5.47	5.29	5.17	6.17	4.80
Retained PF mass > 75 um	7.07	6.12	6.58	6.38	6.67
Collected in the receiver	31.81	32.59	32.50	31.27	33.50
Sum totals	49.86	49.98	49.93	50.17	50.05

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
6	20.00	1.08	74.80	1.10	
7	20.00	1.08	74.80	1.10	
8	20.00	1.08	74.80	1.10	
9	20.00	1.08	74.80	1.10	
10	20.00	1.08	74.80	1.10	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, Rotoprobe</u>		TEST No.	6 to 10
PA FLOW (kg/s) 13.80		PF Pipe Diameter = 356 mm		DATE	06-08-15
		Sampling time : 4 minutes			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	0.88	3.95	1.10	74.80	20.00	97.74	88.98	78.04	63.90
7	0.85	-0.05	1.10	74.80	20.00	97.52	88.04	77.46	65.22
8	0.88	2.62	1.10	74.80	20.00	97.66	88.64	78.30	65.14
9	0.88	3.29	1.10	74.80	20.00	97.24	87.30	74.96	62.20
10	0.82	-4.04	1.10	74.80	20.00	97.80	89.84	80.24	66.90
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.59	88.43	77.69	64.82



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	1
TEST No.	11 to 15
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
Sampling time : 4 minutes

SAMPLE ID	RTP1-41	RTP1-42	RTP1-43	RTP1-44	RTP1-45
Masses in grams					
TEST No.	11	12	13	14	15
Container + sample	163.00	156.00	159.00	154.00	155.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	161.00	154.00	157.00	152.00	153.00
Average	150.07				
% deviation from mean	7.28	2.62	4.62	1.29	1.95

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.51	58.48	58.50	58.47	58.46
% PF MOISTURE	2.48	2.54	2.50	2.56	2.58

SIEVING

50 grams sieved

TEST No.	11	12	13	14	15
Retained PF mass > 300 um	1.05	1.24	1.13	1.24	1.24
Retained PF mass > 150 um	4.82	4.87	4.47	4.82	4.84
Retained PF mass > 106 um	5.47	7.92	5.14	5.31	5.52
Retained PF mass > 75 um	6.85	8.79	9.23	6.23	8.19
Collected in the receiver	31.75	27.28	30.08	32.37	30.04
Sum totals	49.94	50.10	50.05	49.97	49.83

PF PIPE MEASUREMENTS

TEST	Velocity	g factor	Temp	Diff	Comment
No.					
	m/s		°C	kPa	
11	20.00	1.08	74.80	1.10	
12	20.00	1.08	74.80	1.10	
13	20.00	1.08	74.80	1.10	
14	20.00	1.08	74.80	1.10	
15	20.00	1.08	74.80	1.10	

Power Station A PF SAMPLING TEST RESULTS

MILL **1B**

PF PIPE **1**

TEST CONDITIONS : **SINGLE PIPE, Rotoprobe**

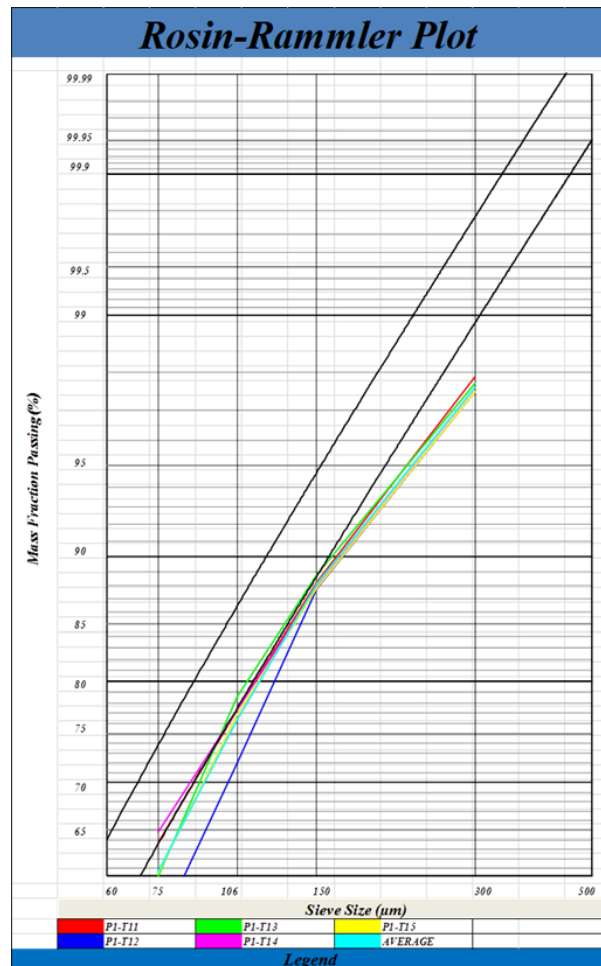
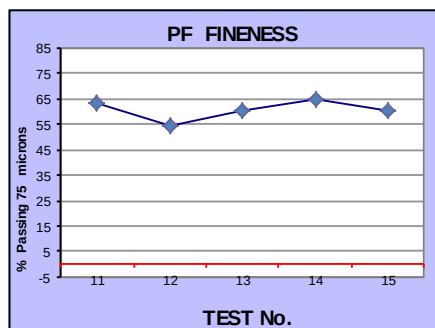
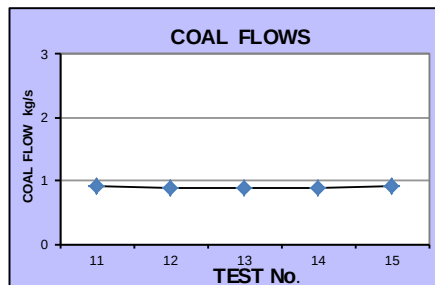
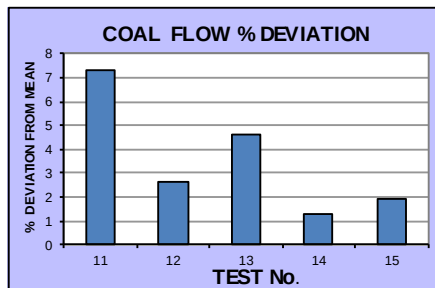
TEST No. **11 to 15**

PA FLOW (kg/s) **13.80** PF Pipe Diameter = **356 mm**

DATE **06-08-15**

Sampling time : 4 minutes

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
11	0.91	7.28	1.10	74.80	20.00	97.90	88.26	77.32	63.62
12	0.87	2.62	1.10	74.80	20.00	97.52	87.78	71.94	54.36
13	0.88	4.62	1.10	74.80	20.00	97.74	88.80	78.52	60.06
14	0.87	1.29	1.10	74.80	20.00	97.52	87.88	77.26	64.80
15	0.90	1.95	1.10	74.80	20.00	97.52	87.84	76.80	60.42
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.64	88.08	76.14	59.91



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	1
TEST No.	16 to 20
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
Sampling time : 4 minutes

SAMPLE ID	RTP1-46	RTP1-47	RTP1-48	RTP1-49	RTP1-50
Masses in grams					
TEST No.	16	17	18	19	20
Container + sample	140.00	153.00	152.00	150.00	154.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	138.00	151.00	150.00	148.00	152.00
Average	150.07				
% deviation from mean	-8.04	0.62	-0.05	-1.38	1.29

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.43	58.43	59.49	59.34	59.45
% PF MOISTURE	2.63	2.63	0.85	1.10	0.92

SIEVING

50 grams sieved

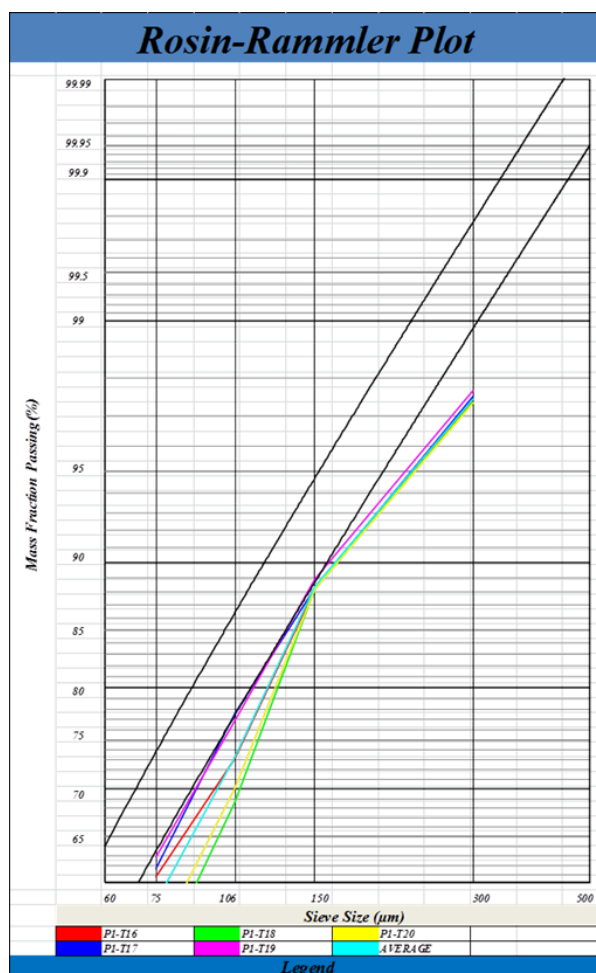
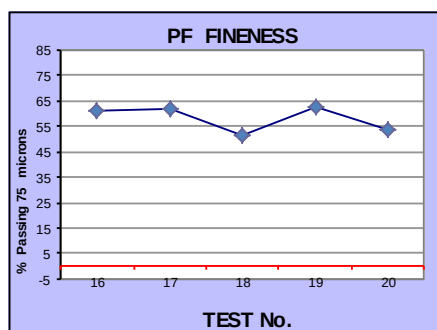
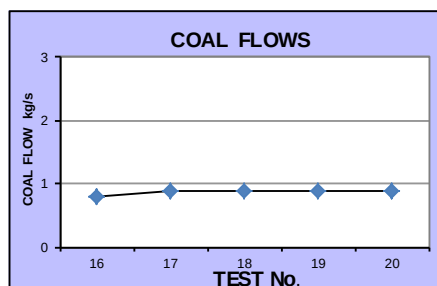
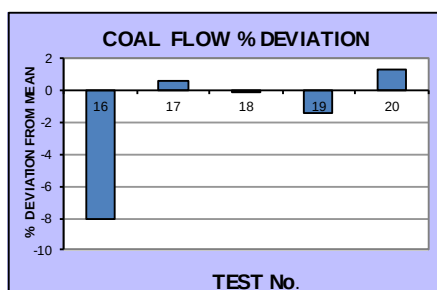
TEST No.	16	17	18	19	20
Retained PF mass > 300 um	1.29	1.23	1.30	1.15	1.31
Retained PF mass > 150 um	4.60	4.64	4.61	4.41	4.60
Retained PF mass > 106 um	7.53	5.34	9.75	5.98	9.03
Retained PF mass > 75 um	6.17	7.98	8.66	7.03	8.12
Collected in the receiver	30.45	30.78	25.67	31.55	26.92
Sum totals	50.04	49.97	49.99	50.12	49.98

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
16	20.00	1.08	74.80	1.10	
17	20.00	1.08	74.80	1.10	
18	20.00	1.08	74.80	1.10	
19	20.00	1.08	74.80	1.10	
20	20.00	1.08	74.80	1.10	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
TEST CONDITIONS :		SINGLE PIPE, Rotoprobe		PF PIPE	1
PA FLOW (kg/s) 13.80		PF Pipe Diameter = 356 mm		TEST No.	16 to 20
Sampling time : 4 minutes				DATE	06-08-15

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
16	0.80	-8.04	1.10	74.80	20.00	97.42	88.22	73.16	60.82
17	0.88	0.62	1.10	74.80	20.00	97.54	88.26	77.58	61.62
18	0.88	-0.05	1.10	74.80	20.00	97.40	88.18	68.68	51.36
19	0.87	-1.38	1.10	74.80	20.00	97.70	88.88	76.92	62.86
20	0.89	1.29	1.10	74.80	20.00	97.38	88.18	70.12	53.88
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.49	88.37	73.32	57.42



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	1
TEST No.	21 to 25
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
 Sampling time : 4 minutes

SAMPLE ID	RTP1-51	RTP1-52	RTP1-53	RTP1-54	RTP1-55
Masses in grams					
TEST No.	21	22	23	24	25
Container + sample	156.00	154.00	154.00	155.00	159.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	154.00	152.00	152.00	153.00	157.00
Average	150.07				
% deviation from mean	2.62	1.29	1.29	1.95	4.62

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.41	58.41	58.39	58.18	58.58
% PF MOISTURE	2.65	2.67	2.70	3.03	2.38

SIEVING

50 grams sieved

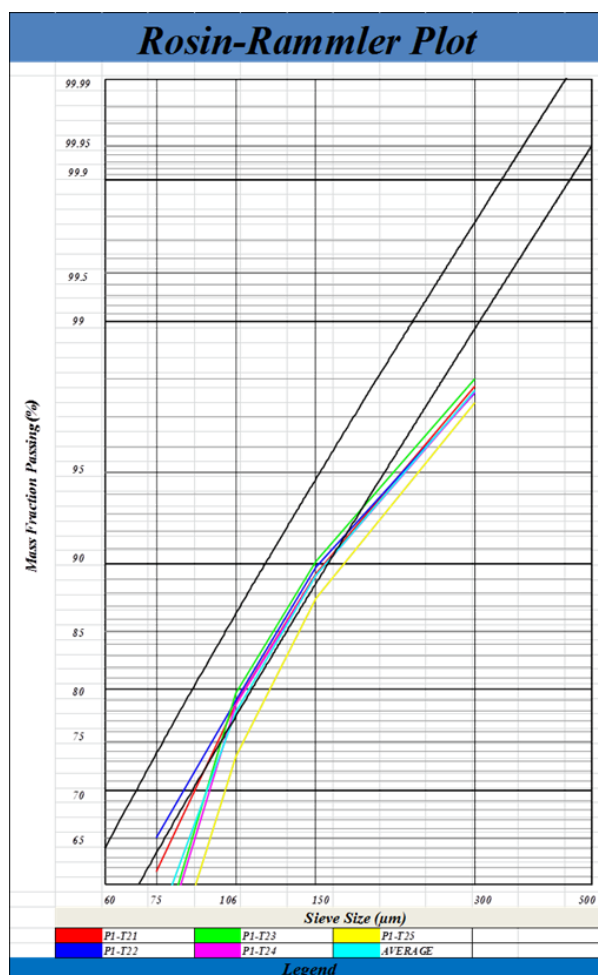
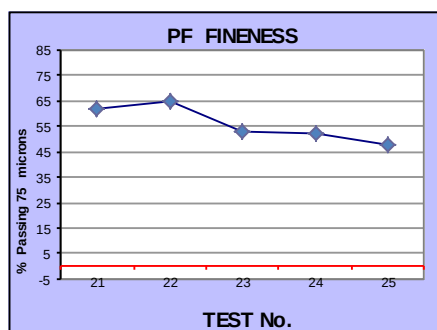
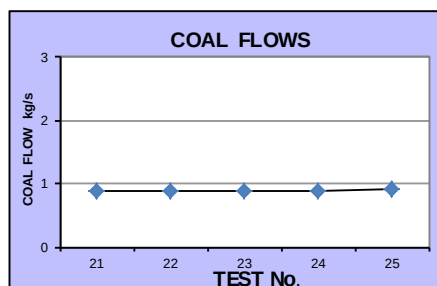
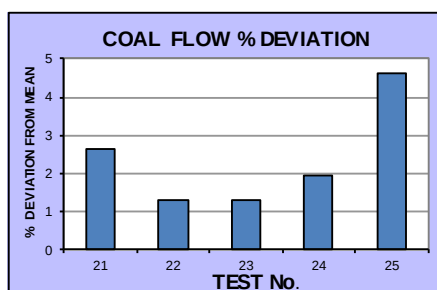
TEST No.	21	22	23	24	25
Retained PF mass > 300 um	1.09	1.17	1.01	1.16	1.30
Retained PF mass > 150 um	4.23	3.92	3.91	4.23	4.91
Retained PF mass > 106 um	5.38	5.43	5.25	5.33	7.04
Retained PF mass > 75 um	8.53	6.90	13.48	13.30	13.01
Collected in the receiver	30.58	32.34	26.34	25.56	23.40
Sum totals	49.81	49.76	49.99	49.58	49.66

PF PIPE MEASUREMENTS

TEST	Velocity	g factor	Temp	Diff	Comment
No.					
	m/s		°C	kPa	
21	20.00	1.08	74.80	1.10	
22	20.00	1.08	74.80	1.10	
23	20.00	1.08	74.80	1.10	
24	20.00	1.08	74.80	1.10	
25	20.00	1.08	74.80	1.10	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
TEST CONDITIONS :		SINGLE PIPE, Rotoprobe		PF PIPE	1
PA FLOW (kg/s) 13.80		PF Pipe Diameter = 356 mm		TEST No.	21 to 25
Sampling time : 4 minutes				DATE	06-08-15

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
21	0.89	2.62	1.10	74.80	20.00	97.82	89.36	78.60	61.54
22	0.89	1.29	1.10	74.80	20.00	97.66	89.82	78.96	65.16
23	0.89	1.29	1.10	74.80	20.00	97.98	90.16	79.66	52.70
24	0.89	1.95	1.10	74.80	20.00	97.68	89.22	78.56	51.96
25	0.92	4.62	1.10	74.80	20.00	97.40	87.58	73.50	47.48
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.71	89.18	77.64	54.26



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	1
TEST No.	26 to 30
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
Sampling time : 4 minutes

SAMPLE ID	RTP1-56	RTP1-57	RTP1-58	RTP1-59	RTP1-60
Masses in grams					
TEST No.	26	27	28	29	30
Container + sample	154.00	156.00	123.00	152.00	149.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	152.00	154.00	121.00	150.00	147.00
Average	150.07				
% deviation from mean	1.29	2.62	-19.37	-0.05	-2.05

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.60	58.59	58.53	58.49	58.54
% PF MOISTURE	2.33	2.35	2.45	2.52	2.43

SIEVING

50 grams sieved

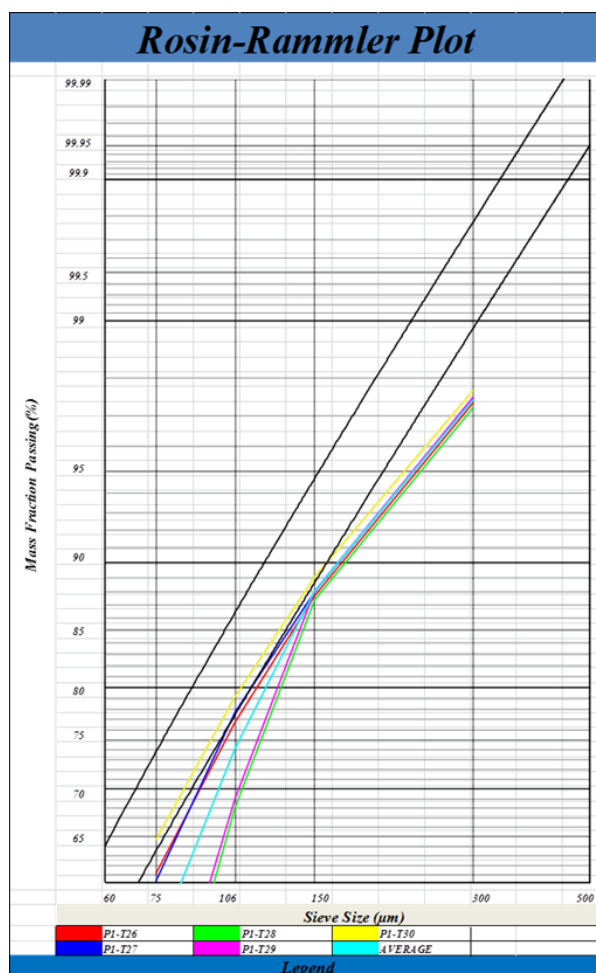
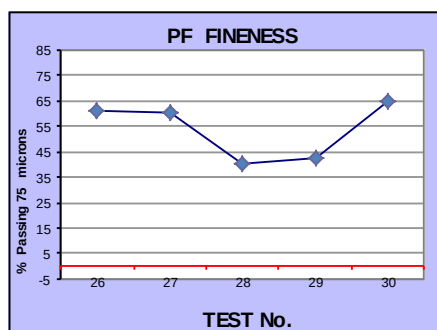
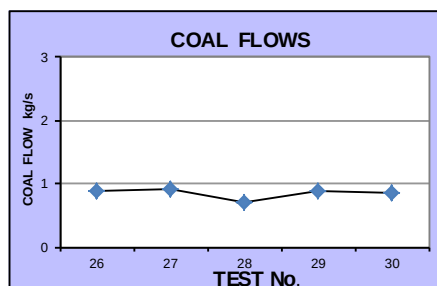
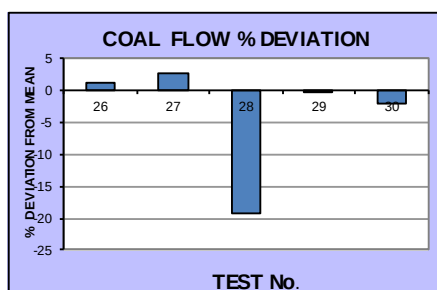
TEST No.	26	27	28	29	30
Retained PF mass > 300 um	1.31	1.26	1.38	1.24	1.15
Retained PF mass > 150 um	4.83	4.72	4.92	4.73	4.32
Retained PF mass > 106 um	5.48	5.18	9.68	9.54	4.96
Retained PF mass > 75 um	7.82	8.67	14.04	13.27	7.23
Collected in the receiver	30.45	30.01	19.54	20.85	32.05
Sum totals	49.89	49.84	49.56	49.63	49.71

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
26	20.00	1.08	74.80	1.10	
27	20.00	1.08	74.80	1.10	
28	20.00	1.08	74.80	1.10	
29	20.00	1.08	74.80	1.10	
30	20.00	1.08	74.80	1.10	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
TEST CONDITIONS :		SINGLE PIPE, Rotoprobe		PF PIPE	1
PA FLOW (kg/s) 13.80		PF Pipe Diameter = 356 mm		TEST No.	26 to 30
Sampling time : 4 minutes				DATE	06-08-15

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
26	0.89	1.29	1.10	74.80	20.00	97.38	87.72	76.76	61.12
27	0.90	2.62	1.10	74.80	20.00	97.48	88.04	77.68	60.34
28	0.71	-19.37	1.10	74.80	20.00	97.24	87.40	68.04	39.96
29	0.88	-0.05	1.10	74.80	20.00	97.52	88.06	68.98	42.44
30	0.86	-2.05	1.10	74.80	20.00	97.70	89.06	79.14	64.68
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.47	88.17	73.73	52.44



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	2
TEST No.	1 to 5
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
Sampling time : 4 minutes

SAMPLE ID	RTP2-9	RTP2-12	RTP2-13	RTP2-14	RTP2-15
Masses in grams					
TEST No.	1	2	3	4	5
Container + sample	177.00	185.00	181.00	191.00	182.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	175.00	183.00	179.00	189.00	180.00
Average	180.90				
% deviation from mean	-3.26	1.16	-1.05	4.48	-0.50

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.41	58.32	58.20	58.36	58.39
% PF MOISTURE	2.65	2.80	3.02	2.73	2.70

SIEVING

50 grams sieved

TEST No.	1	2	3	4	5
Retained PF mass > 300 um	1.50	1.26	1.20	1.54	1.43
Retained PF mass > 150 um	6.28	5.66	4.94	6.74	6.31
Retained PF mass > 106 um	10.22	6.06	8.66	6.77	6.94
Retained PF mass > 75 um	9.05	13.07	9.28	13.69	13.30
Collected in the receiver	23.01	23.46	25.56	20.96	21.69
Sum totals	50.06	49.51	49.64	49.70	49.67

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
1	21.00	1.11	70.50	1.30	
2	21.00	1.11	70.50	1.30	
3	21.00	1.11	70.50	1.30	
4	21.00	1.11	70.50	1.30	
5	21.00	1.11	70.50	1.30	

Power Station A PF SAMPLING TEST RESULTS

MILL **1B**

PF PIPE **2**

TEST CONDITIONS : **SINGLE PIPE, Rotoprobe**

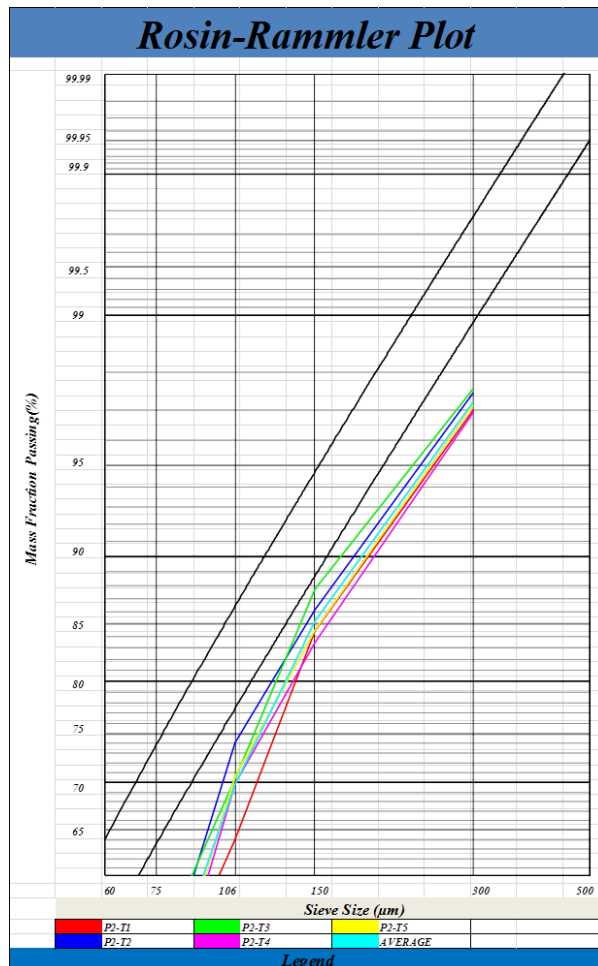
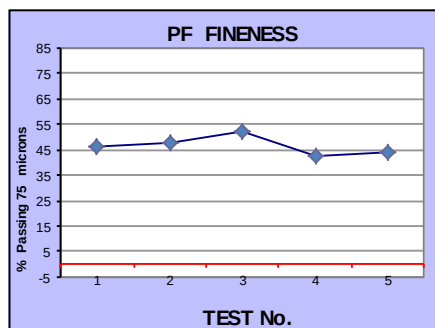
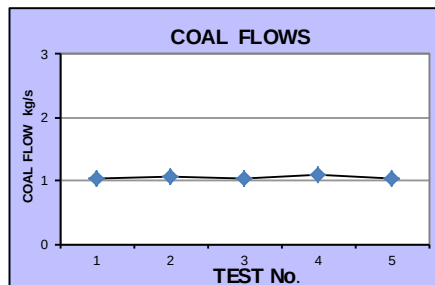
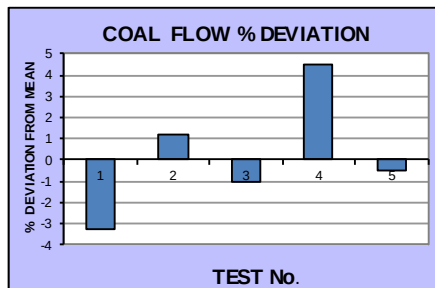
TEST No. **1 to 5**

PA FLOW (kg/s) **13.80** PF Pipe Diameter = **356 mm**

DATE **06-08-15**

Sampling time : 4 minutes

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.03	-3.26	1.30	70.50	21.00	97.00	84.44	64.00	45.90
2	1.08	1.16	1.30	70.50	21.00	97.48	86.16	74.04	47.90
3	1.04	-1.05	1.30	70.50	21.00	97.60	87.72	70.40	51.84
4	1.10	4.48	1.30	70.50	21.00	96.92	83.44	69.90	42.52
5	1.04	-0.50	1.30	70.50	21.00	97.14	84.52	70.64	44.04
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.23	85.44	71.25	46.53



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.50	kg/s
COAL FLOW B	8.40	kg/s

MILL	1B
PF PIPE	2
TEST No.	6 to 10
DATE	06-08-15

SINGLE PIPE, Rotoprobe
PF Pipe Diameter = 356 mm
Sampling time : 4 minutes

SAMPLE ID	RTP2-16	RTP2-17	RTP2-18	RTP2-19	RTP2-20
Masses in grams					
TEST No.	6	7	8	9	10
Container + sample	184.00	181.00	182.00	179.00	187.00
Mass of Container	2.00	2.00	2.00	2.00	2.00
Mass of Sample	182.00	179.00	180.00	177.00	185.00
Average	180.90				
% deviation from mean	0.61	-1.05	-0.50	-2.16	2.27

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour					
DRY MASS grams	58.42	58.37	58.50	58.89	58.86
% PF MOISTURE	2.63	2.72	2.52	1.85	1.92

SIEVING

50 grams sieved

TEST No.	6	7	8	9	10
Retained PF mass > 300 um	1.48	1.74	1.66	1.53	1.45
Retained PF mass > 150 um	6.67	6.87	6.88	6.76	6.43
Retained PF mass > 106 um	6.91	7.27	6.75	7.25	6.85
Retained PF mass > 75 um	15.45	15.94	11.92	12.37	13.26
Collected in the receiver	19.25	18.04	22.51	21.86	21.85
Sum totals	49.76	49.86	49.72	49.77	49.84

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
6	21.00	1.11	70.50	1.30	
7	21.00	1.11	70.50	1.30	
8	21.00	1.11	70.50	1.30	
9	21.00	1.11	70.50	1.30	
10	21.00	1.11	70.50	1.30	

Power Station A PF SAMPLING TEST RESULTS

MILL **1B**

PF PIPE **2**

TEST CONDITIONS : **SINGLE PIPE, Rotoprobe**

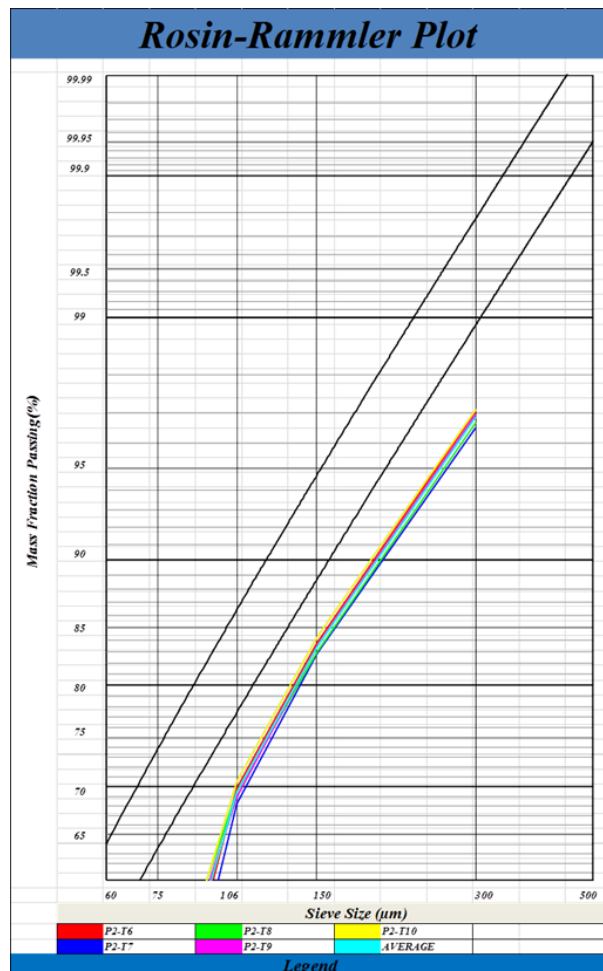
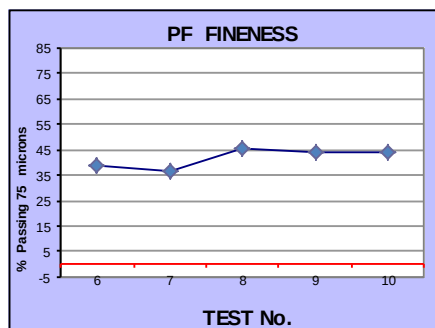
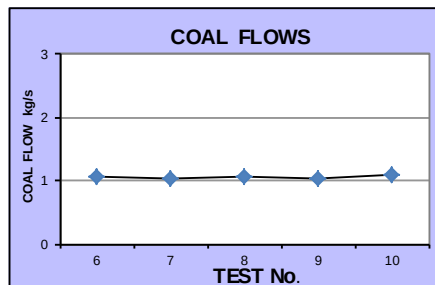
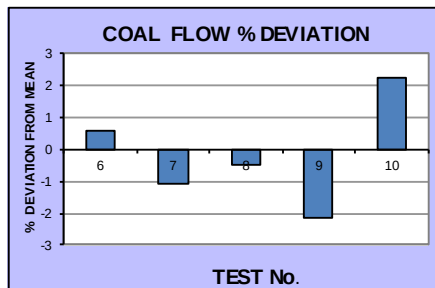
TEST No. **6 to 10**

PA FLOW (kg/s) **13.80** PF Pipe Diameter = **356 mm**

DATE **06-08-15**

Sampling time : 4 minutes

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	1.06	0.61	1.30	70.50	21.00	97.04	83.70	69.88	38.98
7	1.04	-1.05	1.30	70.50	21.00	96.52	82.78	68.24	36.36
8	1.05	-0.50	1.30	70.50	21.00	96.68	82.92	69.42	45.58
9	1.03	-2.16	1.30	70.50	21.00	96.94	83.42	68.92	44.18
10	1.08	2.27	1.30	70.50	21.00	97.10	84.24	70.54	44.02
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						96.86	83.35	69.29	42.55



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	96.0
MILL POWER	(kW)	1143.6
MILL OUTLET TEMP.	(°C)	79.1
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	1
TEST No.	1 to 5
DATE	04-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-1-T01	TP-1-T02	TP-1-T03	TP-1-T04	TP-1-T05
Masses in grams					
TEST No.	1	2	3	4	5
container + sample	826.1	810.3	830.2	802.0	680.1
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	822.4	806.6	826.5	798.3	676.4
Average	699.9				
% deviation from mean	17.5	15.3	18.1	14.1	-3.4

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.9	58.9	58.8	58.8
% PF MOISTURE	2.2	1.8	1.8	2.0	2.0

SIEVING

50 grams sieved

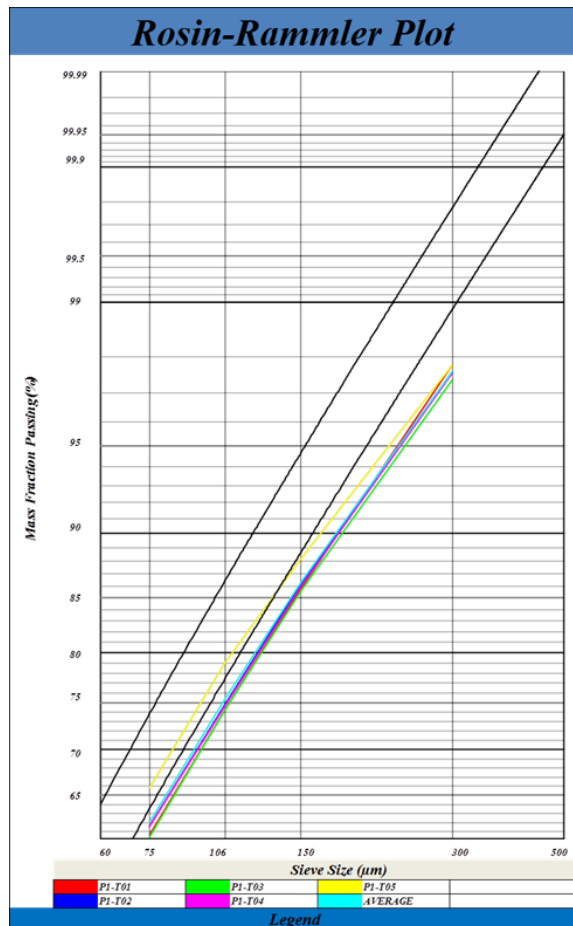
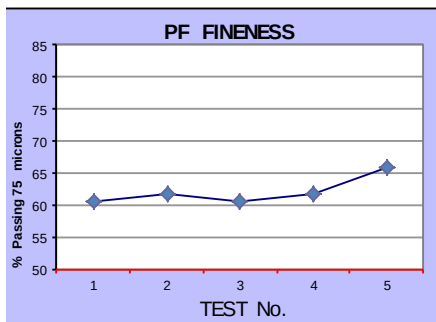
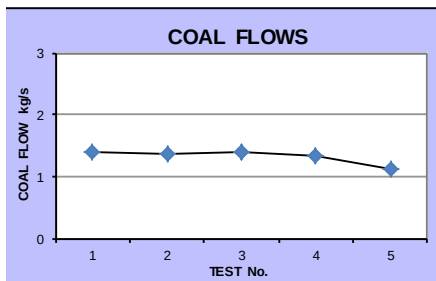
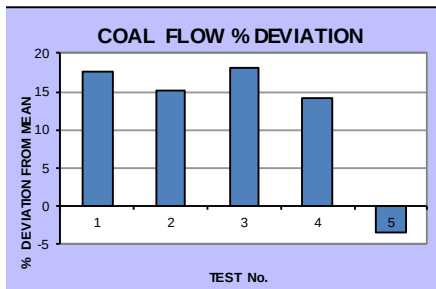
TEST No.	1	2	3	4	5
Retained PF mass > 300 um	1.1	1.2	1.3	1.2	1.1
Retained PF mass > 150 um	6.0	5.7	5.9	5.8	4.8
Retained PF mass > 106 um	5.8	5.7	5.7	5.7	4.6
Retained PF mass > 75 um	6.8	6.6	6.9	6.5	6.6
Collected in the receiver	30.5	31.1	30.5	31.1	33.1
Sum totals	50.2	50.3	50.3	50.3	50.2

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.32	0.8	79	84.0	0.8390
2	0.32	0.8	79		0.8390
3	0.32	0.9	79		0.8392
4	0.32	0.8	79		0.8390
5	0.32	0.8	79		0.8388

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	1 to 5
PA FLOW (kg/s) 13.8		PF Pipe Diameter = 356 mm		DATE	04-08-15
Sampling time : 15 sec x 32 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.39	17.5	1.77	79	21.1	97.8	85.8	74.2	60.6
2	1.36	15.3	1.77	79	21.1	97.6	86.2	74.8	61.6
3	1.40	18.1	1.77	79	21.1	97.4	85.6	74.2	60.4
4	1.35	14.1	1.77	79	21.1	97.6	86.0	74.6	61.6
5	1.14	-3.4	1.77	79	21.1	97.8	88.2	79.0	65.8
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.6	86.4	75.5	62.2



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	96.0
MILL POWER	(kW)	1143.6
MILL OUTLET TEMP.	(°C)	79.1
COAL FLOW A	(kg/s)	8.0
COAL FLOW B	(kg/s)	8.0

MILL	1B
PF PIPE	1
TEST No.	6 to 10
DATE	04-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-1-T06	TP-1-T07	TP-1-T08	TP-1-T09	TP-1-T10
Masses in grams					
TEST No.	6	7	8	9	10
container + sample	823.1	771.0	793.3	807.1	697.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	819.4	767.3	789.6	803.4	693.3
Average	699.9				
% deviation from mean	17.1	9.6	12.8	14.8	-0.9

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.9	58.9	58.6	58.8
% PF MOISTURE	1.8	1.8	1.8	2.3	2.0

SIEVING

50 grams sieved

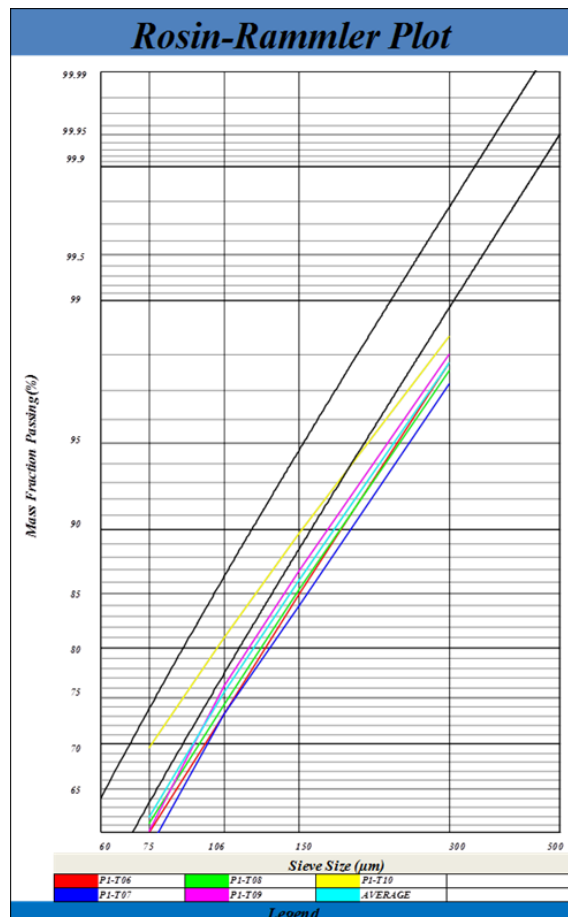
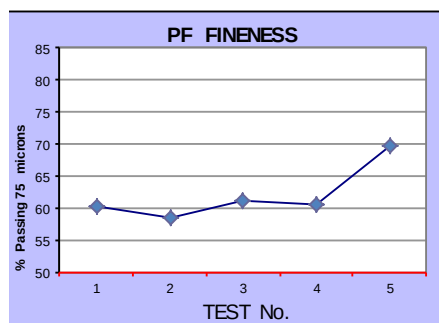
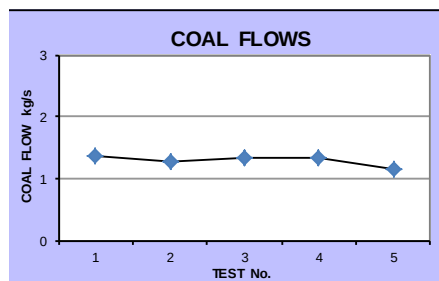
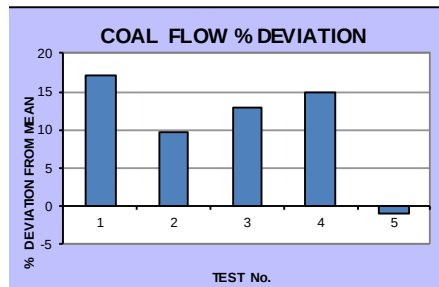
TEST No.	6	7	8	9	10
Retained PF mass > 300 um	1.1	1.4	1.2	1.0	0.8
Retained PF mass > 150 um	6.4	6.6	6.1	5.5	4.3
Retained PF mass > 106 um	5.9	5.4	5.6	5.4	4.4
Retained PF mass > 75 um	6.5	7.4	6.5	7.9	5.7
Collected in the receiver	30.1	29.5	30.7	30.3	35.1
Sum totals	50.0	50.3	50.1	50.1	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
6	0.32	0.8	79	84.0	0.8390
7	0.32	0.8	79		0.8388
8	0.32	0.8	79		0.8390
9	0.32	0.8	79		0.8390
10	0.32	0.8	79		0.8388

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	6 to 10
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 356 mm		DATE	04-08-15
		Sampling time : 15 sec x 32 points			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	1.38	17.1	1.77	79	21.1	97.8	85.0	73.2	60.2
7	1.30	9.6	1.77	79	21.1	97.2	84.0	73.2	58.4
8	1.33	12.8	1.77	79	21.1	97.6	85.4	74.2	61.2
9	1.36	14.8	1.77	79	21.1	98.0	87.0	76.2	60.4
10	1.17	-0.9	1.77	79	21.1	98.4	89.8	81.0	69.6
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.8	86.5	76.0	62.2



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1108.1
MILL OUTLET TEMP.	(°C)	72.1
COAL FLOW A	(kg/s)	8.4
COAL FLOW B	(kg/s)	8.3

MILL	1B
PF PIPE	1
TEST No.	11 to 15
DATE	06-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-1-T11	TP-1-T12	TP-1-T13	TP-1-T14	TP-1-T15
Masses in grams					
TEST No.	11	12	13	14	15
container + sample	728.0	752.8	721.4	751.3	697.9
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	724.3	749.1	717.7	747.6	694.2
Average	699.9				
% deviation from mean	3.5	7.0	2.5	6.8	-0.8

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.2	58.4	58.3	58.4	58.4
% PF MOISTURE	3.0	2.7	2.8	2.7	2.7

SIEVING

50 grams sieved

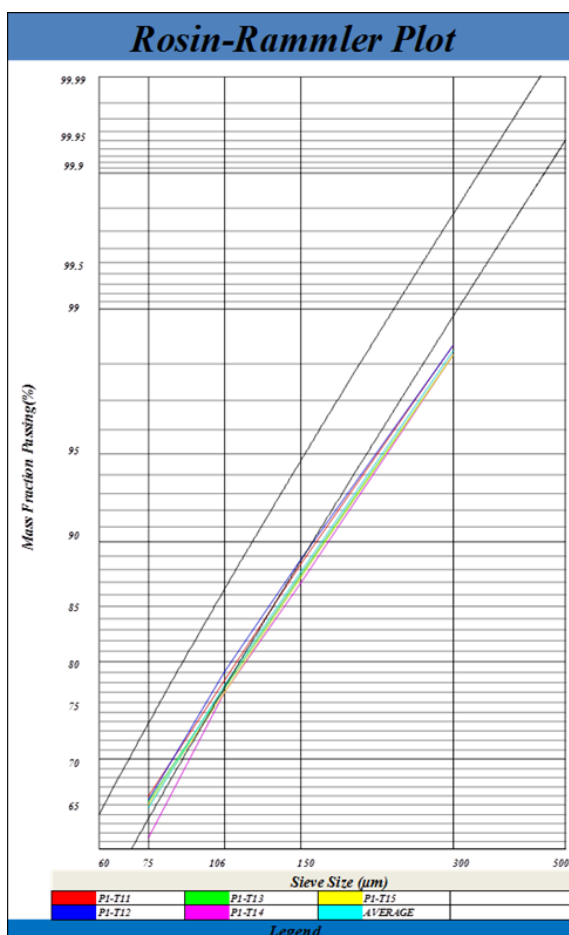
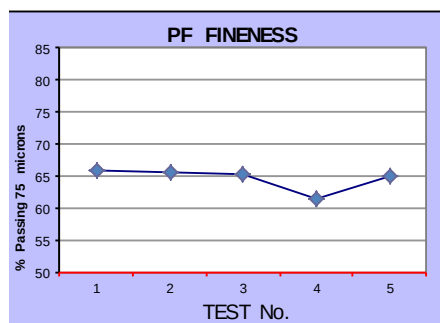
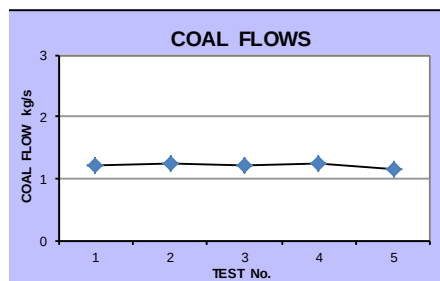
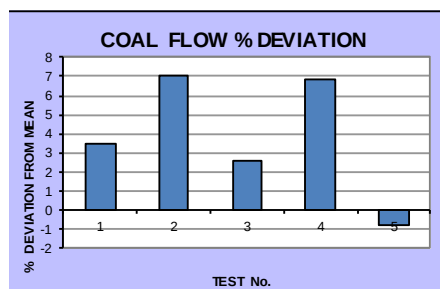
TEST No.	11	12	13	14	15
Retained PF mass > 300 um	0.8	0.8	0.9	0.9	0.9
Retained PF mass > 150 um	5.0	4.8	5.3	5.6	5.4
Retained PF mass > 106 um	5.1	4.9	5.1	5.0	5.2
Retained PF mass > 75 um	6.1	6.7	6.0	7.8	6.0
Collected in the receiver	33.0	32.9	32.8	30.9	32.5
Sum totals	50.0	50.1	50.1	50.2	50.0

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
11	0.34	0.8	70	84.0	0.8604
12	0.32	0.8	70		0.8607
13	0.34	0.8	70		0.8611
14	0.32	0.8	70		0.8604
15	0.34	0.8	70		0.8604

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	11 to 15
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 356 mm		DATE	06-08-15
Sampling time : 15 sec x 32 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
11	1.22	3.5	1.83	70	21.8	98.4	88.4	78.2	66.0
12	1.27	7.0	1.80	70	20.9	98.4	88.8	79.0	65.6
13	1.21	2.5	1.85	70	21.5	98.2	87.6	77.4	65.4
14	1.26	6.8	1.80	70	20.9	98.2	87.0	77.0	61.4
15	1.17	-0.8	1.85	70	21.5	98.2	87.4	77.0	65.0
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.3	87.7	77.6	64.3



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.6
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1119.2
MILL OUTLET TEMP.	(°C)	83.0
COAL FLOW A	(kg/s)	8.9
COAL FLOW B	(kg/s)	8.6

MILL	1B
PF PIPE	1
TEST No.	16 to 20
DATE	11-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-1-T16	TP-1-T17	TP-1-T18	TP-1-T19	TP-1-T20
Masses in grams					
TEST No.	16	17	18	19	20
container + sample	675.4	545.8	505.2	443.1	462.7
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	671.7	542.1	501.5	439.4	459.0
Average	699.9				
% deviation from mean	-4.0	-22.5	-28.3	-37.2	-34.4

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.6	58.7	58.8	58.7	58.7
% PF MOISTURE	2.3	2.2	2.0	2.2	2.2

SIEVING

50 grams sieved

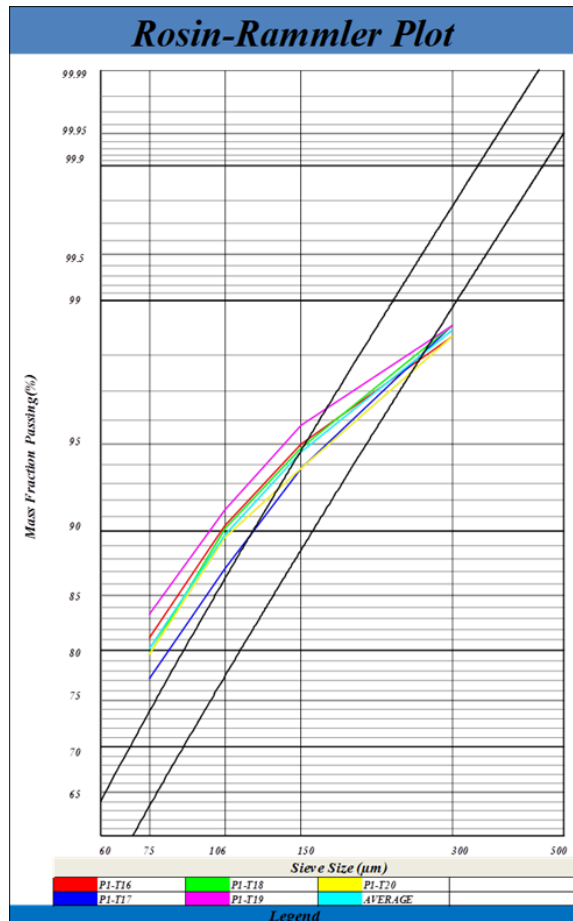
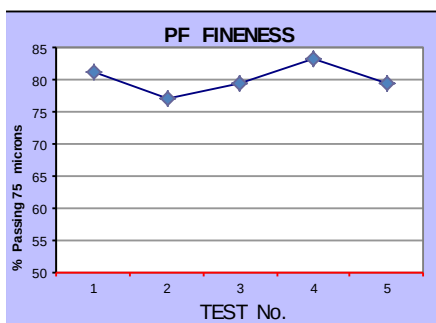
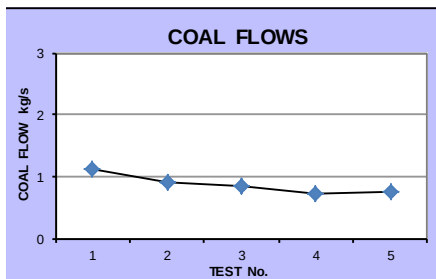
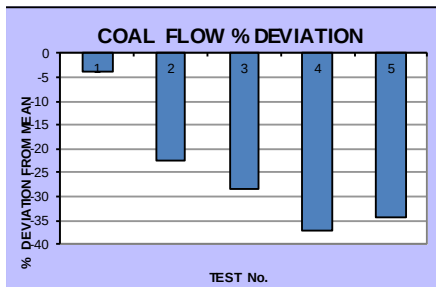
TEST No.	16	17	18	19	20
Retained PF mass > 300 um	0.8	0.7	0.7	0.7	0.8
Retained PF mass > 150 um	1.7	2.4	1.9	1.4	2.3
Retained PF mass > 106 um	2.3	3.3	2.3	2.2	2.1
Retained PF mass > 75 um	4.6	5.0	5.3	4.0	5.0
Collected in the receiver	40.7	38.7	39.9	42.1	40.1
Sum totals	50.1	50.1	50.1	50.4	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
16	0.28	0.6	80	84.0	0.8349
17	0.28	0.6	80		0.8343
18	0.28	0.6	80		0.8341
19	0.28	0.6	80		0.8347
20	0.28	0.6	80		0.8349

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	16 to 20
PA FLOW (kg/s)	13.6	PF Pipe Diameter = 356 mm		DATE	11-08-15
		Sampling time : 15 sec x 32 points			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
16	1.14	-4.0	1.66	80	19.8	98.4	95.0	90.4	81.2
17	0.92	-22.5	1.65	80	19.8	98.6	93.8	87.2	77.2
18	0.85	-28.3	1.65	80	19.8	98.6	94.8	90.2	79.6
19	0.74	-37.7	1.65	80	19.8	98.6	95.8	91.4	83.4
20	0.78	-34.4	1.65	80	19.8	98.4	93.8	89.6	79.6
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.5	94.5	89.5	79.8



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1119.2
MILL OUTLET TEMP.	(°C)	92.4
COAL FLOW A	(kg/s)	8.7
COAL FLOW B	(kg/s)	8.7

MILL	1B
PF PIPE	1
TEST No.	21 to 25
DATE	11-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-1-T21	TP-1-T22	TP-1-T23	TP-1-T24	TP-1-T25
Masses in grams					
TEST No.	21	22	23	24	25
container + sample	685.0	669.4	660.5	622.7	643.6
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	681.3	665.7	656.8	619.0	639.9
Average	699.9				
% deviation from mean	-2.7	-4.9	-6.2	-11.6	-8.6

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.9	58.6	58.6	58.5
% PF MOISTURE	1.8	1.8	2.3	2.3	2.5

SIEVING

50 grams sieved

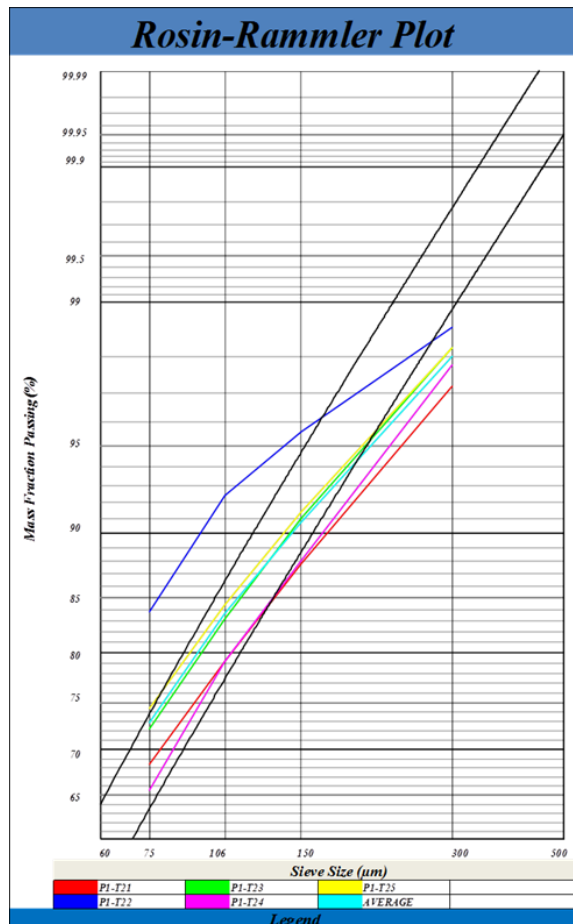
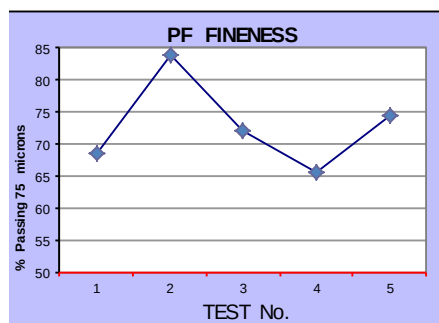
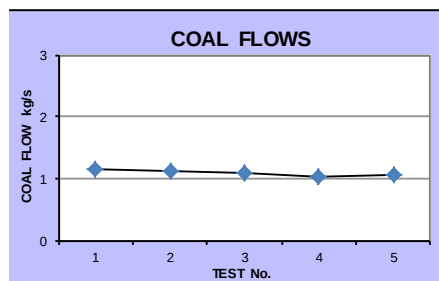
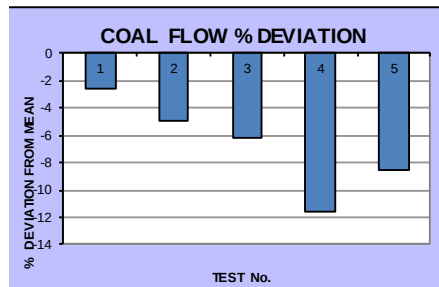
TEST No.	21	22	23	24	25
Retained PF mass > 300 um	1.4	0.7	0.9	1.1	0.9
Retained PF mass > 150 um	4.7	1.5	3.6	4.9	3.4
Retained PF mass > 106 um	4.3	1.6	3.9	4.4	3.5
Retained PF mass > 75 um	5.4	4.3	5.5	6.8	5.0
Collected in the receiver	34.4	42.0	36.3	33.1	37.4
Sum totals	50.2	50.1	50.2	50.3	50.2

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
21	0.28	0.5	82	84.0	0.8292
22	0.28	0.6	82		0.8300
23	0.32	0.8	82		0.8321
24	0.34	0.8	82		0.8320
25	0.34	0.9	82		0.8323

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	21 to 25
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 356 mm		DATE	11-08-15
Sampling time : 15 sec x 32 points					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
21	1.15	-2.7	1.66	82	19.8	97.2	87.8	79.2	68.4
22	1.12	-4.9	1.65	82	19.9	98.6	95.6	92.4	83.8
23	1.11	-6.2	1.77	82	21.2	98.2	91.0	83.2	72.2
24	1.05	-11.6	1.82	82	21.9	97.8	88.0	79.2	65.6
25	1.08	-8.6	1.82	82	21.9	98.2	91.4	84.4	74.4
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.0	91.6	84.9	74.2



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	14.4
MILL DEMAND	(%)	90.1
MILL POWER	(kW)	1056.0
MILL OUTLET TEMP.	(°C)	92.2
COAL FLOW A	(kg/s)	9.9
COAL FLOW B	(kg/s)	9.5

MILL	1B
PF PIPE	1
TEST No.	25 to 30
DATE	17-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-1-T26	TP-1-T27	TP-1-T28	TP-1-T29	TP-1-T30
Masses in grams					
TEST No.	26	27	28	29	30
container + sample	776.3	834.0	763.8	637.1	690.6
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	772.6	830.3	760.1	633.4	686.9
Average	699.9				
% deviation from mean	10.4	18.6	8.6	-9.5	-1.9

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.8	59.0	59.0	59.0
% PF MOISTURE	2.2	2.0	1.7	1.7	1.7

SIEVING

50 grams sieved

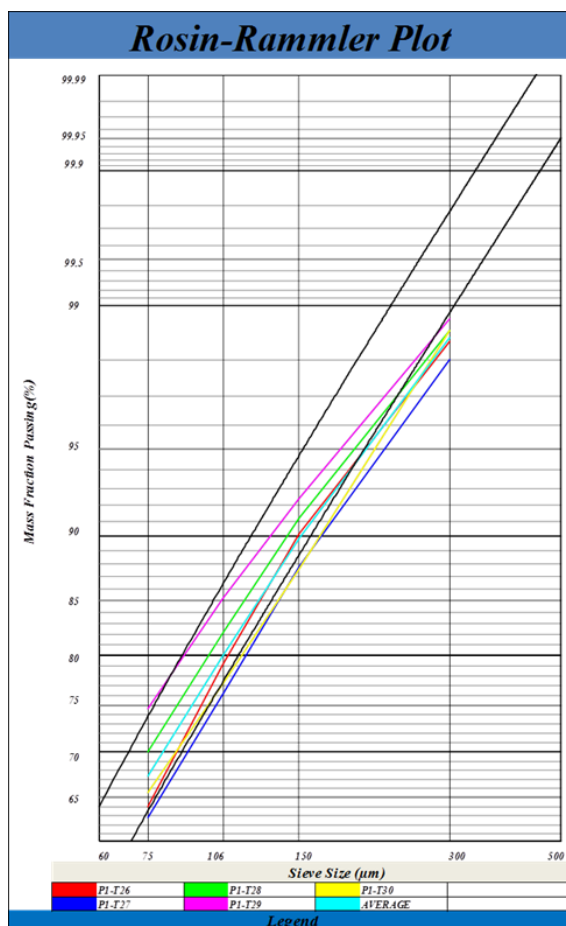
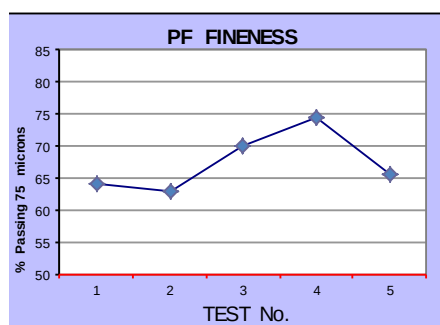
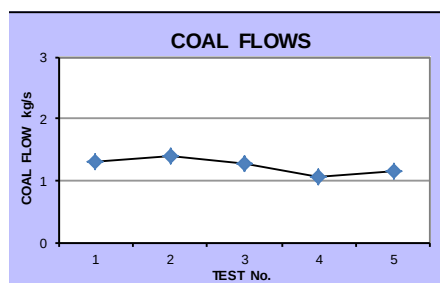
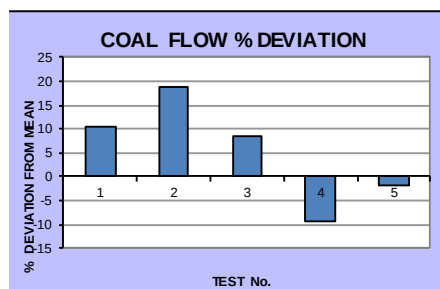
TEST No.	26	27	28	29	30
Retained PF mass > 300 um	0.8	1.0	0.7	0.6	0.7
Retained PF mass > 150 um	4.1	5.1	3.7	3.2	5.5
Retained PF mass > 106 um	5.5	5.8	4.5	3.6	5.2
Retained PF mass > 75 um	7.6	6.7	6.1	5.3	5.8
Collected in the receiver	32.3	32.1	35.3	37.6	33.1
Sum totals	50.3	50.7	50.3	50.3	50.3

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
26	0.36	0.8	80	84.0	0.8369
27	0.38	0.9	80		0.8379
28	0.36	1.0	80		0.8388
29	0.34	1.1	80		0.8390
30	0.38	1.1	80		0.8392

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	25 to 30
PA FLOW (kg/s)	14.4	PF Pipe Diameter = 356 mm		DATE	17-08-15
		Sampling time : 15 sec x 32 points			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
26	1.31	10.4	1.88	80	22.4	98.4	90.2	79.2	64.0
27	1.40	18.6	1.93	80	23.0	98.0	87.8	76.2	62.8
28	1.28	8.6	1.88	80	22.4	98.6	91.2	82.2	70.0
29	1.07	-9.5	1.83	80	21.8	98.8	92.4	85.2	74.6
30	1.16	-1.9	1.93	80	23.0	98.6	87.6	77.2	65.6
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.5	89.6	80.0	67.9



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1104.9
MILL OUTLET TEMP.	(°C)	73.6
COAL FLOW A	(kg/s)	8.8
COAL FLOW B	(kg/s)	8.7

MILL	1B
PF PIPE	2
TEST No.	1 to 5
DATE	05-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-2-T01	TP-2-T02	TP-2-T03	TP-2-T04	TP-2-T05
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Masses in grams

TEST No.	1	2	3	4	5
container + sample	881.1	848.3	815.8	764.9	755.0
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	877.4	844.6	812.1	761.2	751.3
Average	753.6				
% deviation from mean	16.4	12.1	7.8	1.0	-0.3

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	59.1	59.2	59.0	59.1	59.0
% PF MOISTURE	1.5	1.3	1.7	1.5	1.7

SIEVING

50 grams sieved

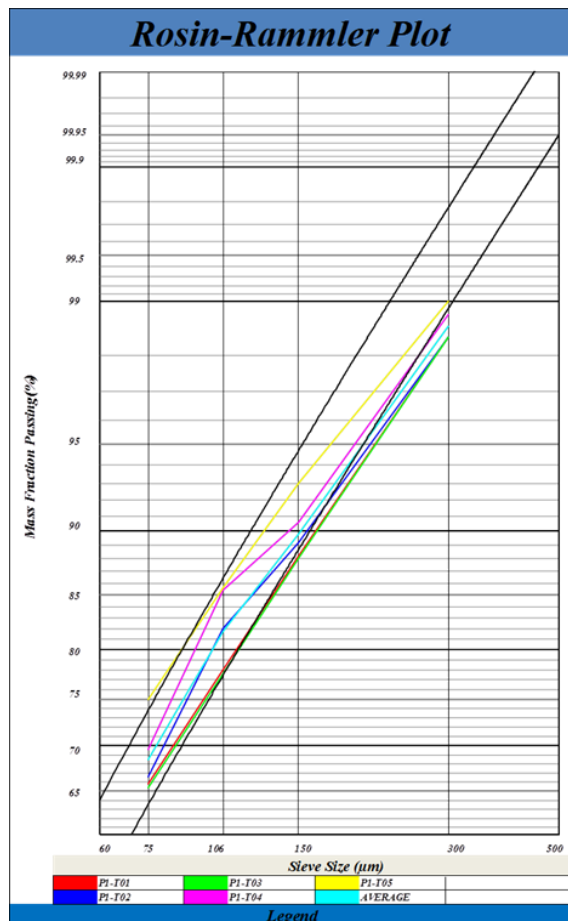
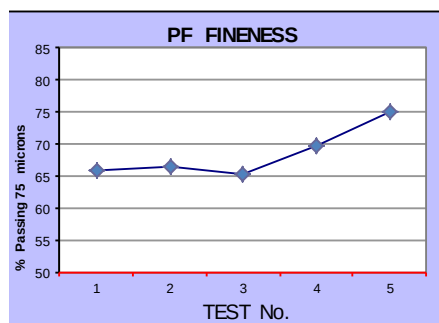
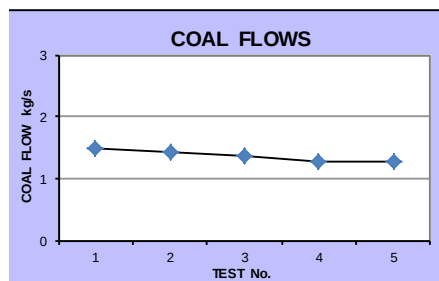
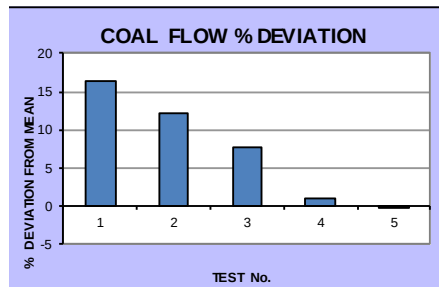
TEST No.	1	2	3	4	5
Retained PF mass > 300 um	0.8	0.8	0.8	0.6	0.5
Retained PF mass > 150 um	5.1	4.6	5.2	4.1	3.0
Retained PF mass > 106 um	5.1	3.6	5.2	2.6	3.7
Retained PF mass > 75 um	6.1	7.7	6.1	7.9	5.3
Collected in the receiver	33.0	33.5	32.7	34.9	37.7
Sum totals	50.1	50.2	50.0	50.1	50.2

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.48	0.8	93	84.0	0.8065
2	0.48	0.8	93		0.8066
3	0.48	1.0	93		0.8089
4	0.44	1.0	93		0.8087
5	0.44	1.0	93		0.8090

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	2
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	1 to 5
PA FLOW (kg/s) 13.7		PF Pipe Diameter = 356 mm		DATE	05-08-15
		Sampling time : 15 sec x 32 points			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.48	16.4	2.17	93	25.9	98.4	88.2	78.0	65.8
2	1.43	12.1	2.13	93	26.4	98.4	89.2	82.0	66.6
3	1.37	7.8	2.13	93	26.4	98.4	88.0	77.6	65.4
4	1.29	1.0	2.04	93	25.2	98.8	90.6	85.4	69.6
5	1.27	-0.3	2.04	93	25.2	99.0	93.0	85.6	75.0
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.6	90.1	82.5	69.0



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	1104.9
MILL OUTLET TEMP.	(°C)	73.6
COAL FLOW A	(kg/s)	8.8
COAL FLOW B	(kg/s)	8.7

MILL	1B
PF PIPE	2
TEST No.	6 to 10
DATE	05-08-15

SINGLE PIPE, TARGET PLATE

PF Pipe Diameter = 356 mm

Sampling time : 15 sec x 32 points

SAMPLE ID	TP-2-T06	TP-2-T07	TP-2-T08	TP-2-T09	TP-2-T10
Masses in grams					
TEST No.	6	7	8	9	10
container + sample	709.0	724.0	741.0	663.4	670.4
Mass of Container	3.7	3.7	3.7	3.7	3.7
Mass of Sample	705.3	720.3	737.3	659.7	666.7
Average	753.6				
% deviation from mean	-6.4	-4.4	-2.2	-12.5	-11.5

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.8	58.8	58.7	58.7
% PF MOISTURE	1.8	2.0	2.0	2.2	2.2

SIEVING

50 grams sieved

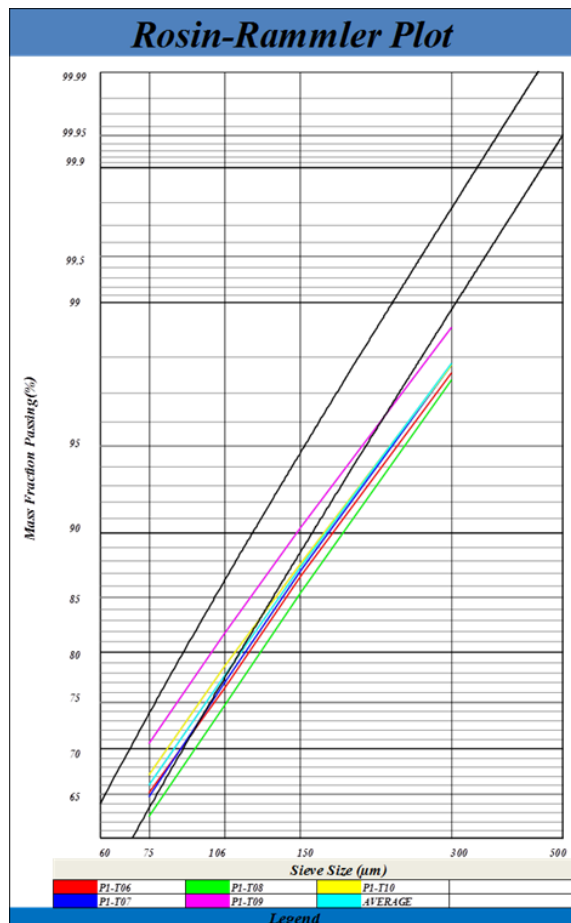
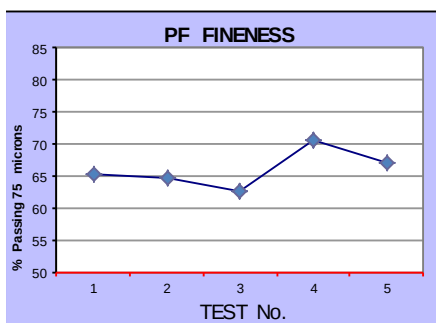
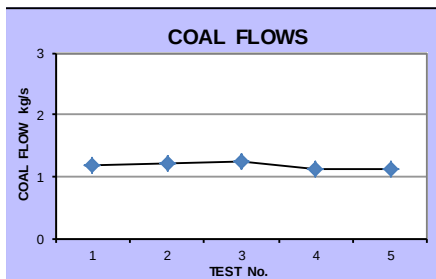
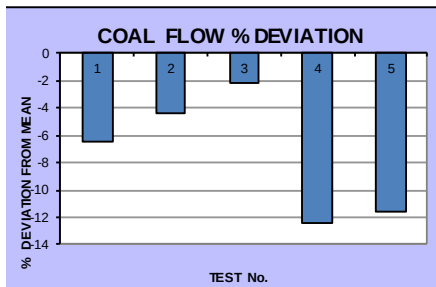
TEST No.	6	7	8	9	10
Retained PF mass > 300 um	1.2	1.1	1.3	0.7	1.1
Retained PF mass > 150 um	5.4	5.3	6.0	4.1	5.0
Retained PF mass > 106 um	5.2	5.1	5.4	4.3	4.6
Retained PF mass > 75 um	5.6	6.1	6.0	5.6	5.7
Collected in the receiver	32.6	32.4	31.4	35.5	33.7
Sum totals	50.0	50.0	50.1	50.2	50.1

PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
6	0.34	0.9	73	84.0	0.8540
7	0.36	0.9	73		0.8548
8	0.36	0.8	73		0.8538
9	0.32	0.8	73		0.8532
10	0.38	0.8	73		0.8532

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	2
TEST CONDITIONS :		<u>SINGLE PIPE, TARGET PLATE</u>		TEST No.	6 to 10
PA FLOW (kg/s) 13.7		PF Pipe Diameter = 356 mm		DATE	05-08-15
		Sampling time : 15 sec x 32 points			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
6	1.19	-6.4	1.83	73	21.8	97.6	86.8	76.4	65.2
7	1.22	-4.4	1.90	73	22.2	97.8	87.2	77.0	64.8
8	1.25	-2.2	1.90	73	22.2	97.4	85.4	74.6	62.6
9	1.11	-12.5	1.79	73	21.0	98.6	90.4	81.8	70.6
10	1.13	-11.5	1.95	73	22.8	97.8	87.8	78.6	67.2
						WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						97.8	87.6	77.9	66.2



Appendix R 1 Axis results vertical pipes B1 to B4

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.3
MILL POWER	(kW)	3.7
MILL OUTLET TEMP.	(°C)	92.2
RAW COAL FLOW A (wet)	(kg/s)	8.2
RAW COAL FLOW B (wet)	(kg/s)	8.1

MILL	1B
PF PIPE	1-4
TEST No.	1
DATE	18-08-15

Mill 4 PIPES, SINGLE AXIS

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	SA-B1-T1	SA-B2-T1	SA-B3-T1	SA-B4-T1
Masses in grams				
TEST No.	1	2	3	4
container + sample	362.6	277.1	290.6	323.6
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	352.2	266.7	280.2	313.2
Average	303.1			
% deviation from mean	16.2	-12.0	-7.5	3.3

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.4	58.6	58.5	58.6
% PF MOISTURE	2.7	2.3	2.5	2.3

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	1.2	0.2	0.3	0.6
Retained PF mass > 150 um	4.2	2.0	2.9	2.9
Retained PF mass > 106 um	4.3	3.0	4.0	4.0
Retained PF mass > 75 um	5.2	4.4	5.6	5.6
Collected in the receiver	35.4	40.7	37.5	37.2
Sum totals	50.3	50.3	50.3	50.3

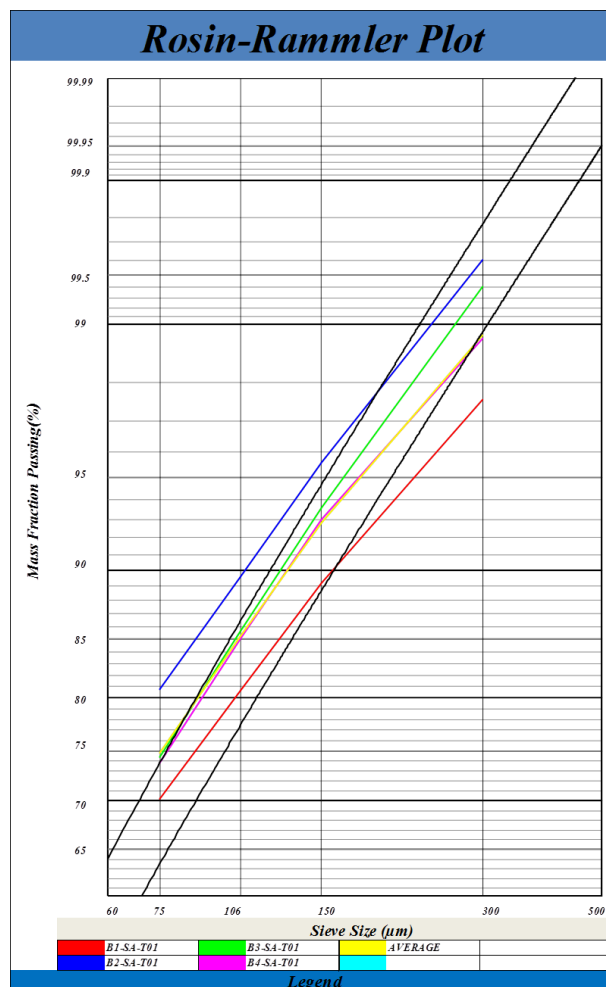
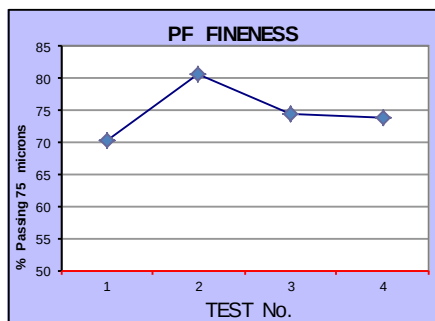
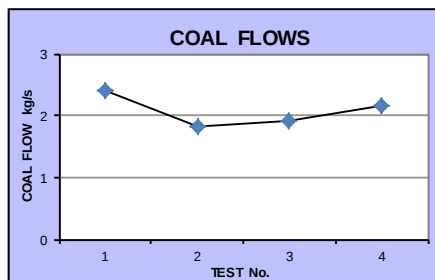
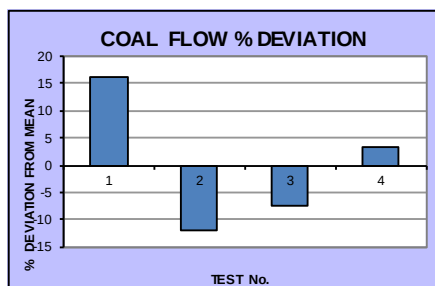
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.54	2.0	89	84.0	0.8268
2	0.52	1.9	88		0.8283
3	0.64	1.9	88		0.8289
4	0.52	2.1	85		0.8370

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		Mill 4 PIPES, SINGLE AXIS		TEST No.	1
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	18-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	2.42	16.2	4.57	89	27.6	97.6	89.2	80.6	70.2
2	1.83	-12.0	4.49	88	27.1	99.6	95.6	89.6	80.8
3	1.93	-7.5	4.98	88	30.1	99.4	93.6	85.6	74.4
4	2.15	3.3	4.51	85	27.0	98.8	93.0	85.0	73.8
Totals	8.34		18.56			WEIGHTED AVERAGE FOR THE MILL			
%	8.10	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.44	Raw Coal Flow B (dry)				98.8	94.0	86.6	76.2
%	112.05	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.3
MILL POWER	(kW)	3.7
MILL OUTLET TEMP.	(°C)	92.2
RAW COAL FLOW A (wet)	(kg/s)	8.2
RAW COAL FLOW B (wet)	(kg/s)	8.1

MILL	1B
PF PIPE	1-4
TEST No.	2
DATE	19-08-15

Mill 4 PIPES, SINGLE AXIS

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	SA-B1-T2	SA-B2-T2	SA-B3-T2	SA-B4-T2
Masses in grams				
TEST No.	1	2	3	4
container + sample	350.9	323.4	299.1	285.6
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	340.5	313.0	288.7	275.2
Average	304.4			
% deviation from mean	11.9	2.8	-5.1	-9.6

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.3	58.3	58.3	58.5
% PF MOISTURE	2.8	2.8	2.8	2.5

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	1.1	0.4	0.3	0.4
Retained PF mass > 150 um	4.8	3.2	2.9	2.2
Retained PF mass > 106 um	4.2	4.0	3.5	3.4
Retained PF mass > 75 um	5.3	5.3	5.2	5.2
Collected in the receiver	34.8	37.2	38.2	39.1
Sum totals	50.2	50.1	50.1	50.3

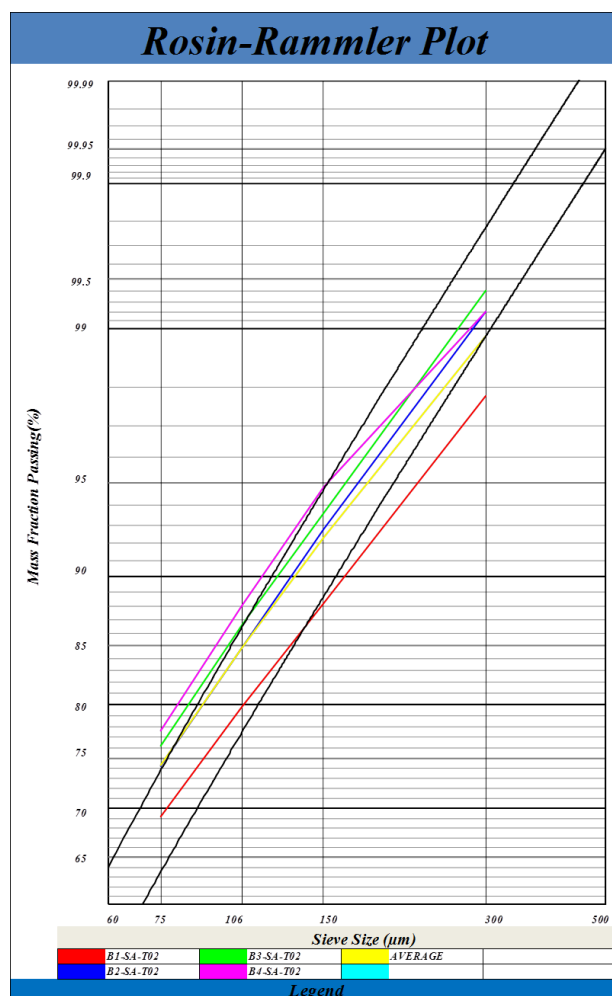
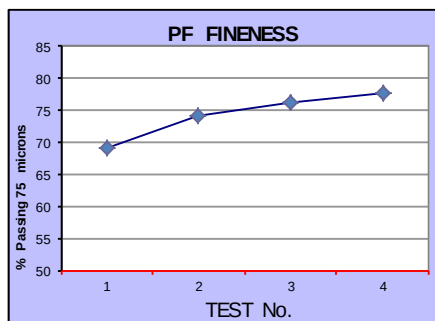
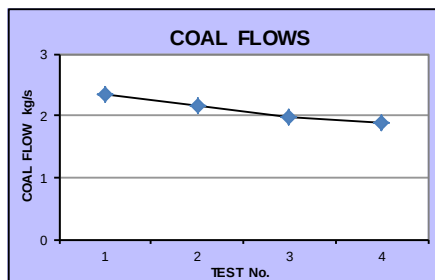
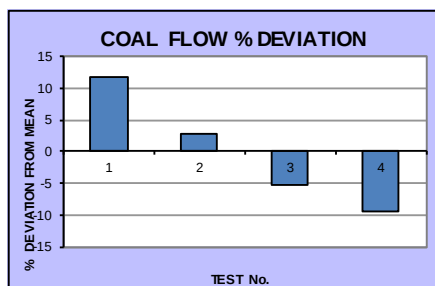
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.54	2.0	87	84.0	0.8314
2	0.52	2.0	86		0.8343
3	0.68	1.9	89		0.8261
4	0.52	2.0	88		0.8293

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		Mill 4 PIPES, SINGLE AXIS		TEST No.	2
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	19-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	2.34	11.9	4.60	87	27.5	97.8	88.2	79.8	69.2
2	2.15	2.8	4.51	86	27.0	99.2	92.8	84.8	74.2
3	1.99	-5.1	5.13	89	31.0	99.4	93.6	86.6	76.2
4	1.89	-9.6	4.49	88	27.1	99.2	94.8	88.0	77.6
Totals	8.38		18.73			WEIGHTED AVERAGE FOR THE MILL			
%	8.10	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.44	Raw Coal Flow B (dry)				98.9	93.7	86.4	75.9
%	112.52	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.3
MILL POWER	(kW)	3.7
MILL OUTLET TEMP.	(°C)	92.2
RAW COAL FLOW A (wet)	(kg/s)	8.2
RAW COAL FLOW B (wet)	(kg/s)	8.1

MILL	1B
PF PIPE	1-4
TEST No.	3
DATE	19-08-15

Mill 4 PIPES, SINGLE AXIS

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	SA-B1-T3	SA-B2-T3	SA-B3-T3	SA-B4-T3
Masses in grams				
TEST No.	1	2	3	4
container + sample	302.6	315.0	266.6	304.1
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	292.2	304.6	256.2	293.7
Average	286.7			
% deviation from mean	1.9	6.3	-10.6	2.5

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.2	58.4	58.4	58.4
% PF MOISTURE	3.0	2.7	2.7	2.7

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.7	0.4	0.4	0.4
Retained PF mass > 150 um	4.0	3.5	3.9	2.7
Retained PF mass > 106 um	3.6	4.2	4.1	4.1
Retained PF mass > 75 um	5.0	5.7	5.2	5.9
Collected in the receiver	36.9	36.3	36.5	37.1
Sum totals	50.2	50.1	50.1	50.2

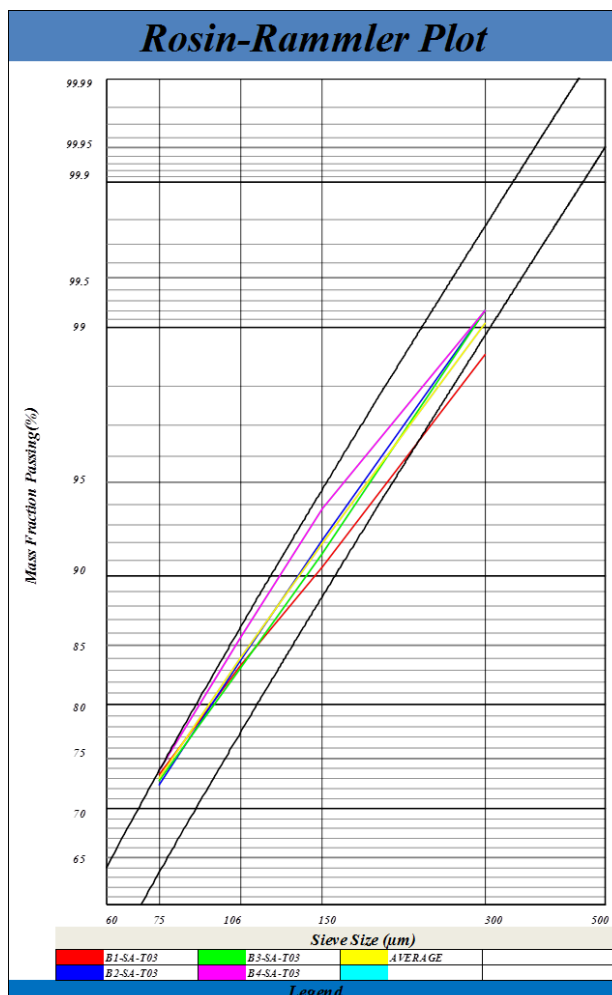
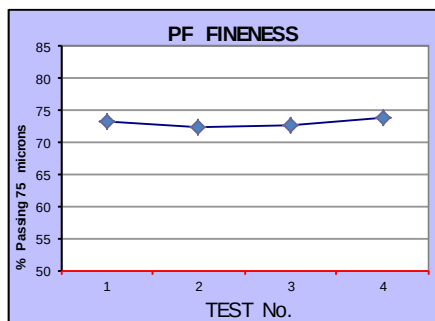
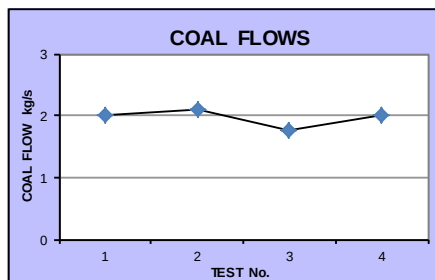
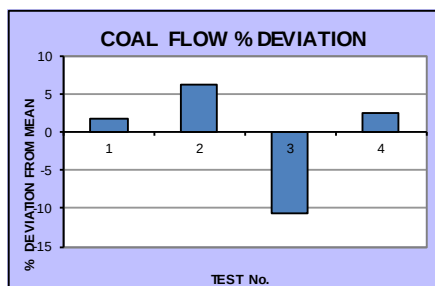
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.68	1.9	88	84.0	0.8283
2	0.64	1.9	87		0.8312
3	0.58	1.9	86		0.8334
4	0.52	2.1	88		0.8301

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		MILL 4 PIPES, SINGLE AXIS		TEST No.	3
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	19-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	2.01	1.9	5.16	88	30.8	98.6	90.6	83.4	73.4
2	2.10	6.3	4.99	87	30.0	99.2	92.2	83.8	72.4
3	1.76	-10.6	4.76	86	28.5	99.2	91.4	83.2	72.8
4	2.02	2.5	4.50	88	27.1	99.2	93.8	85.6	73.8
Totals	7.89		19.41			WEIGHTED AVERAGE FOR THE MILL			
%	8.10	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.44	Raw Coal Flow B (dry)				99.0	92.5	84.2	73.0
%	105.98	Recovery Rate							



Appendix S Target Plate results vertical pipes B1 to B4

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	3.8
MILL OUTLET TEMP.	(°C)	89.9
RAW COAL FLOW A (wet)	(kg/s)	8.4
RAW COAL FLOW B (wet)	(kg/s)	8.3

MILL	1B
PF PIPE	1 to 4
TEST No.	1
DATE	13-08-15

Mill 4 PIPES, TARGET PLATE

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	TP-B1-T1	TP-B2-T1	TP-B3-T1	TP-B4-T1
Masses in grams				
TEST No.	1	2	3	4
container + sample	815.4	753.3	643.9	817.1
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	805.0	742.9	633.5	806.7
Average	747.0			
% deviation from mean	7.8	-0.6	-15.2	8.0

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.8	58.7	58.8
% PF MOISTURE	2.2	2.0	2.2	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	1.0	1.0	0.6	1.1
Retained PF mass > 150 um	3.9	3.8	2.1	4.8
Retained PF mass > 106 um	4.2	3.9	2.7	5.4
Retained PF mass > 75 um	5.8	5.3	4.7	6.8
Collected in the receiver	35.4	36.3	40.2	32.2
Sum totals	50.3	50.3	50.3	50.3

PF PIPE MEASUREMENTS

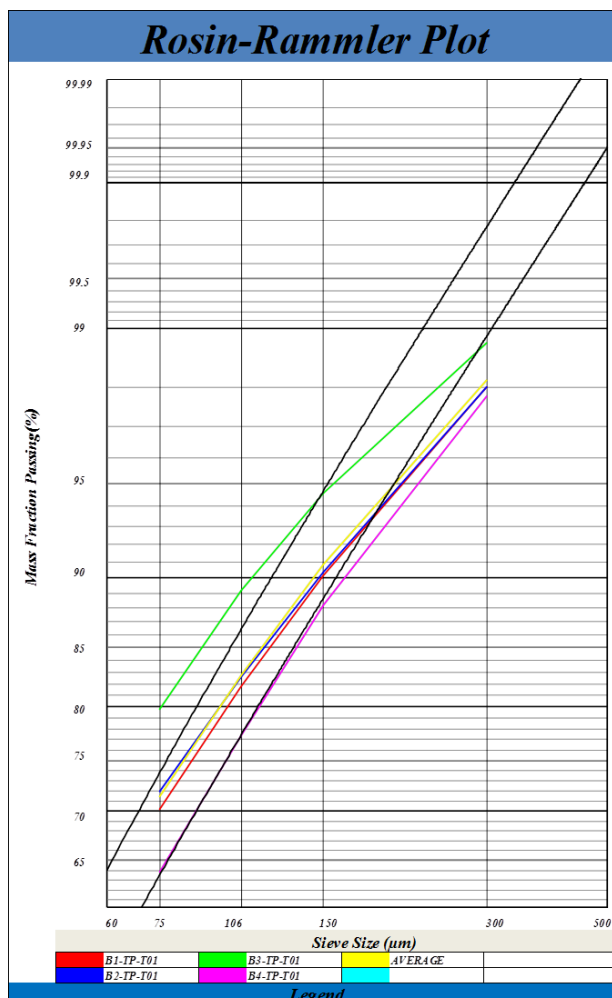
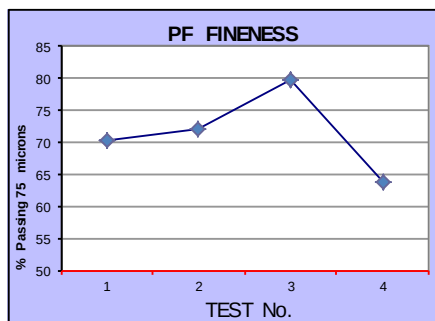
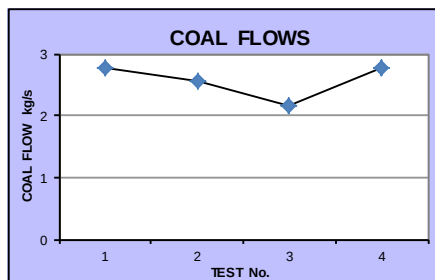
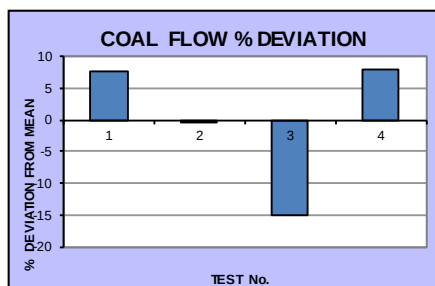
TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.34	2.3	88	84.0	0.8319
2	0.42	2.5	86		0.8386
3	0.44	2.3	87		0.8342
4	0.22	2.5	88		0.8341

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
TEST CONDITIONS : <u>Mill 4 PIPES, TARGET PLATE</u>		PF PIPE			1 to 4
PA FLOW (kg/s) 13.8		PF Pipe Diameter = 508 mm		TEST No.	1
				DATE	13-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	2.77	7.8	3.65	88	21.8	98.0	90.2	81.8	70.2
2	2.56	-0.6	4.06	86	24.2	98.0	90.4	82.6	72.0
3	2.18	-15.2	4.15	87	24.8	98.8	94.6	89.2	79.8
4	2.78	8.0	2.93	88	17.6	97.8	88.2	77.4	63.8
Totals	10.28		14.79			WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.1	90.8	82.6	71.2

%	5.40	Raw Coal moisture
kg/s	7.85	Raw Coal Flow B (dry)
%	130.95	Recovery Rate



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	3.8
MILL OUTLET TEMP.	(°C)	89.9
RAW COAL FLOW A (wet)	(kg/s)	8.4
RAW COAL FLOW B (wet)	(kg/s)	8.3

MILL	1B
PF PIPE	1 to 4
TEST No.	3
DATE	13-08-15

Mill 4 PIPES, TARGET PLATE

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	TP-B1-T2	TP-B2-T2	TP-B3-T2	TP-B4-T2
Masses in grams				
TEST No.	1	2	3	4
container + sample	552.8	694.9	664.1	753.4
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	542.4	684.5	653.7	743.0
Average	655.9			
% deviation from mean	-17.3	4.4	-0.3	13.3

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.9	58.9	58.8
% PF MOISTURE	1.8	1.8	1.8	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	1.1	1.5	0.9	1.0
Retained PF mass > 150 um	3.4	5.9	3.1	4.5
Retained PF mass > 106 um	4.1	5.4	3.3	4.9
Retained PF mass > 75 um	5.8	6.6	5.4	6.5
Collected in the receiver	35.9	30.8	37.6	33.4
Sum totals	50.3	50.2	50.3	50.3

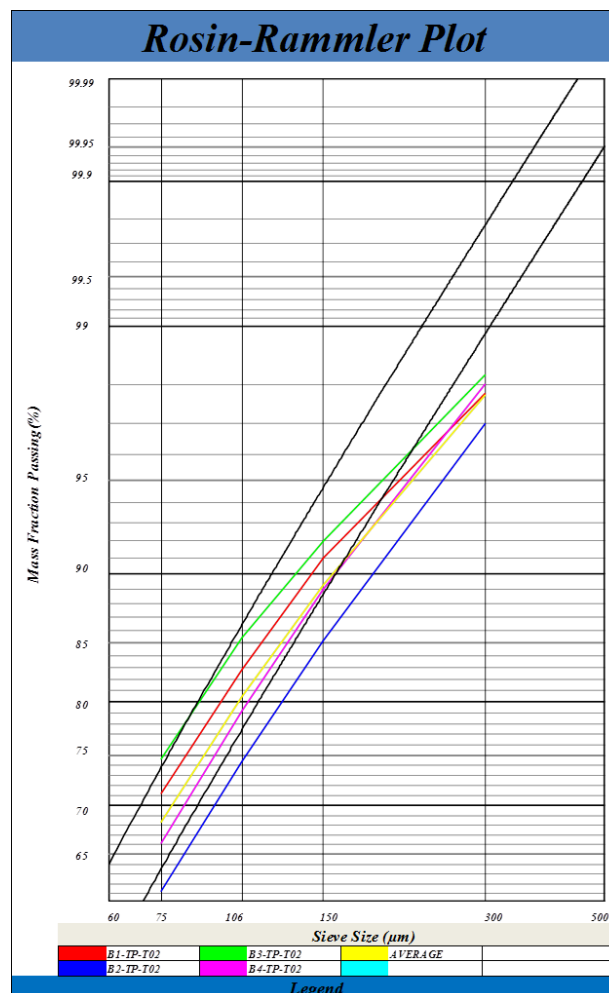
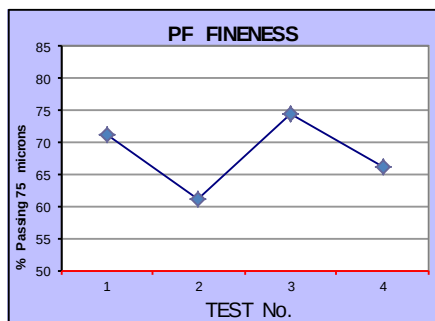
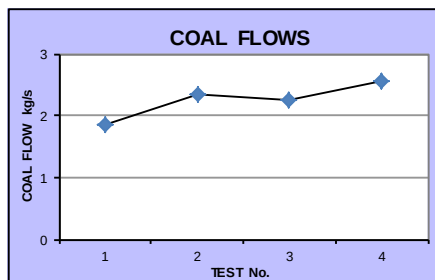
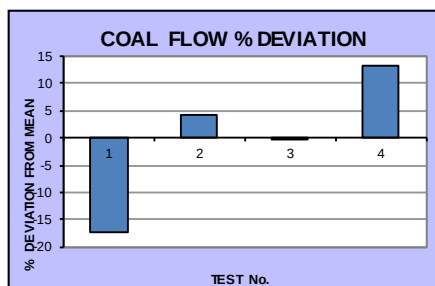
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.34	2.5	88	84.0	0.8341
2	0.46	2.3	82		0.8460
3	0.44	2.5	85		0.8411
4	0.42	3.2	86		0.8453

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1 to 4
TEST CONDITIONS :		<u>Mill 4 PIPES, TARGET PLATE</u>		TEST No.	3
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 508 mm		DATE	13-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.87	-17.3	3.65	88	21.8	97.8	91.0	82.8	71.2
2	2.36	4.4	4.27	82	25.2	97.0	85.2	74.4	61.2
3	2.25	-0.3	4.16	85	24.7	98.2	92.0	85.4	74.6
4	2.56	13.3	4.08	86	24.1	98.0	89.0	79.2	66.2
Totals	9.03		16.16			WEIGHTED AVERAGE FOR THE MILL			
%	5.40	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.85	Raw Coal Flow B (dry)				97.7	88.7	79.6	67.2
%	114.97	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.8
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	3.8
MILL OUTLET TEMP.	(°C)	89.9
RAW COAL FLOW A (wet)	(kg/s)	8.4
RAW COAL FLOW B (wet)	(kg/s)	8.3

MILL	1B
PF PIPE	1 to 4
TEST No.	3
DATE	13-08-15

Mill 4 PIPES, TARGET PLATE

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	TP-B1-T3	TP-B2-T3	TP-B3-T3	TP-B4-T3
Masses in grams				
TEST No.	1	2	3	4
container + sample	803.3	529.2	682.4	826.3
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	792.9	518.8	672.0	815.9
Average	699.9			
% deviation from mean	13.3	-25.9	-4.0	16.6

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.8	58.9	58.8	58.8
% PF MOISTURE	2.0	1.8	2.0	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.7	1.4	0.7	0.9
Retained PF mass > 150 um	2.7	4.3	2.9	3.3
Retained PF mass > 106 um	3.3	4.1	3.3	4.2
Retained PF mass > 75 um	5.0	5.4	5.0	5.8
Collected in the receiver	38.6	35.1	38.4	36.1
Sum totals	50.3	50.3	50.3	50.3

PF PIPE MEASUREMENTS

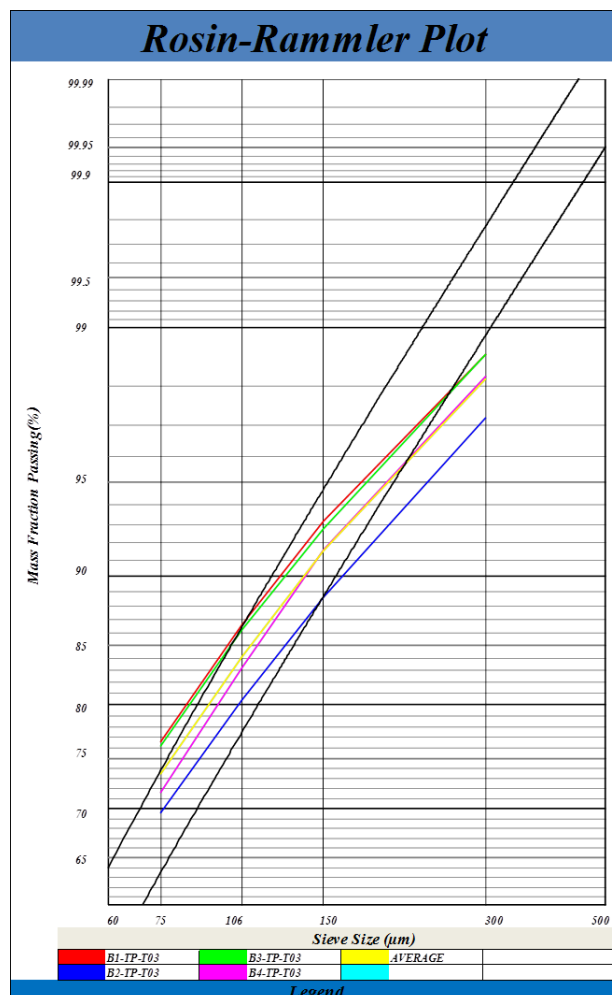
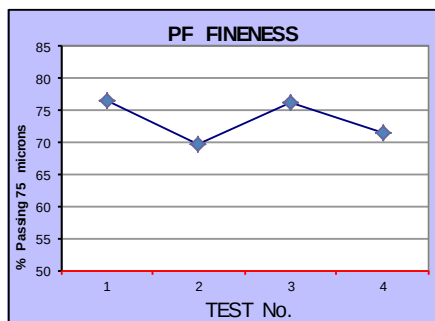
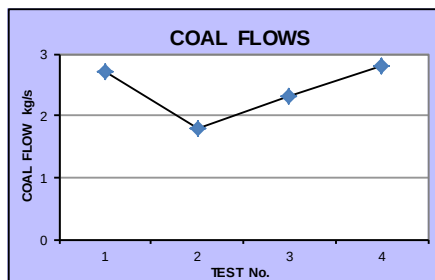
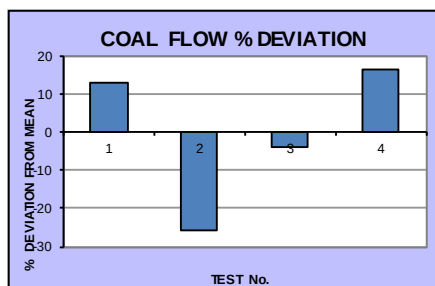
TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.42	2.3	88	84.0	0.8319
2	0.36	2.5	89		0.8315
3	0.38	2.3	87		0.8342
4	0.36	2.5	87		0.8363

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1 to 4
TEST CONDITIONS :		<u>Mill 4 PIPES, TARGET PLATE</u>		TEST No.	3
PA FLOW (kg/s)	13.8	PF Pipe Diameter = 508 mm		DATE	13-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	2.73	13.3	4.06	88	24.2	98.6	93.2	86.6	76.6
2	1.79	-25.9	3.74	89	22.5	97.2	88.6	80.4	69.6
3	2.31	-4.0	3.85	87	23.1	98.6	92.8	86.2	76.2
4	2.81	16.6	3.75	87	22.4	98.2	91.6	83.2	71.6
Totals	9.63		15.41			WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						98.2	91.2	83.5	72.6

%	5.40	Raw Coal moisture
kg/s	7.85	Raw Coal Flow B (dry)
%	122.69	Recovery Rate



Appendix T Rotoprobe results vertical pipes B1 to B4

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.82	kg/s
COAL FLOW B	8.85	kg/s

MILL	1B
PF PIPE	1-4
TEST No.	1
DATE	17-08-15

Mill 4 PIPES, Rotoprobe
PF Pipe Diameter = 508 mm

Sampling time : 4 minutes

SAMPLE ID	B1P1-T1	B2P2-T1	B3P3-T1	B4P4-T1
Masses in grams				
TEST No.	B1T1	B2T1	B3T1	B4T1
Container + sample	199.41	177.88	177.58	204.09
Mass of Container	2.00	2.00	2.00	2.00
Mass of Sample	197.41	175.88	175.58	202.09
Average	187.74			
% deviation from mean	5.15	-6.32	-6.48	7.64

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.89	58.95	59.10	59.02
% PF MOISTURE	1.85	1.75	1.50	1.63

SIEVING

50 grams sieved

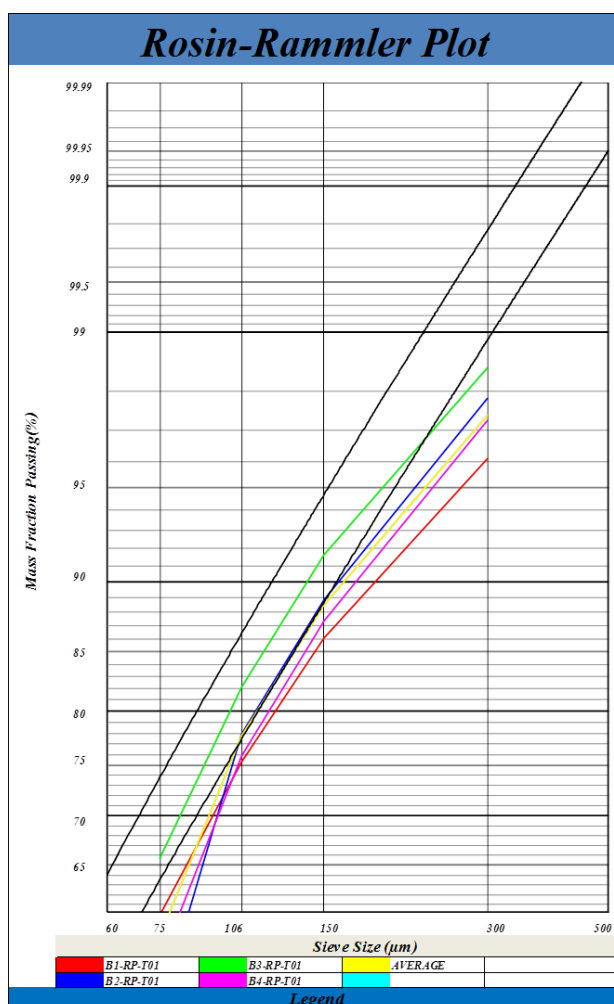
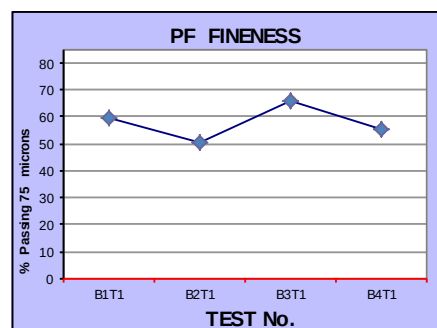
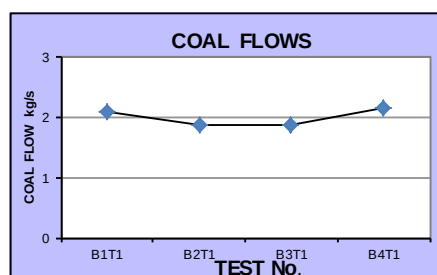
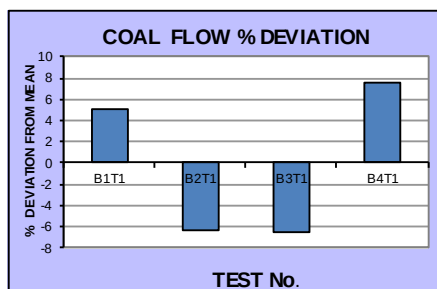
TEST No.	B1T1	B2T1	B3T1	B4T1
Retained PF mass > 300 um	1.96	1.08	0.77	1.36
Retained PF mass > 150 um	5.00	4.50	3.41	4.97
Retained PF mass > 106 um	5.38	5.46	4.77	5.75
Retained PF mass > 75 um	7.70	13.70	8.17	10.38
Collected in the receiver	29.93	25.07	32.76	27.46
Sum totals	49.97	49.81	49.88	49.92

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
B1T1	18.00	1.11	93.50	0.80	
B2T1	19.00	1.11	93.60	0.90	
B3T1	19.00	1.11	93.80	0.90	
B4T1	19.00	1.11	94.30	0.90	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		<u>Mill 4 PIPES, Rotoprobe</u>		TEST No.	1
PA FLOW (kg/s) 13.80		PF Pipe Diameter = 508 mm		DATE	17-08-15
Sampling time : 4 minutes					

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
B1T1	2.10	5.15	1.10	74.80	20.00	96.1	86.1	75.3	59.9
B2T1	1.88	-6.32	1.10	74.80	20.00	97.8	88.8	77.9	50.5
B3T1	1.88	-6.48	1.10	74.80	20.00	98.5	91.6	82.1	65.8
B4T1	2.16	7.64	1.10	74.80	20.00	97.3	87.3	75.8	55.1
Totals	8.02		4.40			WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
%	7.60	Raw Coal moisture							
kg/s	8.18	Raw Coal Flow B (dry)							
%	98.11	Recovery Rate							
						97.37	89.18	78.49	57.03



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.82	kg/s
COAL FLOW B	8.85	kg/s

MILL	1B
PF PIPE	1-4
TEST No.	2
DATE	17-08-15

Mill 4 PIPES, Rotoprobe
PF Pipe Diameter = 508 mm
 Sampling time : 4 minutes

SAMPLE ID	B1P1-T2	B2P2-T2	B3P3-T2	B4P4-T2
Masses in grams				
TEST No.	B1T2	B2T2	B3T2	B4T2
Container + sample	205.31	178.07	180.24	206.10
Mass of Container	2.00	2.00	2.00	2.00
Mass of Sample	203.31	176.07	178.24	204.10
Average	190.43			
% deviation from mean	6.76	-7.54	-6.40	7.18

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.97	59.04	59.09	58.95
% PF MOISTURE	1.72	1.60	1.52	1.75

SIEVING

50 grams sieved

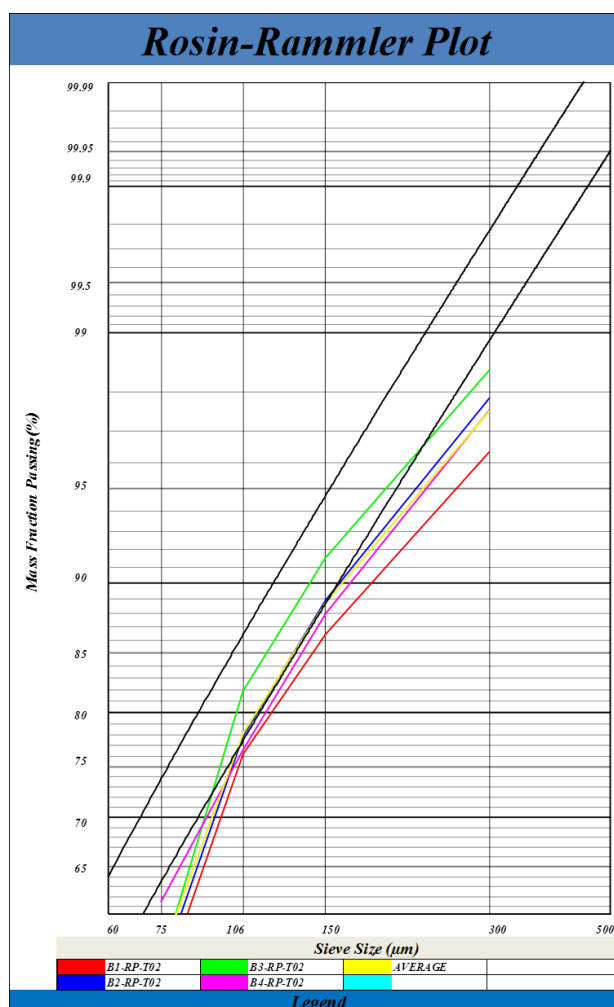
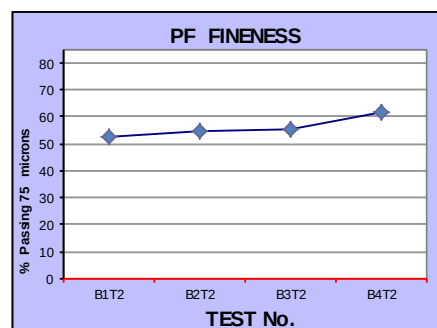
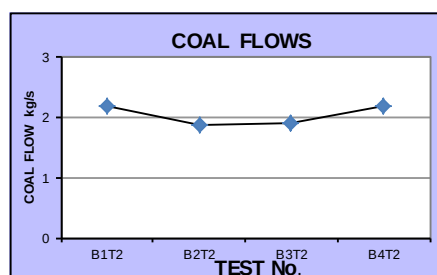
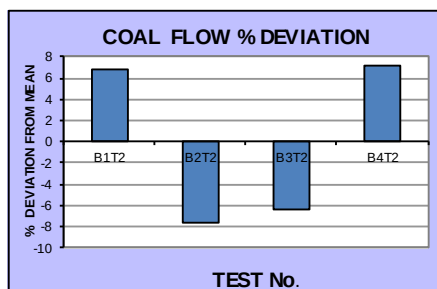
TEST No.	B1T2	B2T2	B3T2	B4T2
Retained PF mass > 300 um	1.82	1.07	0.79	1.22
Retained PF mass > 150 um	4.96	4.48	3.44	4.80
Retained PF mass > 106 um	5.14	5.51	4.83	5.71
Retained PF mass > 75 um	11.75	11.66	13.24	7.51
Collected in the receiver	26.08	27.12	27.51	30.60
Sum totals	49.75	49.84	49.81	49.84

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
B1T2	18.00	1.11	93.50	0.80	
B2T2	19.00	1.11	93.60	0.90	
B3T2	19.00	1.11	93.80	0.90	
B4T2	19.00	1.11	94.30	0.90	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		<u>Mill 4 PIPES, Rotoprobe</u>		TEST No.	2
PA FLOW (kg/s)	13.80	PF Pipe Diameter = 508 mm		DATE	17-08-15
		Sampling time : 4 minutes			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
B1T2	2.17	6.76	1.10	74.80	20.00	96.4	86.4	76.2	52.7
B2T2	1.88	-7.54	1.10	74.80	20.00	97.9	88.9	77.9	54.6
B3T2	1.91	-6.40	1.10	74.80	20.00	98.4	91.5	81.9	55.4
B4T2	2.18	7.18	1.10	74.80	20.00	97.6	88.0	76.5	61.5
Totals	8.14		4.40			WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
%	7.60	Raw Coal moisture							
kg/s	8.18	Raw Coal Flow B (dry)							
%	99.53	Recovery Rate							
						97.51	89.40	78.67	57.37



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.82	kg/s
COAL FLOW B	8.85	kg/s

MILL	1B
PF PIPE	1-4
TEST No.	2
DATE	17-08-15

Mill 4 PIPES, Rotoprobe
PF Pipe Diameter = 508 mm
 Sampling time : 4 minutes

SAMPLE ID	B1P1-T3	B2P2-T3	B3P3-T3	B4P4-T3
Masses in grams				
TEST No.	B1T3	B2T3	B3T3	B4T3
Container + sample	210.16	176.48	182.17	210.07
Mass of Container	2.00	2.00	2.00	2.00
Mass of Sample	208.16	174.48	180.17	208.07
Average	192.72			
% deviation from mean	8.01	-9.46	-6.51	7.96

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	59.26	58.91	58.93	58.77
% PF MOISTURE	1.23	1.82	1.78	2.05

SIEVING

50 grams sieved

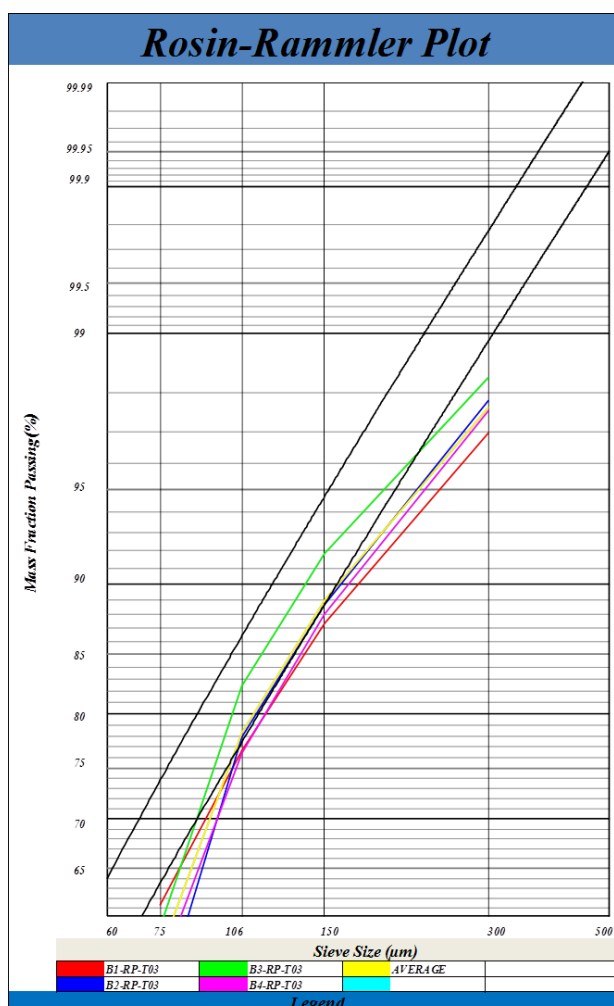
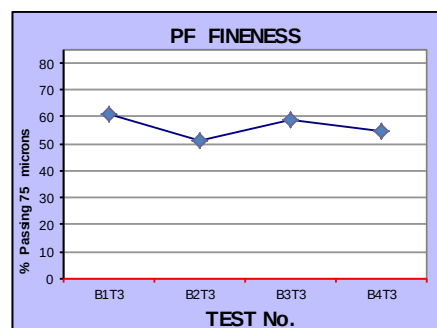
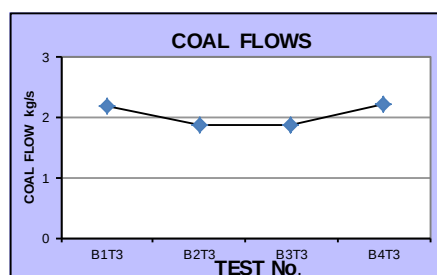
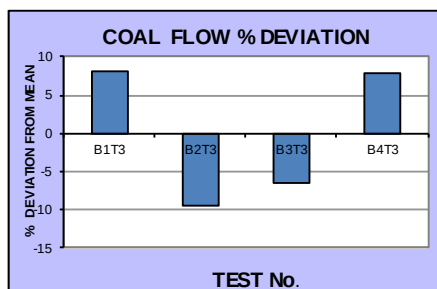
TEST No.	B1T3	B2T3	B3T3	B4T3
Retained PF mass > 300 um	1.52	1.09	0.85	1.22
Retained PF mass > 150 um	4.81	4.58	3.23	4.78
Retained PF mass > 106 um	5.34	5.38	4.69	5.80
Retained PF mass > 75 um	7.66	13.48	11.68	10.90
Collected in the receiver	30.43	25.23	29.49	27.03
Sum totals	49.76	49.76	49.94	49.73

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
B1T3	18.00	1.11	93.50	0.80	
B2T3	19.00	1.11	93.60	0.90	
B3T3	19.00	1.11	93.80	0.90	
B4T3	19.00	1.11	94.30	0.90	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		<u>Mill 4 PIPES, Rotoprobe</u>		TEST No.	2
PA FLOW (kg/s) 13.80		PF Pipe Diameter = 508 mm		DATE	17-08-15
		Sampling time : 4 minutes			

PF PIPE MEASUREMENTS						PF GRADING RESULTS									
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u						
B1T3	2.17	8.01	1.10	74.80	20.00	97.0	87.3	76.7	61.3						
B2T3	1.88	-9.46	1.10	74.80	20.00	97.8	88.7	77.9	50.9						
B3T3	1.86	-6.51	1.10	74.80	20.00	98.3	91.8	82.5	59.1						
B4T3	2.23	7.96	1.10	74.80	20.00	97.6	88.0	76.4	54.6						
Totals	8.14		4.40	WEIGHTED AVERAGE FOR THE MILL											
%	7.60	Raw Coal moisture													
kg/s	8.18	Raw Coal Flow B (dry)													
%	99.53	Recovery Rate													
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u						
						97.63	89.40	78.76	54.85						



Appendix U Results – 1 Axis results horizontal pipes B1H to B4H4

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.3
MILL POWER	(kW)	3.7
MILL OUTLET TEMP.	(°C)	92.2
RAW COAL FLOW A (wet)	(kg/s)	8.2
RAW COAL FLOW B (wet)	(kg/s)	8.1

MILL	1B
PF PIPE	1-4
TEST No.	1
DATE	26-08-15

Mill 4 PIPES, SINGLE AXIS **PF Pipe Diameter = 508 mm**

Sampling time : 30 sec x 8 points

SAMPLE ID	H-SA-B1-T1	H-SA-B2-T1	H-SA-B3-T1	H-SA-B4-T1
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Masses in grams

TEST No.	1	2	3	4
container + sample	216.5	241.1	264.1	318.8
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	206.1	230.7	253.7	308.4
Average	249.7			
% deviation from mean	-17.5	-7.6	1.6	23.5

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.7	58.7	58.8
% PF MOISTURE	1.8	2.2	2.2	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.1	0.5	0.2	0.4
Retained PF mass > 150 um	0.7	1.0	1.3	3.0
Retained PF mass > 106 um	1.5	1.9	2.7	4.2
Retained PF mass > 75 um	3.0	3.7	5.2	6.0
Collected in the receiver	44.9	43.3	40.9	36.6
Sum totals	50.2	50.4	50.3	50.2

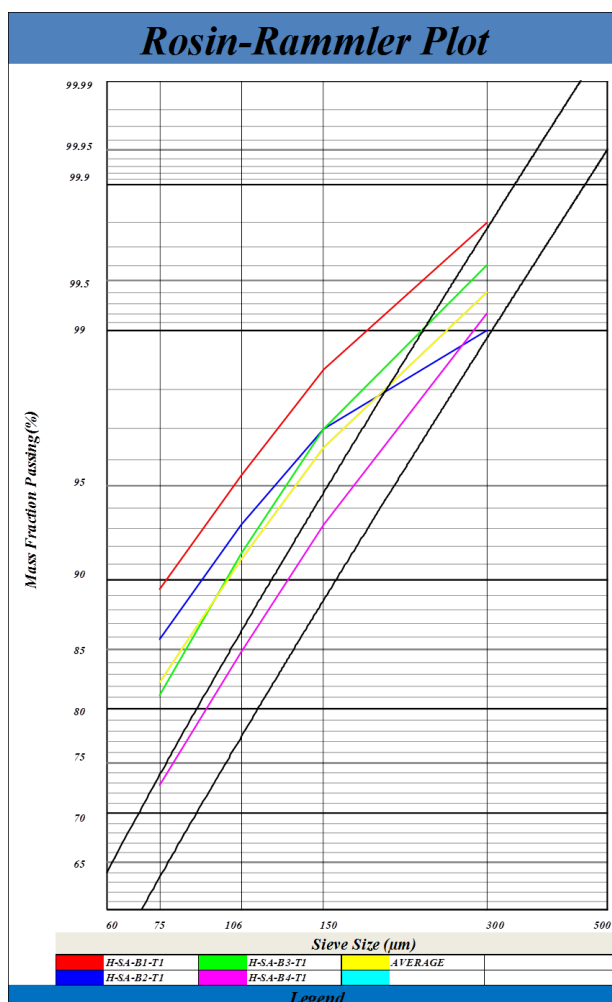
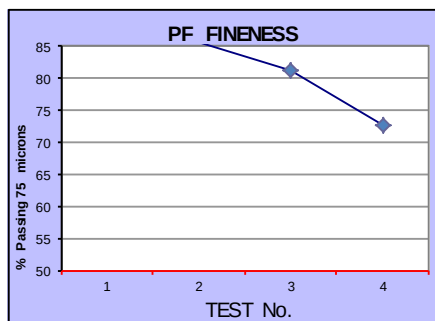
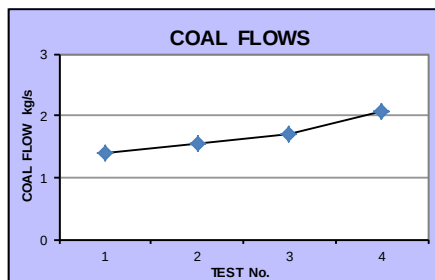
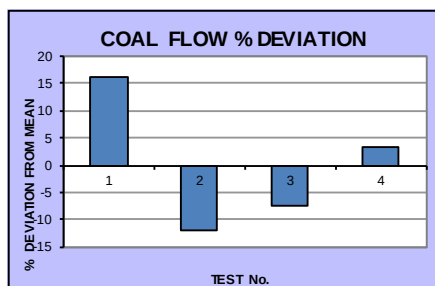
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.44	1.04	91	84.0	0.8135
2	0.34	2.22	92		0.8225
3	0.36	1.60	91		0.8188
4	0.4	1.76	92		0.8181

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		Mill 4 PIPES, SINGLE AXIS		TEST No.	1
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	26-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.39	16.2	4.57	89	27.6	99.8	98.4	95.4	89.4
2	1.55	-12.0	4.49	88	27.1	99.0	97.0	93.2	85.8
3	1.71	-7.5	4.98	88	30.1	99.6	97.0	91.6	81.2
4	2.08	3.3	4.51	85	27.0	99.2	93.2	84.8	72.8
Totals	6.73		18.56			WEIGHTED AVERAGE FOR THE MILL			
%	6.00	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.61	Raw Coal Flow B (dry)				99.4	95.5	89.4	79.3
%	88.44	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.3
MILL POWER	(kW)	3.7
MILL OUTLET TEMP.	(°C)	92.2
RAW COAL FLOW A (wet)	(kg/s)	8.2
RAW COAL FLOW B (wet)	(kg/s)	8.1

MILL	1B
PF PIPE	1-4
TEST No.	2
DATE	26-08-15

Mill 4 PIPES, SINGLE AXIS

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	H-SA-B1-T2	H-SA-B2-T2	H-SA-B3-T2	H-SA-B4-T2
Masses in grams				
TEST No.	1	2	3	4
container + sample	219.6	212.8	248.1	366.8
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	209.2	202.4	237.7	356.4
Average	251.4			
% deviation from mean	-16.8	-19.5	-5.5	41.8

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.6	58.7	58.8
% PF MOISTURE	1.8	2.3	2.2	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.2	0.4	0.2	0.5
Retained PF mass > 150 um	0.5	1.4	1.5	3.7
Retained PF mass > 106 um	1.3	2.3	3.2	4.5
Retained PF mass > 75 um	2.4	3.8	5.7	5.6
Collected in the receiver	45.8	42.3	39.7	36.0
Sum totals	50.2	50.2	50.3	50.3

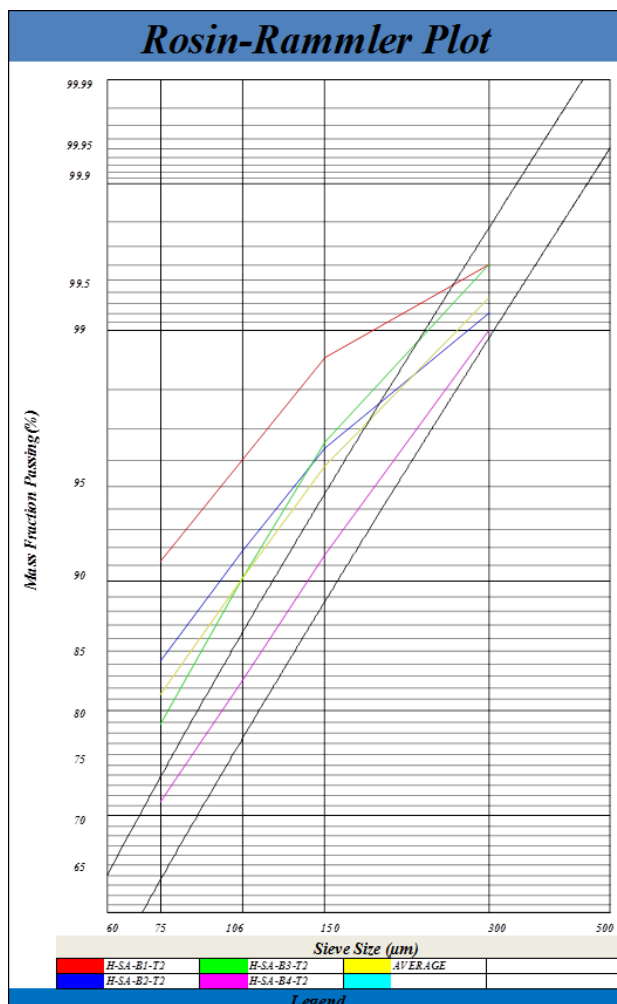
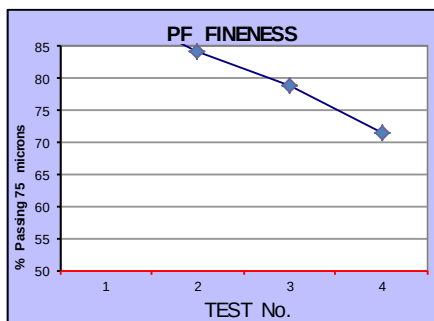
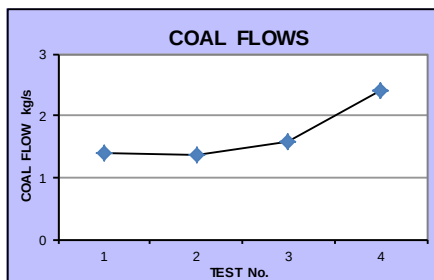
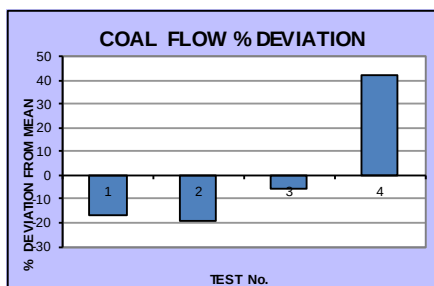
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.44	1.98	92	84.0	0.8202
2	0.34	2.14	91		0.8240
3	0.34	1.80	92		0.8185
4	0.38	1.82	92		0.8187

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		Mill 4 PIPES, SINGLE AXIS		TEST No.	2
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	26-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.41	-16.8	4.57	89	27.6	99.6	98.6	96.0	91.2
2	1.36	-19.5	4.49	88	27.1	99.2	96.4	91.8	84.2
3	1.60	-5.5	4.98	88	30.1	99.6	96.6	90.2	78.8
4	2.40	41.8	4.51	85	27.0	99.0	91.6	82.6	71.4
Totals	6.78		18.56			WEIGHTED AVERAGE FOR THE MILL			
%	6.00	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.61	Raw Coal Flow B (dry)				99.3	94.3	87.2	76.9
%	89.01	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.3
MILL POWER	(kW)	3.7
MILL OUTLET TEMP.	(°C)	92.2
RAW COAL FLOW A (wet)	(kg/s)	8.2
RAW COAL FLOW B (wet)	(kg/s)	8.1

MILL	1B
PF PIPE	1-4
TEST No.	3
DATE	26-08-15

Mill 4 PIPES, SINGLE AXIS

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	H-SA-B1-T3	H-SA-B2-T3	H-SA-B3-T3	H-SA-B4-T3
Masses in grams				
TEST No.	1	2	3	4
container + sample	229.1	221.4	232.1	361.1
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	218.7	211.0	221.7	350.7
Average	250.5			
% deviation from mean	-12.7	-15.8	-11.5	40.0

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.9	58.7	58.7	58.8
% PF MOISTURE	1.8	2.2	2.2	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.2	0.4	0.2	0.5
Retained PF mass > 150 um	1.0	1.2	1.3	3.5
Retained PF mass > 106 um	2.2	2.3	3.0	4.1
Retained PF mass > 75 um	3.8	3.8	5.8	5.3
Collected in the receiver	43.1	42.6	40.0	36.9
Sum totals	50.3	50.3	50.3	50.3

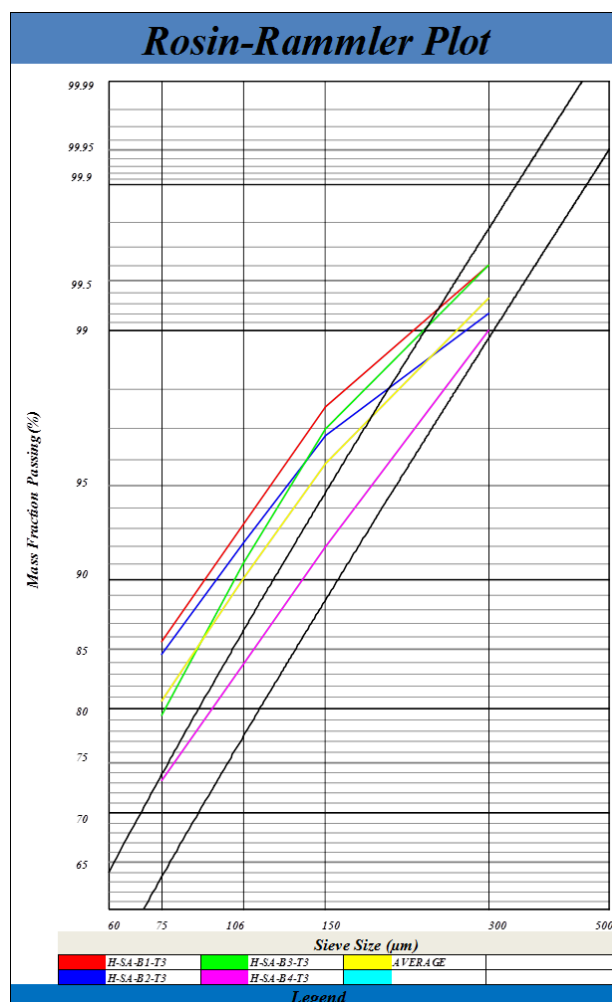
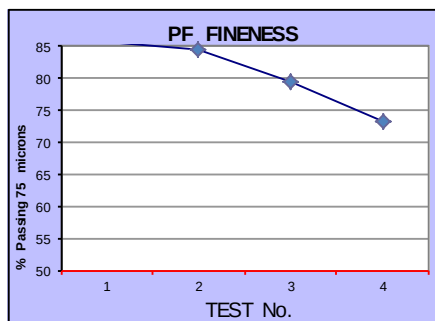
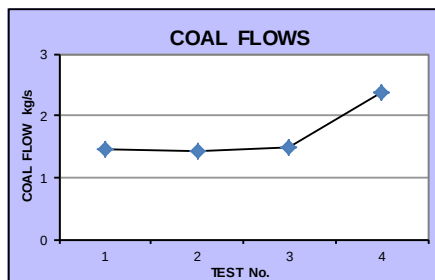
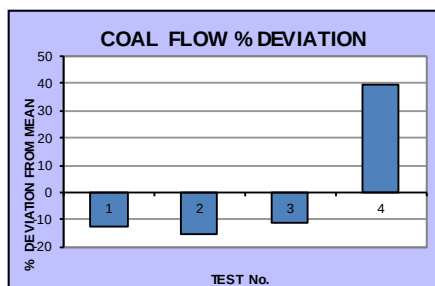
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.42	1.88	91	84.0	0.8215
2	0.34	2.24	92		0.8227
3	0.40	1.80	90		0.8230
4	0.46	1.86	91		0.8213

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		Mill 4 PIPES, SINGLE AXIS		TEST No.	3
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	26-08-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.48	-12.7	4.57	89	27.6	99.6	97.6	93.2	85.6
2	1.42	-15.8	4.49	88	27.1	99.2	96.8	92.2	84.6
3	1.49	-11.5	4.98	88	30.1	99.6	97.0	91.0	79.4
4	2.37	40.0	4.51	85	27.0	99.0	92.0	83.8	73.2
Totals	6.76		18.56			WEIGHTED AVERAGE FOR THE MILL			
%	6.00	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	7.61	Raw Coal Flow B (dry)				99.3	94.7	88.1	78.0
%	88.73	Recovery Rate							



Appendix V Results – Target Plate results horizontal pipes B1H1 to B4H4

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	3.0
MILL OUTLET TEMP.	(°C)	89.9
RAW COAL FLOW A (wet)	(kg/s)	8.9
RAW COAL FLOW B (wet)	(kg/s)	9.2

MILL	1B
PF PIPE	1 to 4
TEST No.	1
DATE	01-09-15

Mill 4 PIPES, TARGET PLATE

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	H-TP-B1-T1	H-TP-B2-T1	H-TP-B3-T1	H-TP-B4-T1
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Masses in grams

TEST No.	1	2	3	4
container + sample	423.9	509.7	674.3	597.9
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	413.5	499.3	663.9	587.5
Average	541.1			
% deviation from mean	-23.6	-7.7	22.7	8.6

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.5	58.4	58.5	58.7
% PF MOISTURE	2.5	2.7	2.5	2.2

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.1	0.4	0.3	0.2
Retained PF mass > 150 um	0.8	2.2	2.9	0.6
Retained PF mass > 106 um	1.5	2.8	3.4	1.5
Retained PF mass > 75 um	2.6	5.0	4.3	3.2
Collected in the receiver	45.1	39.9	39.2	44.7
Sum totals	50.1	50.3	50.1	50.2

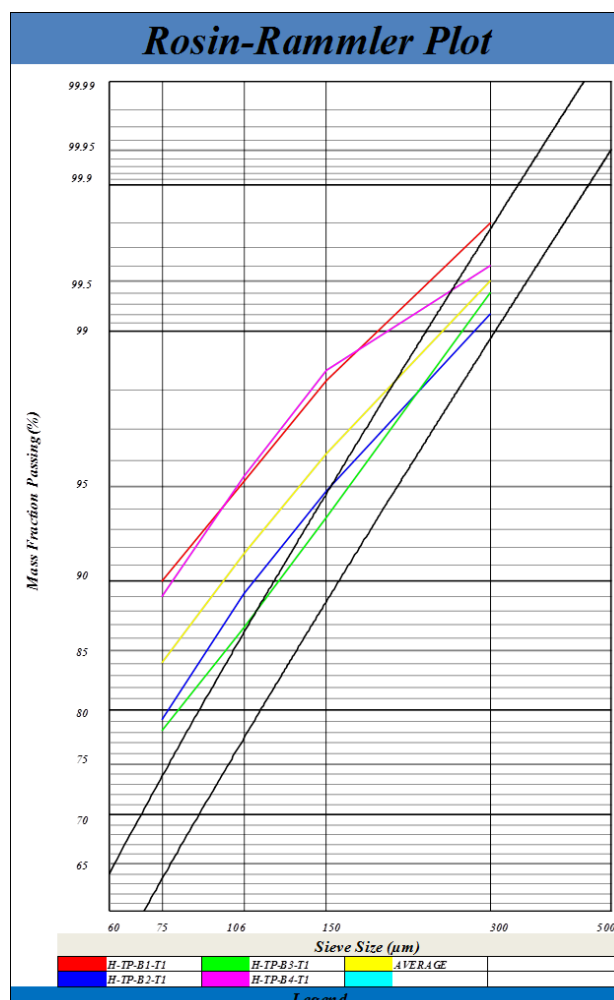
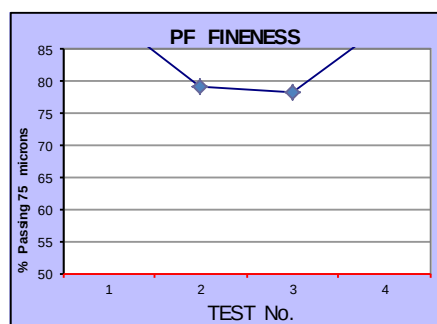
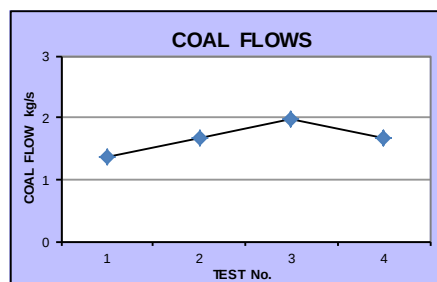
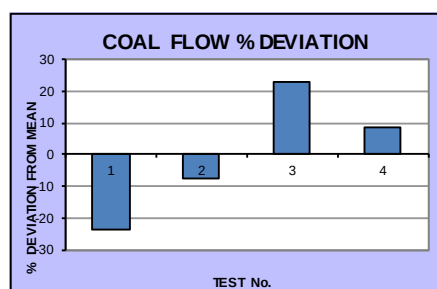
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.68	1.92	91	84.0	0.8219
2	0.35	1.89	93		0.8171
3	0.64	2.22	91		0.8248
4	0.82	2.28	89		0.8299

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1 to 4
TEST CONDITIONS :		Mill 4 PIPES, TARGET PLATE		TEST No.	1
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	01-09-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.39	-23.6	3.65	88	21.8	99.8	98.2	95.2	90.0
2	1.67	-7.7	4.06	86	24.2	99.2	94.8	89.2	79.2
3	1.97	22.7	4.15	87	24.8	99.4	93.6	86.8	78.2
4	1.68	8.6	2.93	88	17.6	99.6	98.4	95.4	89.0
Totals	6.71		14.79			WEIGHTED AVERAGE FOR THE MILL			
%	5.40	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	8.70	Raw Coal Flow B (dry)				99.5	95.5	90.3	81.9
%	77.11	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	3.0
MILL OUTLET TEMP.	(°C)	89.9
RAW COAL FLOW A (wet)	(kg/s)	8.9
RAW COAL FLOW B (wet)	(kg/s)	9.2

MILL	1B
PF PIPE	1 to 4
TEST No.	2
DATE	01-09-15

Mill 4 PIPES, TARGET PLATE

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	H-TP-B1-T2	H-TP-B2-T2	H-TP-B3-T2	H-TP-B4-T2
Masses in grams				
TEST No.	1	2	3	4
container + sample	432.0	408.2	696.9	669.0
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	421.6	397.8	686.5	658.6
Average	541.1			
% deviation from mean	-22.1	-26.5	26.9	21.7

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.6	58.5	58.8	58.8
% PF MOISTURE	2.3	2.5	2.0	2.0

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.1	0.4	0.2	0.2
Retained PF mass > 150 um	1.0	1.9	1.6	0.6
Retained PF mass > 106 um	2.0	2.7	2.3	1.5
Retained PF mass > 75 um	3.8	4.2	3.7	3.3
Collected in the receiver	43.3	41.1	42.4	44.6
Sum totals	50.2	50.3	50.2	50.2

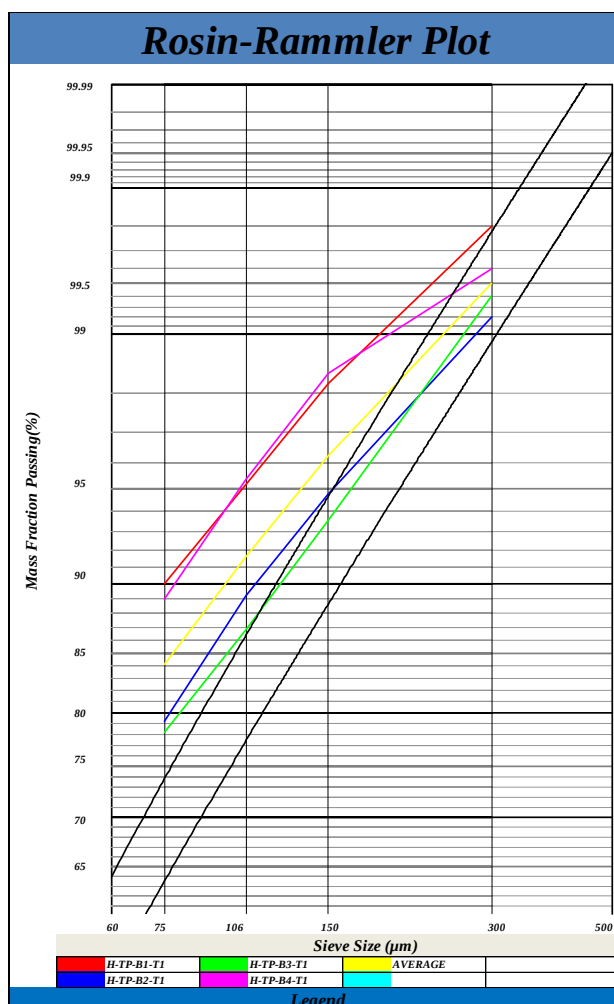
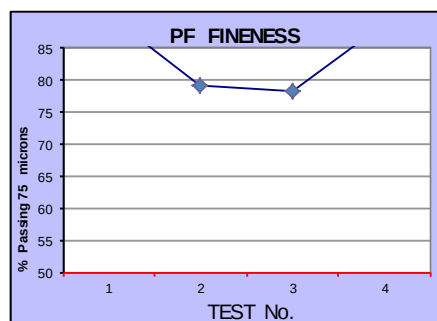
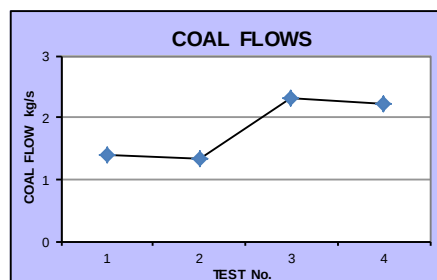
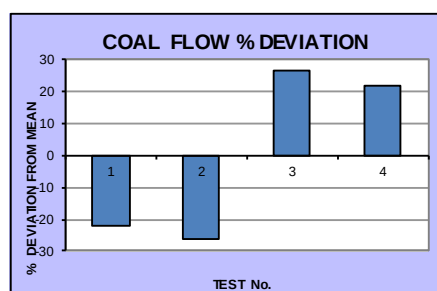
PF PIPE MEASUREMENTS

TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.36	1.94	90	84.0	0.8244
2	0.34	1.98	92		0.8202
3	0.62	2.34	90		0.8282
4	0.52	2.26	92		0.8229

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1 to 4
TEST CONDITIONS :		<u>Mill 4 PIPES, TARGET PLATE</u>		TEST No.	2
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	01-09-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.42	-22.1	3.65	88	21.8	99.8	98.2	95.2	90.0
2	1.33	-26.5	4.06	86	24.2	99.2	94.8	89.2	79.2
3	2.31	26.9	4.15	87	24.8	99.4	93.6	86.8	78.2
4	2.22	21.7	2.93	88	17.6	99.6	98.4	95.4	89.0
Totals	7.29		14.79			WEIGHTED AVERAGE FOR THE MILL			
%	5.40	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	8.70	Raw Coal Flow B (dry)				99.5	95.7	90.6	82.5
%	83.73	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	(kg/s)	13.7
MILL DEMAND	(%)	90.0
MILL POWER	(kW)	3.0
MILL OUTLET TEMP.	(°C)	89.9
RAW COAL FLOW A (wet)	(kg/s)	8.9
RAW COAL FLOW B (wet)	(kg/s)	9.2

MILL	1B
PF PIPE	1 to 4
TEST No.	3
DATE	01-09-15

Mill 4 PIPES, TARGET PLATE

PF Pipe Diameter = 508 mm

Sampling time : 30 sec x 8 points

SAMPLE ID	H-TP-B1-T3	H-TP-B2-T3	H-TP-B3-T3	H-TP-B4-T3
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Masses in grams

TEST No.	1	2	3	4
container + sample	443.0	564.3	672.5	617.8
Mass of Container	10.4	10.4	10.4	10.4
Mass of Sample	432.6	553.9	662.1	607.4
Average	564.0			
% deviation from mean	-23.3	-1.8	17.4	7.7

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	58.7	58.5	58.7	58.7
% PF MOISTURE	2.2	2.5	2.2	2.2

SIEVING

50 grams sieved

TEST No.	1	2	3	4
Retained PF mass > 300 um	0.1	0.7	0.1	0.2
Retained PF mass > 150 um	1.1	2.9	0.8	0.7
Retained PF mass > 106 um	2.2	3.4	1.8	1.8
Retained PF mass > 75 um	3.7	5.0	3.5	4.3
Collected in the receiver	43.2	38.3	44.0	43.2
Sum totals	50.3	50.3	50.2	50.2

PF PIPE MEASUREMENTS

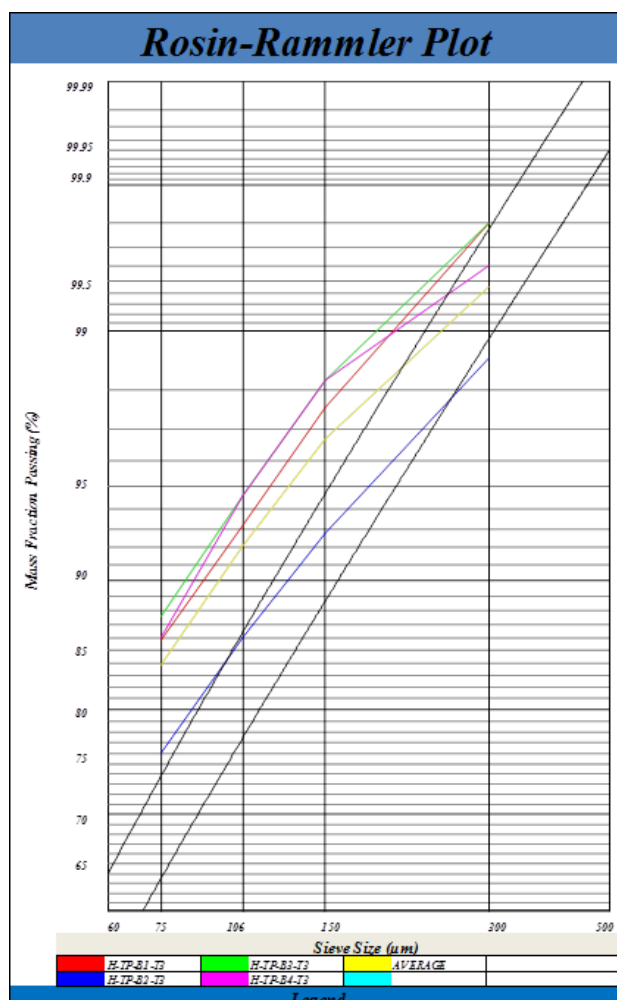
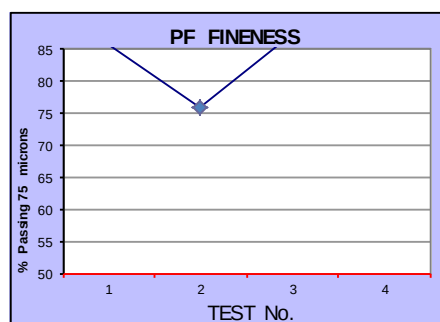
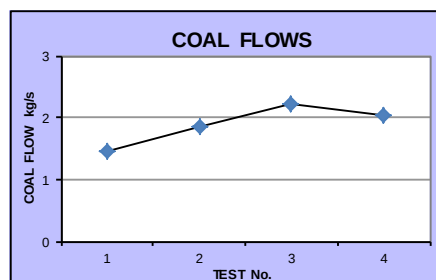
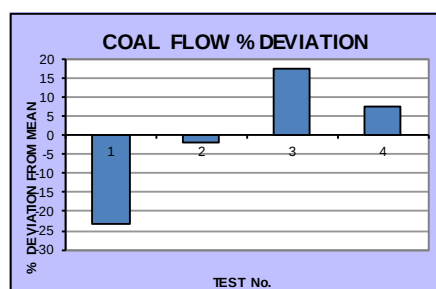
TEST No.	Velocity	Static	Temp	Atm	Density
	Pressure	Pressure		Pressure	
	kPa	kPa	°C	kPa	kg/m ³
1	0.42	1.89	94	84.0	0.8149
2	0.32	1.88	93		0.8170
3	0.86	2.38	88		0.8332
4	1.22	2.38	89		0.8309

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1 to 4
TEST CONDITIONS :		Mill 4 PIPES, TARGET PLATE		TEST No.	3
PA FLOW (kg/s)	13.7	PF Pipe Diameter = 508 mm		DATE	01-09-15

Sampling time : 30 sec x 8 points

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Airflow kg/s	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
1	1.46	-23.3	3.65	88	21.8	99.8	97.6	93.2	85.8
2	1.86	-1.8	4.06	86	24.2	98.6	92.8	86.0	76.0
3	2.23	17.4	4.15	87	24.8	99.8	98.2	94.6	87.6
4	2.04	7.7	2.93	88	17.6	99.6	98.2	94.6	86.0
Totals	7.59		14.79			WEIGHTED AVERAGE FOR THE MILL			
						% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
						99.5	96.6	92.0	83.6

%	5.40	Raw Coal moisture
kg/s	8.70	Raw Coal Flow B (dry)
%	87.19	Recovery Rate



Appendix W Results – Rotoprobe results horizontal pipes B1H1 to B4H4

Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.82	kg/s
COAL FLOW B	8.85	kg/s

MILL	1B
PF PIPE	1-4
TEST No.	1
DATE	21-08-15

Mill 4 PIPES, Rotoprobe
PF Pipe Diameter = 508 mm
 Sampling time : 4 minutes

SAMPLE ID	B1H1-T1	B2H2-T1	B3H3-T1	B4H4-T1
Masses in grams				
TEST No.	B1HT1	B2HT1	B3HT1	B4HT1
Container + sample	119.90	194.57	47.41	132.14
Mass of Container	2.00	2.00	2.00	2.00
Mass of Sample	117.90	192.57	45.41	130.14
Average	121.51			
% deviation from mean	-2.97	58.49	-62.63	7.11

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	59.26	58.91	58.93	58.77
% PF MOISTURE	1.23	1.82	1.78	2.05

SIEVING

50 grams sieved

TEST No.	B1HT1	B2HT1	B3HT1	B4HT1
Retained PF mass > 300 um	0.28	0.99	1.28	0.57
Retained PF mass > 150 um	1.46	3.93	5.07	1.39
Retained PF mass > 106 um	5.16	11.61	6.02	10.09
Retained PF mass > 75 um	11.88	10.81	7.76	10.95
Collected in the receiver	31.26	22.84	24.61	27.03
Sum totals	50.04	50.18	44.74	50.03

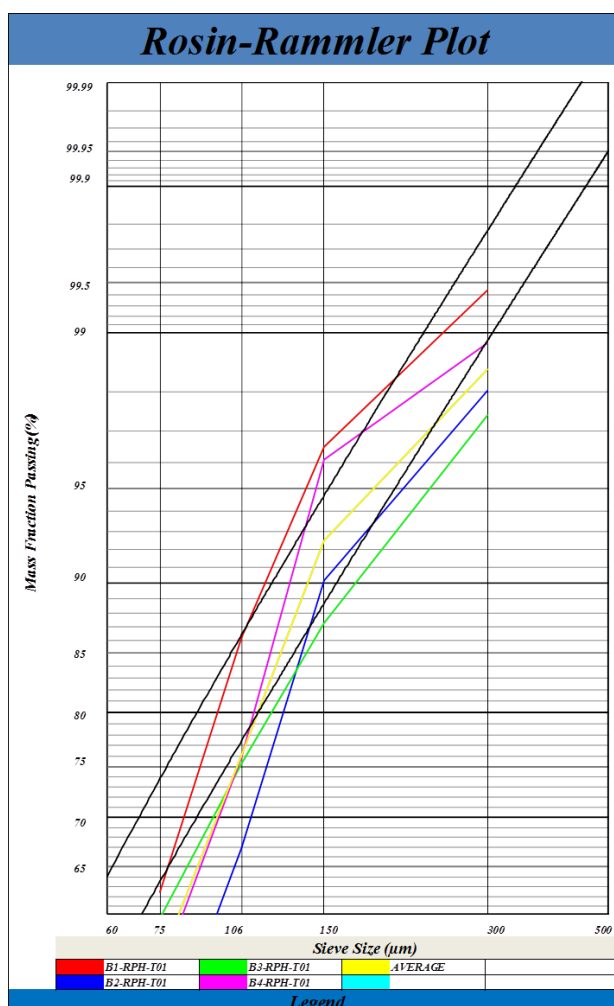
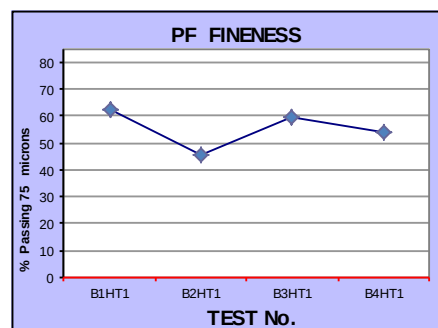
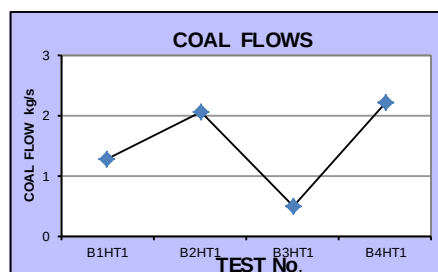
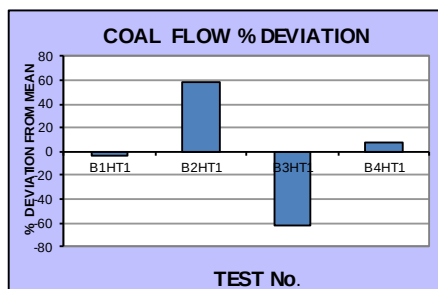
(44.16)

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
B1HT1	20.00	1.11	91.70	1.10	
B2HT1	23.00	1.11	92.70	1.40	
B3HT1	22.00	1.11	92.70	1.30	
B4HT1	19.00	1.11	91.20	0.90	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		<u>Mill 4 PIPES, Rotoprobe</u>		TEST No.	1
PA FLOW (kg/s)	13.80	PF Pipe Diameter = 508 mm		DATE	21-08-15
		Sampling time : 4 minutes			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
B1HT1	1.27	-2.97	1.10	74.80	20.00	99.4	96.5	86.2	62.4
B2HT1	2.06	58.49	1.10	74.80	20.00	98.0	90.2	66.9	45.3
B3HT1	0.50	-62.63	1.10	74.80	20.00	97.4	87.3	75.3	59.7
B4HT1	2.21	7.11	1.10	74.80	20.00	98.9	96.1	75.9	54.0
Totals	6.04		4.40			WEIGHTED AVERAGE FOR THE MILL			
%	7.60	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	8.18	Raw Coal Flow B (dry)				98.58	92.60	71.96	50.85
%	73.86	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.82	kg/s
COAL FLOW B	8.85	kg/s

MILL	1B
PF PIPE	1-4
TEST No.	2
DATE	21-08-15

Mill 4 PIPES, Rotoprobe
PF Pipe Diameter = 508 mm
 Sampling time : 4 minutes

SAMPLE ID	B1H1-T3	B2H2-T2	B3H3-T2	B4H4-T2
Masses in grams				
TEST No.	B1HT2	B2HT2	B3HT2	B4HT2
Container + sample	124.63	197.01	49.18	134.28
Mass of Container	2.00	2.00	2.00	2.00
Mass of Sample	122.63	195.01	47.18	132.28
Average	124.28			
% deviation from mean	-1.32	56.92	-62.04	6.44

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	59.26	58.91	58.93	58.77
% PF MOISTURE	1.23	1.82	1.78	2.05

SIEVING

50 grams sieved

TEST No.	B1HT2	B2HT2	B3HT2	B4HT2
Retained PF mass > 300 um	0.47	1.11	1.39	0.49
Retained PF mass > 150 um	1.63	3.97	5.13	1.81
Retained PF mass > 106 um	5.56	8.70	6.28	5.63
Retained PF mass > 75 um	13.45	12.42	7.77	13.53
Collected in the receiver	28.84	23.90	25.98	28.56
Sum totals	49.95	50.10	46.55	50.02

(45.94)

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
B1HT2	20.00	1.11	91.70	1.10	
B2HT2	23.00	1.11	92.70	1.40	
B3HT2	22.00	1.11	92.70	1.30	
B4HT2	19.00	1.11	91.20	0.90	

Power Station A PF SAMPLING TEST RESULTS

MILL **1B**

PF PIPE **1-4**

TEST CONDITIONS : **Mill 4 PIPES, Rotoprobe**

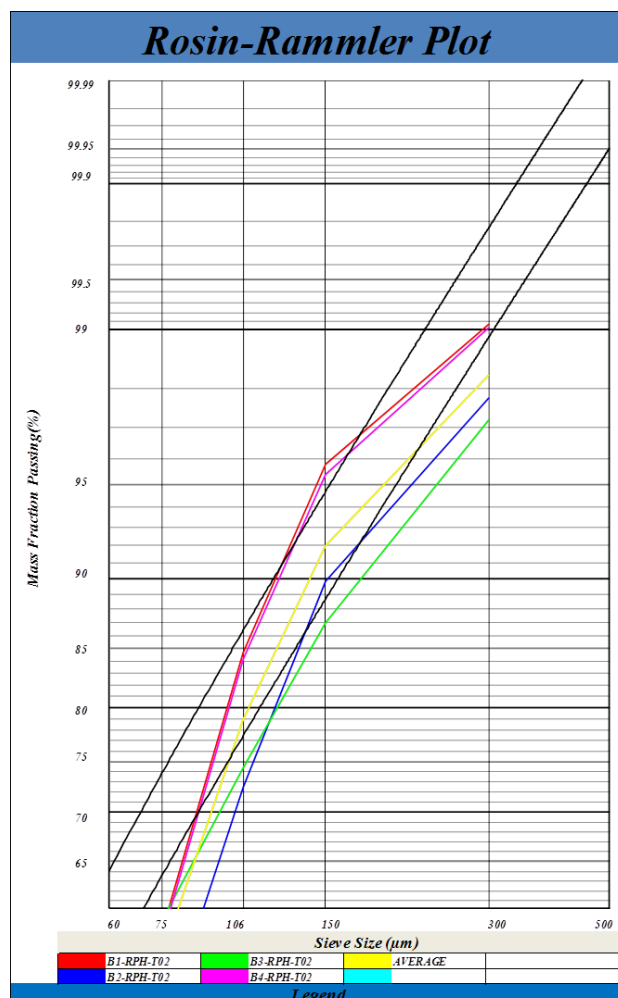
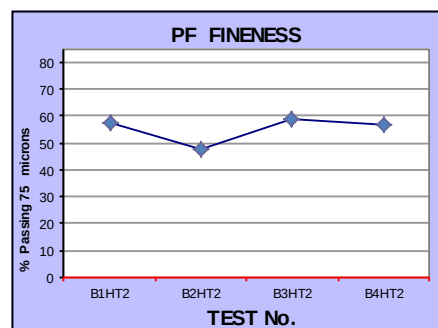
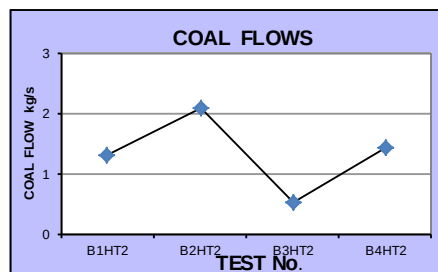
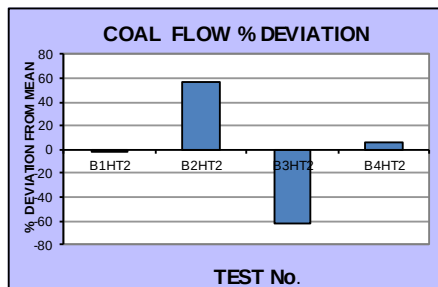
TEST No. **2**

PA FLOW (kg/s) **13.80** PF Pipe Diameter = 508 mm

DATE **21-08-15**

Sampling time : 4 minutes

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
B1HT2	1.32	-1.32	1.10	74.80	20.00	99.1	95.8	84.7	57.8
B2HT2	2.08	56.92	1.10	74.80	20.00	97.8	89.8	72.4	47.6
B3HT2	0.52	-62.04	1.10	74.80	20.00	97.2	87.0	74.4	58.9
B4HT2	1.42	6.44	1.10	74.80	20.00	99.0	95.4	84.1	57.1
Totals	5.34		4.40			WEIGHTED AVERAGE FOR THE MILL			
%	7.60	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	8.18	Raw Coal Flow B (dry)				98.37	91.43	76.83	52.41
%	65.30	Recovery Rate							



Power Station A	PF SAMPLING & GRADING
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TEST MEASUREMENTS

MILL PANEL READINGS

AIRFLOW	13.80	kg/s
MILL DEMAND	90.00	%
MILL POWER	1106.30	kW
MILL OUTLET TEMP.	72.00	°C
COAL FLOW A	8.82	kg/s
COAL FLOW B	8.85	kg/s

MILL	1B
PF PIPE	1-4
TEST No.	3
DATE	21-08-15

Mill 4 PIPES, Rotoprobe
PF Pipe Diameter = 508 mm
 Sampling time : 4 minutes

SAMPLE ID	B1H1-T4	B2H2-T3	B3H3-T3	B4H4-T3
Masses in grams				
TEST No.	B1HT3	B2HT3	B3HT3	B4HT3
Container + sample	130.70	204.41	35.98	131.34
Mass of Container	2.00	2.00	2.00	2.00
Mass of Sample	128.70	202.41	33.98	129.34
Average	123.61			
% deviation from mean	4.12	63.75	-72.51	4.64

Each sample is reduced to a representative sample

60 grams of sample is dried in oven @ 105 °C for one hour

DRY MASS grams	59.26	58.91	58.93	58.77
% PF MOISTURE	1.23	1.82	1.78	2.05

SIEVING

50 grams sieved

TEST No.	B1HT3	B2HT3	B3HT3	B4HT3
Retained PF mass > 300 um	0.34	1.03	0.97	0.56
Retained PF mass > 150 um	1.64	4.37	3.97	1.39
Retained PF mass > 106 um	6.89	13.11	4.18	5.82
Retained PF mass > 75 um	13.86	10.04	5.41	12.93
Collected in the receiver	27.37	21.44	18.80	29.36
Sum totals	50.10	49.99	33.33	50.06

(32.88)

PF PIPE MEASUREMENTS

TEST No.	Velocity	g factor	Temp	Diff	Comment
	m/s		°C	kPa	
B1HT3	20.00	1.11	91.70	1.10	
B2HT3	23.00	1.11	92.70	1.40	
B3HT3	22.00	1.11	92.70	1.30	
B4HT3	19.00	1.11	91.20	0.90	

Power Station A		PF SAMPLING TEST RESULTS		MILL	1B
				PF PIPE	1-4
TEST CONDITIONS :		<u>Mill 4 PIPES, Rotoprobe</u>		TEST No.	3
PA FLOW (kg/s)	13.80	PF Pipe Diameter = 508 mm		DATE	21-08-15
		Sampling time : 4 minutes			

PF PIPE MEASUREMENTS						PF GRADING RESULTS			
TEST No.	Coalflow kg/s	% Deviation	Diff	Temp °C	Velocity m/s	% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
B1HT3	1.32	4.12	1.10	74.80	20.00	99.3	96.0	82.3	54.5
B2HT3	2.08	63.75	1.10	74.80	20.00	97.9	89.2	63.0	42.9
B3HT3	0.52	-72.51	1.10	74.80	20.00	98.1	90.1	81.8	70.9
B4HT3	1.42	4.64	1.10	74.80	20.00	98.9	96.1	84.5	58.6
Totals	5.34		4.40			WEIGHTED AVERAGE FOR THE MILL			
%	7.60	Raw Coal moisture				% Passing 300 u	% Passing 150 u	% Passing 106 u	% Passing 75 u
kg/s	8.18	Raw Coal Flow B (dry)				98.54	91.76	73.00	52.07
%	65.30	Recovery Rate							

