TUNRA Coal & Minerals

Development of an Online Ash Slurry Analyser

ACARP Project No. C11013

Noel Lambert

Abstract

This report describes a new type of online slurry ash analyser. The device calculates the density of particles in a slurry and makes use of the relationship between particle density and ash content. Particle density is measured by using a commercial online slurry density unit (Micro Motion Coriolis Meter) and a commercial online solids concentration meter (Markland 502 -TP Suspended Solids Meter). The results from these two meters are combined to calculate the average particle density.

Experimental results showed that slurry density can be measured accurately, but accurate solids concentration results were more difficult to achieve. Comparison between online ash content and the laboratory results often displayed constant offsets. This could be explained by the fact that laboratory methods used to calculate slurry density and ash value do not allow for the effect of salt concentration or water temperature on density. A revised laboratory method for determining slurry density has been included in Appendix 1.

With the removal of the constant offset noted above, the online meter provides a reasonable determination of the current conditions in a particular slurry stream. The constant information gathered from the online meter can be used to accurately follow trends in particle density. Knowledge of particle density has been shown in this work to be sufficient enough to improve the control of flotation systems. The conversion from particle density to ash content simply provides a familiar term that one can relate to.

The a pplication of thi s system is r elevant to   more tha n just the c ontrol of f lotation systems. The use of this technology could extend into any application where a coal or any other slurry is measured.

Table of Contents

List of Figures

Acknowledgments

The author of this report would like to thank the following for their assistance throughout this project.

Firstly to ACARP for providing the funding to complete this project.

Emerson processes, particularly Jeff Quirk for his extremely professional assistance and in depth knowledge of the Coriolis flowmeters.

To Mt Thorley – Warkworth for the supply of samples and allowing test work to be carried out on site and to Clinton Brockwell for helping compile this report.

1. Introduction

Recovery of fine coal particles (-0.5 mm) in many coal preparation plants is achieved through the use of flotation. A concentrated product stream of low ash content can regularly occur with continual optimisation of the flotation circuit. However variances in concentration, size distribution and ash content of the feed stream change the entire dynamic of the flotation system resulting in poor product recovery. Control of the flotation circuit can be improved by knowledge of ash content, mass flow and density of the coal slurries. Information on mass flow and slurry density can be obtained accurately using a number of commercially available devices, whereas the measurement of ash content requires a slurry sample to be analysed by a laboratory. Receiving results from the laboratory is time consuming and consequently the data received may no longer be relevant to the current feed conditions to the circuit.

This report focuses on a new method to calculate the ash content of coal particles within a slurry. The device developed combines a Coriolis flow meter and an ultrasonic concentration meter to compute a value for the particle density. Using the relationship between particle density and ash content a value for ash content of the slurry is attained.

Availability of this data in real time allows flotation systems to be controlled accurately, ensuring the product yield and ash is maintained. Trends can also be monitored to optimise system efficiency over a prolonged time period, which has been almost impossible to achieve in plant scale flotation systems.

2. Theory

One of the most important sale contract criteria for product coal is the ash content. The ash content is related to the particle density via the particle mineral matter content. Coal components have low densities and low ash values compared to mineral components, which have high densities and consequently high ash values. In any coal there would usually be several different mineral components, each with their own properties so a detailed relationship is difficult. Relationships have been proposed by both Armstrong and Whitmore (1981) and King and Birtek (1990) that shows a linear relationship between the ash content and the reciprocal of particle density. A general form of this relationship is provided in (Partridge 1994) as:

(1.)

Where the constants *x* and *y* have the values of between 160 to 200 and between 200 to 250 respectively. An alternative relationship that may be used defined by (Sanders 1994) relates the apparent relative density of a particle to the ash content via the following relationship.

(2.)

For bituminous coals, a factor '*K*' of between 1.22 and 1.30 is considered reasonable. The above shows that there is a definite relationship between particle density and ash content that holds true over a range of density values. With these relationships, an accurate ash content may be obtained online by calibrating the device to particular coals. For this study a variation of the general equation was used, allowing the user to input their own seam specific values depending on coal and mineral matter properties.

——

(3.)

Where ρ_p, ρ_c, ρ_{mm} are relative densities of the particle, pure coal and mineral matter respectively. A_{mm} is an approximation of the maximum ash content possible, for this work a value of 90 was used. Relative density of mineral matter (ρ_{mm}) used for a particular system would vary depending on concentrations of minerals present. A value of 2.4 was used for this system, which corresponds to an approximate value for bentonite. Table 1 lists relative density ranges of other common minerals values taken from table 3-118 Perry's Chemical Engineers Handbook 6th ed.

Table 1 Relative Densities of Common Species

Substance	Relative Density
Clay, Marl	1.8 - 2.6
Limestone	2.1 - 2.86
Bentonite	2.2 -2.4
Quartz	2.5 - 2.8
Shale, Slate	2.6 - 2.9
Granite	2.6 - 2.7
Pyrites	5.01

Similarities can be made between equation 3 and published relationships especially by Armstrong and Whitmore (1981). However Armstrong and Whitmore (1981) have expressed their relationship in different terms. Equation (3.) is defined in terms of relative particle density (ρ_p) which is not common but necessary for this study.

Alternatively if we rearrange equation (3.) we can then calculate a value for ash content.

(4.)

In this project the particle density is measured by using a commercial online slurry density unit and a commercial online solids concentration meter. The results from these two units are then combined given that relative density of slurry (ρ_{slurry}) is defined as (kg_{slurry} / L_{slurry}) and concentration of solids (C_s) is defined on a (w/v) basis with units of (kg_{solids} / L_{slurry}). Looking at it from a units perspective we have:

(5.)

If we now multiply the result from (5.) by the relative density of water corrected for salt concentration and temperature of slurry we have:

(6.)

Now if we subtract (6.) from 1.we have:

(7.)

Now the relative density of the particle is defined as

Substituting in (7.) and the definition of C_s we get the equation for the relative density of the particle below:

(8.)

3. Experimental

3.1 Apparatus

Initial test apparatus used to measure slurry density consisted of two pressure gauges at different known heights on a pipe full of slurry. The slurry density was calculated from the well known equation $\Delta P = \rho * g * \Delta H$

Where: ΔP = difference in pressure

ρ = slurry density

g = acceleration due to gravity

ΔH = difference in vertical height

The results from this testwork proved far too inaccurate for the precise slurry densities required for this testwork and the results have not been presented in this report. This method is accurate enough for determining medium density in coarse coal circuits where the nominal slurry density is in the range of 1.4 to 1.8. In the fines circuits however, slurry densities may be as low as 1.01, and the smallest error can lead to a large error in the solids density determination.

In order to increase the accuracy of the slurry density determination, it was decided to use a coriolis type meter. Highly accurate coriolis slurry density meters are readily available, and a Micro Motion Coriolis meter was selected for this test work. The Coriolis flowmeter is a true mass flowmeter, and measures mass directly (as opposed to indirectly, via volume or velocity). Coriolis meters have a wide application in many industries and different process applications. This is due to their ability to provide highly accurate measurements that are independent of variations in process conditions such as fluid density, viscosity, pressure and temperature. This is because Coriolis meters are designed to measure physical properties. Because of this attribute, it is possible to use the Coriolis meter on a variety of process fluids without recalibrating or compensating for specific fluid parameters. Another advantage of the Coriolis meter is it requires very little maintenance as the unit has no moving parts and the only wetted part is the tube, which can be constructed from various materials making it adaptable to many corrosive materials as well as fluids containing solid material.

“Coriolis mass flowmeters are based on the conservation of angular momentum as it applies to the Coriolis acceleration of the fluid” (Spitzer 1990). The Coriolis flowmeter used in this work was manufactured by Micro Motion. It consisted of a dual U-tube design. Fluid flows through the two parallel tubes, which are subjected to sinusoidal vibration about an axis formed between the inlet and outlet. If we look at the meter by splitting the U-tube down the rotational axis we find that in one half of the tube we have the fluid flowing away from the axis while in the other side its flowing towards the axis of rotation. In each associated half, a force resulting from the Coriolis acceleration of the fluid acts in opposite direction, which tends to twist the tube. The twist caused by these forces is directly proportional to the mass flow through the tube. Figure 1 shows the internal design of the Micro Motion Coriolis flowmeter used in this project.

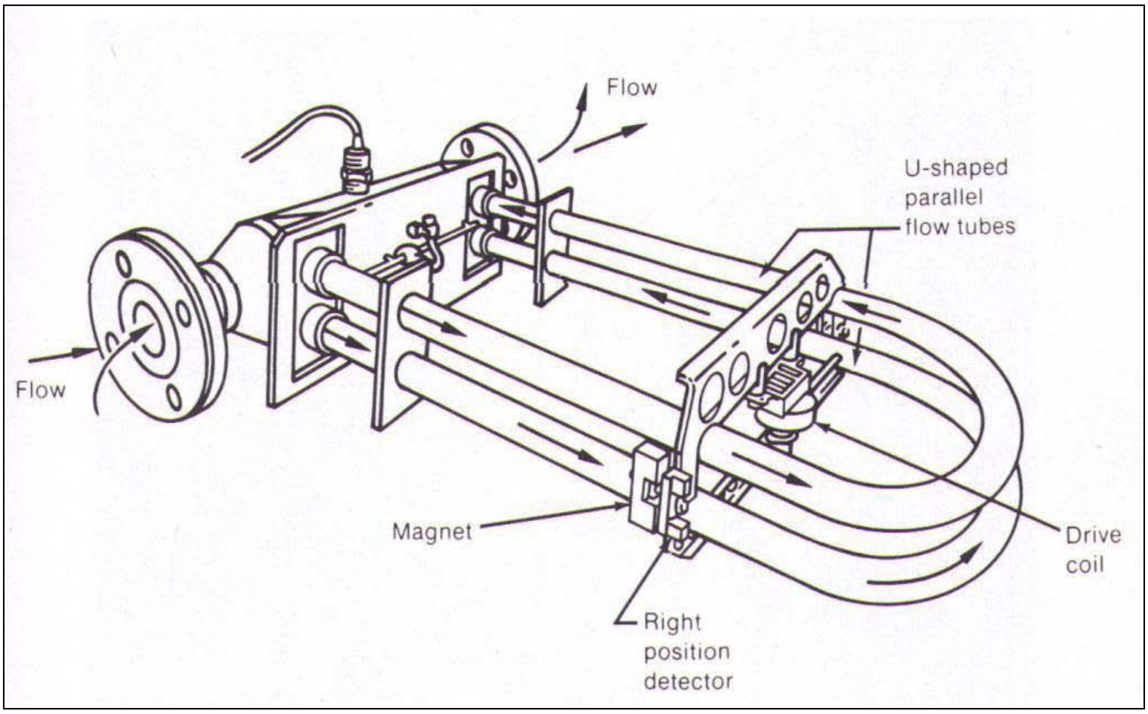


Figure 1 Dual U-Tube Micro Motion Coriolis Flowmeter (Spitzer 1990)

The tubes are constructed to have predictable vibratory characteristics and are vibrated by the drive assembly. The twist of the tube is measured by the side mounted magnetic detector system. Flowmeters are available in various sizes from 1/6 to 6 inch pipe diameters.

To measure the solids concentration, an ultrasonic solids concentration meter (Markland 502-TP Suspended Solids Meter) was used. The ultrasonic solids concentration meter consists of a probe that is placed into the slurry. A signal is sent through the slurry and the strength of the signal is measured upon its return. The difference in signal strength determines the concentration of particles. The larger the attenuation in signal the greater the concentration of particles in the slurry. The ultrasonic meter is calibrated using distilled water to set the zero particle concentration value and also with a known concentration of particles within a slurry mixture.

Combined these two meters form a non-nuclear online ash monitor. The arrangement of the test apparatus is depicted below in Figure 2.

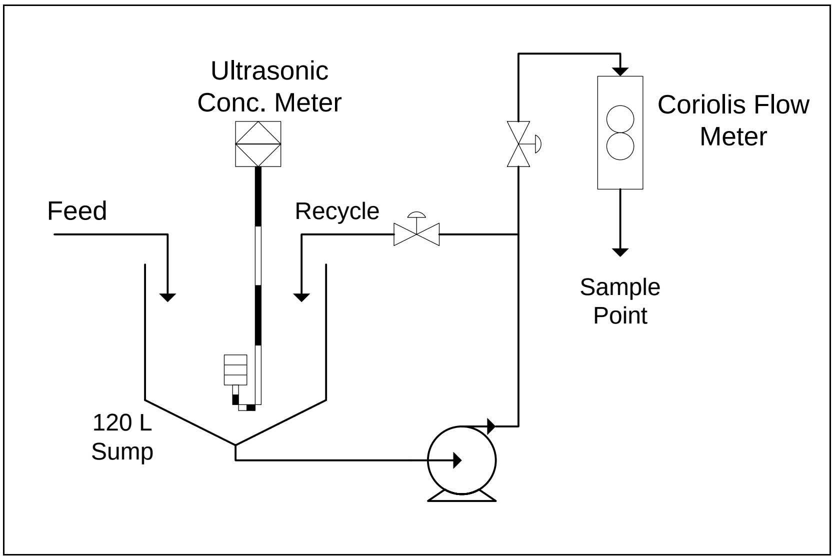


Figure 2 Online slurry analyser test apparatus

3.2 Density Measurement Procedure

The system used for this test work as illustrated in Figure 1 was run using samples taken directly from three Warkworth BDT (flotation) streams, the feed, concentrate and tailings streams. The sample line was fed directly into the 120 L sump where it was continually agitated by both the recycle and feed streams. The solids concentration was measured in the sump using the “drop in” probe from the Markland suspended solids meter. Particular care was taken to ensure that no solids build up occurred around the probe during each test run. Solids concentration was recorded from the Markland suspended solids meter display at time intervals of one minute.

A centrifugal pump was used to deliver slurry through the Coriolis meter at a constant flow rate. A reading of the slurry density was also recorded every minute. A slurry sample was taken once the slurry had passed through the Coriolis meter for comparative testing by laboratory methods. Laboratory slurry samples were taken representatively over 10 minute time intervals. Values of both solids concentration and slurry density recorded from the two meters were averaged over the 10 min time interval to compare with the laboratory values.

3.3 Ash Content

Determination of ash content is achieved mathematically by substituting the calculated particle density into a relationship for ash content and particle density (as per equation (1) or (2)). Figure 3 is an example of a set of data taken from a Hunter Valley plant that shows the progressive changes of ash composition with density at a range of particle sizes. Method one was the preferred method for this particular trial.

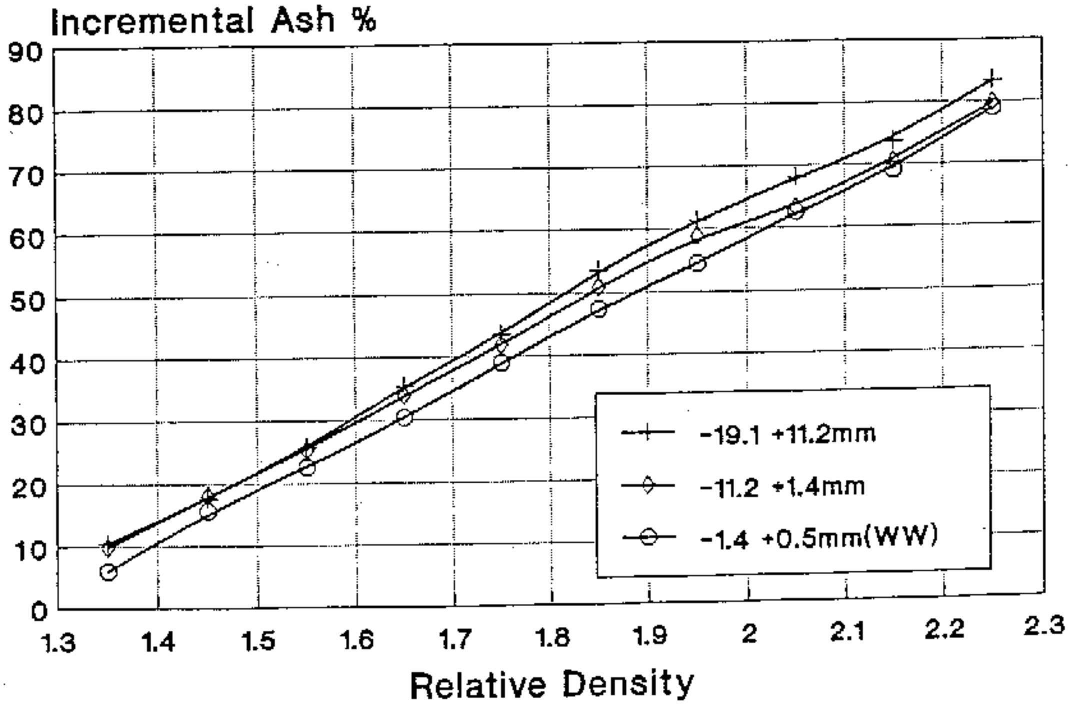


Figure 3 Ash Content / Density relationship for different size fractions (Partridge 1994)

4. Results

Experimental results of both the Coriolis density meter and the Markland ultrasonic concentration meter in comparison to the laboratory results are presented below. Figure 4 illustrates the accuracy of the Coriolis meter in comparison to the laboratory values for the samples taken. Laboratory values used were calculated using the solids concentration and solids density, as the typical laboratory method was considered far too inaccurate. Nevertheless, a good agreement was found between the Coriolis meter and actual slurry density and trends were certainly tracked.

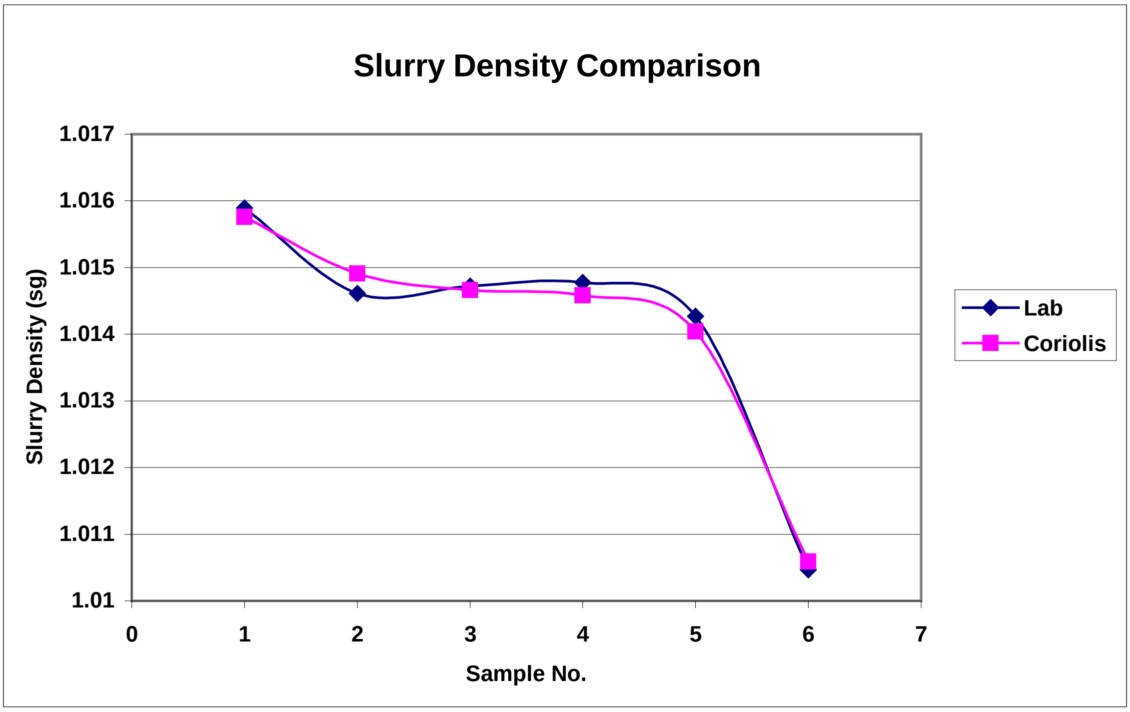


Figure 4 Comparison of Slurry Density

Presented below in Figure 5 is the graphical comparison of the concentration measurements of the Markland ultrasonic meter and laboratory measured values. The graph demonstrates that the concentration meter has a greater variance between measured and actual values. The concentration meter would occasionally give results that were far from the normal observed readings. These readings could be accounted for by the occasional inclusion of air bubbles in the feed. The outlying points further highlight the sensitivity of the ultrasonic device. Averaging of values and removal of outlying values by screening will remove the error.

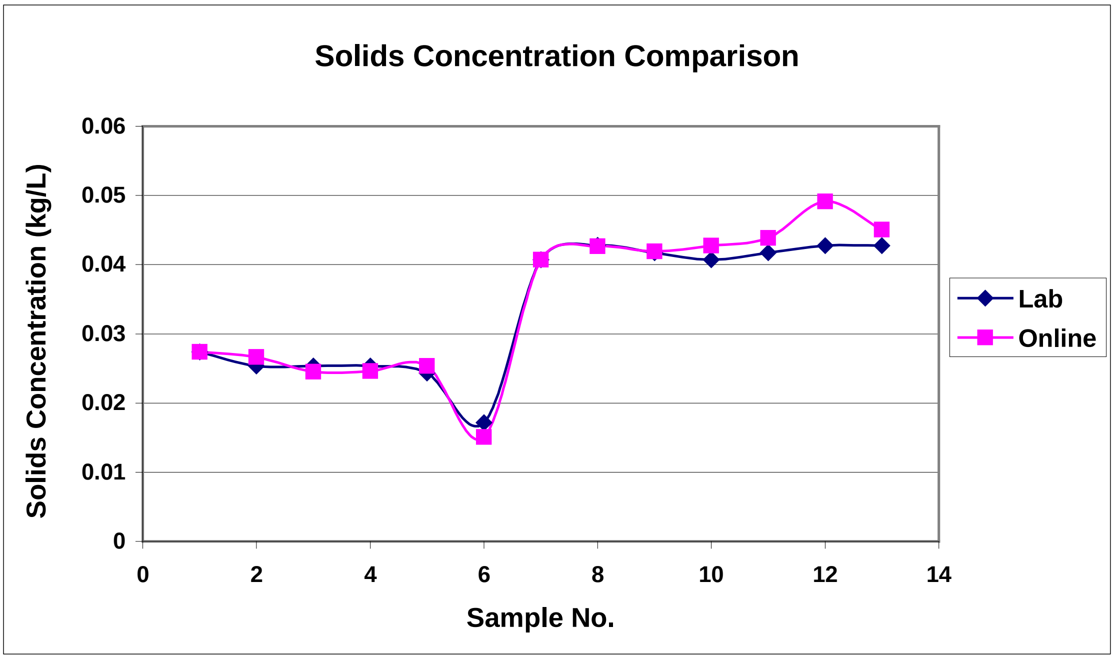


Figure 5 Comparison of Solids Concentration

The results from the slurry density and the solids concentration meters are then combined to produce the particle density determination, typical results of which are shown in the graph below (Figure 6). One result shows a large error that would be quickly discounted, but in general the online analyser follows the trend of the actual particle density.

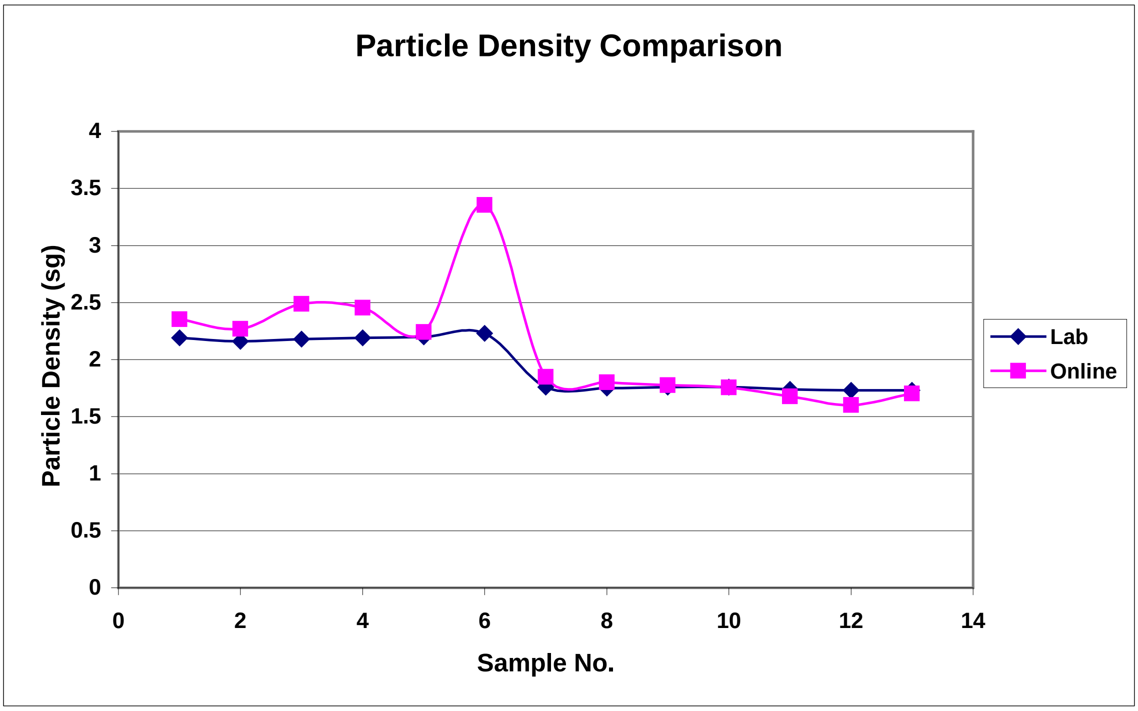


Figure 6 Comparison of Particle Density

Figure 7 Comparison of Ash Content on Warkworth BDT Feed Stream

Once the particle density has been calculated the result can then be used to determine the ash content of the particles. Shown above in Figure 7 are the results from an experimental run using the feed stream to the Warkworth BDT plant. The results from the apparatus may not be perfectly accurate; however it does detect changes in particle ash content. When comparing Figures 6 and 7 it can be seen that the outlying data point is exaggerated during the conversion from particle density to ash content.

5. Discussion

This system worked well for all three flotation streams (feed, concentrate and tailings). The results were consistent for the majority of samples with the occasional outlying value distorting the results. These troubles could be rectified with careful meter positioning and increased control over feed properties. Instances occurred where extra collector was added to the concentrate to breakdown any remaining bubbles from the slurry. The amount of collector added was negligible in terms of effecting slurry density or solids concentration. The added collector effectively removed entrained bubbles in the slurry drastically improved the accuracy of the results obtained.

It should be noted that an accurate measurement of the ash content is not required to improve a flotation system; particle density can be just as effective for plant control. The conversion from particle density to ash content simply provides a familiar term that one can relate to.

A side issue involving the results received from the laboratory for the slurry densities found that laboratory results were very inaccurate and unable to be used in any of the calculations. This is due to the method commonly employed in coal laboratories simply being far too inaccurate. Temperature and salt effects are not taken into account in the common lab methods. At the very least, the temperature of the slurry and of the water used to measure the slurry volume, should be recorded and the slurry density (sg) corrected for the difference between them or for slurry density, the results corrected to a given temperature, say 20 degrees Celsius. Possible points of inaccuracy and an improved method to calculate the slurry density is provided in Appendix 1.

6. Conclusions

Through the trial of the online ash analyser it can be seen that accurate measurements of both slurry density and solids concentration is possible. These results are then used in the calculation of particle density and finally the determination of ash content. The results although not perfectly accurate provide a solid indication of the current conditions present in the measured stream. The ability to follow the trends in particle density or ash content allows for increased control and an improvement in the overall plant efficiency. In addition to the increased plant control the availability of real time data allows for the estimate of expected plant yields. Overall the inclusion of an online device to measure particle density and consequently ash content is necessary to effectively control and optimise flotation and many other systems.

Further work is required to develop a standard method of accurately measuring the slurry density on a laboratory scale. Particular attention needs to be directed into fully investigating the effect of errors associated with temperature and salt concentration.

7. References

.

[1] Sanders, R.H. 1994, "Coal Characterisation" in Swanson, A.R. and Partridge, A.C. (eds) Advanced Coal Preparation Monograph Series, Volume I, Part 1, Australian Coal Preparation Society.

[2] Partridge, A.C. 1994, "Principles of Separation" in Swanson, A.R. and Partridge, A.C. (eds) Advanced Coal Preparation Monograph Series, Volume I, Part 1, Australian Coal Preparation Society

[3] Armstrong and Whitmore, 1981, "The Mathematical Modelling of Coal Washability", First Australian Coal Preparation Conference, Swanson, A.R.,(ed.), Paper E2, pp220.

[4] King, R.P and Birtek, N. 1990, "The Washability of Fine South African Coals", J. South African IMM, 90, 11, pp289-301

[5] Spitzer, D.W. 1990, "Industrial Flow Measurement: resources for measurement and control series", 12, pp197-212

[6] Spitzer, D.W. (ed.) 1991, "Flow Measurement: practical guides for measurement and control", 10, pp221-247

8. Appendix 1 – Improved Slurry Density Measurement

Commonly there are four ways in which the density of a slurry is measured these include the Marcy scale, volumetric flask method, measuring cylinder method and bucket method. Accuracies of these methods range with all of the methods having there own faults. As a result of the work carried out in this project it was found that major discrepancies existed between slurry density results received from the laboratory compared to expected values. Samples that contained significant concentrations of particles (>10% of particle with sg of 1.4) were reported to have specific gravities less than 1. Identified were two points of error that are not taken into consideration by any of the common laboratory methods. These are that:

1. The density of water cannot be simply assumed to be 1 g/mL. The difference in temperature of the slurry sample and the water used to calculate the volume occupied by the slurry should not be considered negligible. Temperature of both the slurry and the water used to find volume must be recorded and its density corrected.

2. If non-potable water is being used, the conductivity of it must also be measured. Process water commonly contains a higher salt content than potable water. Therefore the salt content should be calculated and a correction included for density calculations. Salt concentration is even more relevant if a solids concentration is required as dissolved salts would remain after the water had been removed. The result would be a greater solids content than is actually present.

Further work would need to be carried out to test the various methods to develop an accurate standard that all testing facilities could use. An improved method was developed for our own results to improve the laboratory calculated slurry densities listed in this report. A full description of the improved bucket method has been provided.

Density Determination of a Slurry Sample – Bucket Method

1. Scope

Method is based on determining the slurry density of a slurry sample provided in a 20 L sample bucket.

2. Apparatus Required

- Weighing Device - a balance that has the capacity of 50 kg and is readable to 1 g.

NOTE: balance should be placed on a solid level surface to ensure accuracy.

2. Procedure

The procedure should be as follows:

1. Place slurry sample bucket (without lid) on scales. Record mass of sample to an accuracy of 1 g (m_1).
2. Record temperature of slurry sample (T_1).
3. Measure accurately the distance from bucket lip to slurry surface. Mark slurry level of with a permanent marker on the inside of the bucket.
4. Remove slurry sample (may be moved on for further testwork), clean and dry bucket. Ensure that the bucket shape is not distorted in any way.
5. Place clean, dry empty bucket on scales. Record mass of empty bucket (m_2).
6. Fill sample bucket to the same level as was previously occupied by the slurry (indicated by the mark) with potable water. Record the temperature of the water (T_2)
7. Place re-filled sample bucket on scales. Record mass of the bucket and water (m_3).

3. Calculations

The density of the slurry will be calculated using the following equation.

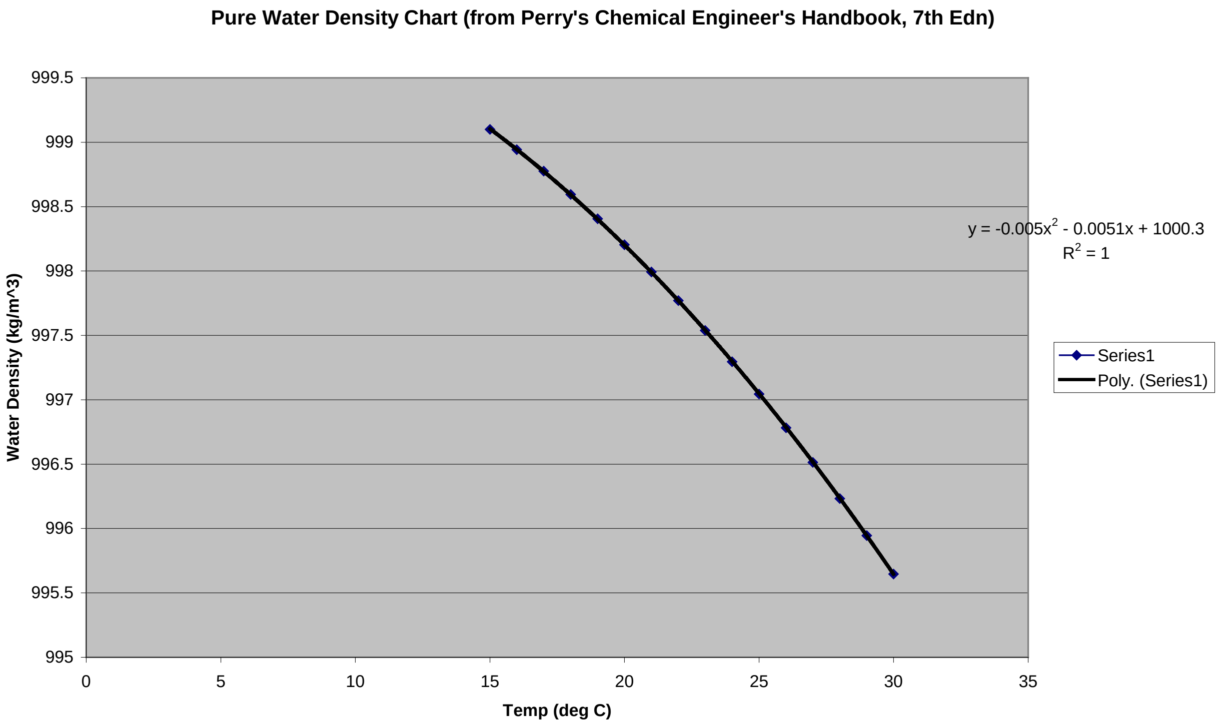
$$Slurry \quad Density = \frac{m_1 - m_2}{(m_3 - m_2) \times \rho_W}$$

m_1 = mass of sample and bucket
m_2 = mass of dry clean bucket
m_3 = mass of make up water
ρ_w = density of water corrected at T_2

NOTE: density of water can be corrected using the relationship given in Appendix 2

9. Appendix 2 – Water Density Determination

Correction for the density of pure water at various temperatures can be determined using the relationship taken from Perry's Chemical Engineer's Handbook, 7th ed shown in the graph below.



10. Appendix 3 – Data From Trial Runs

10.1 Trial Run 3

Date	9/01/2005				
Feed Type:	Fresh Feed		Ash Calcs		
Temp (^oC)	21	0	% ash	1.15	
		90	% ash	2.35	

	Lab Results			Calcs from Lab Results	
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Solids Conc(kg/L)
1	4	1.9	59.8	1.019	0.04077253
2	4.1	1.87	56.5	1.019	0.04179728
3	3.9	1.9	57.3	1.019	0.03973403
4	4.3	1.87	59.4	1.020	0.04387779
5	4	1.87	53.3	1.019	0.0407585
6	4.2	1.87	54.1	1.020	0.04283704

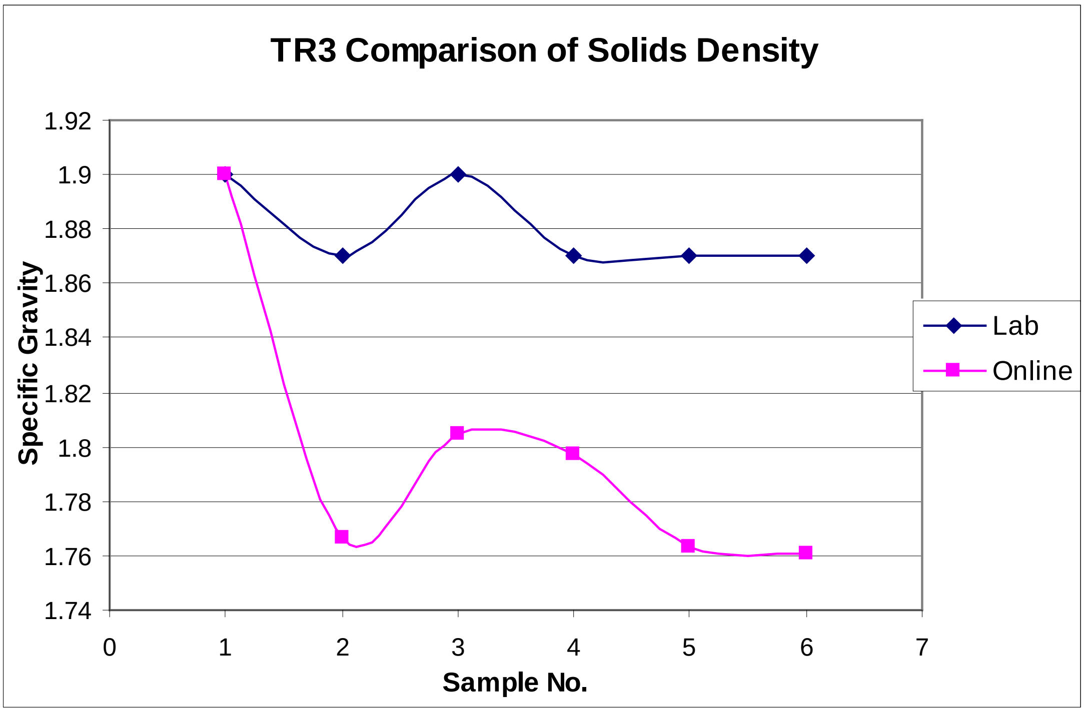
	Online Measurements				
Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Solids Conc(kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.015	1.815	0.0182702	1.57	31.3968646
2	1.014	1.620	0.0162858	1.48	24.9237051
3	1.013	1.616	0.0162471	1.50	25.9759823
4	1.015	1.738	0.0174834	1.52	27.4317088
5	1.013	1.513	0.015204	1.47	24.3125074
6	1.014	1.665	0.016741	1.48	25.0842875

Corrected Online Results **

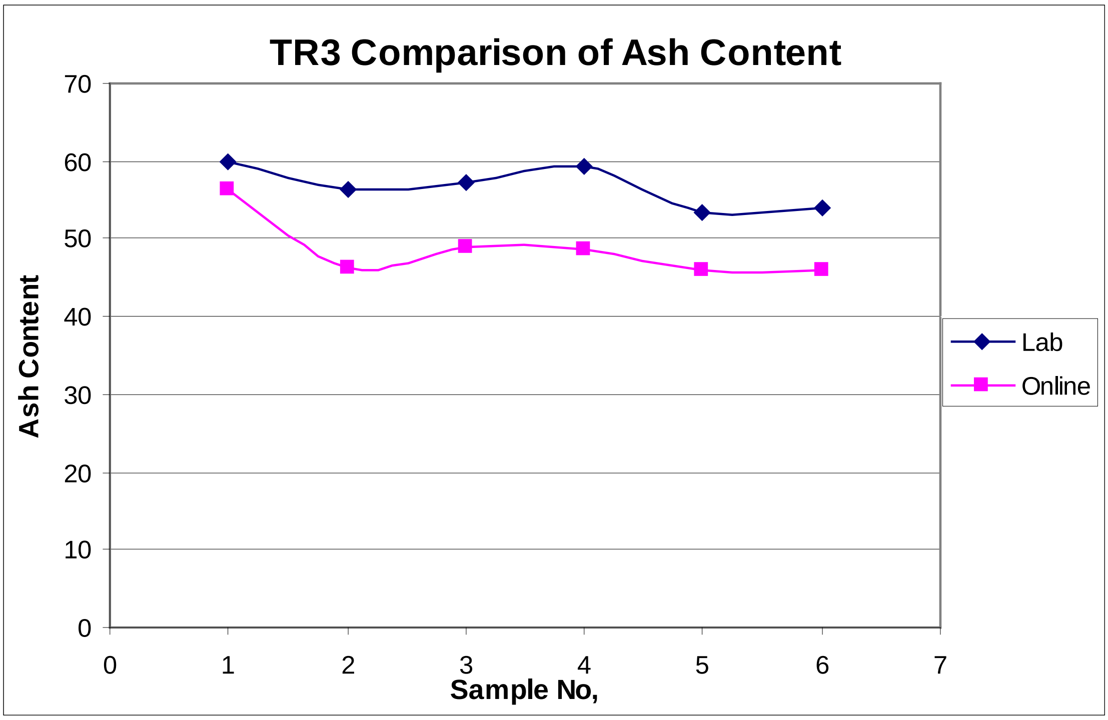
Sample No.	Slurry Density (sg)	Solids Conc(kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.019	0.041	1.900	56.25
2	1.018	0.042	1.766	46.2212398
3	1.018	0.040	1.804	49.0794213
4	1.019	0.044	1.797	48.5402356
5	1.018	0.041	1.763	45.9957993
6	1.019	0.043	1.761	45.8340711

Correction Factors	
Slurry Density Offset(sg)	Solids Conc Calibration
0.005	0.02246421
0.006	0.02580079
0.006	0.02458789
0.005	0.02524614
0.006	0.02693886
0.006	0.02572795

** Results corrected for constant offset



Graph 3.1: Comparison of Solids Density for TR3



Graph 3.2: Comparison of Ash Content for TR3

10.2 Trial Run 4

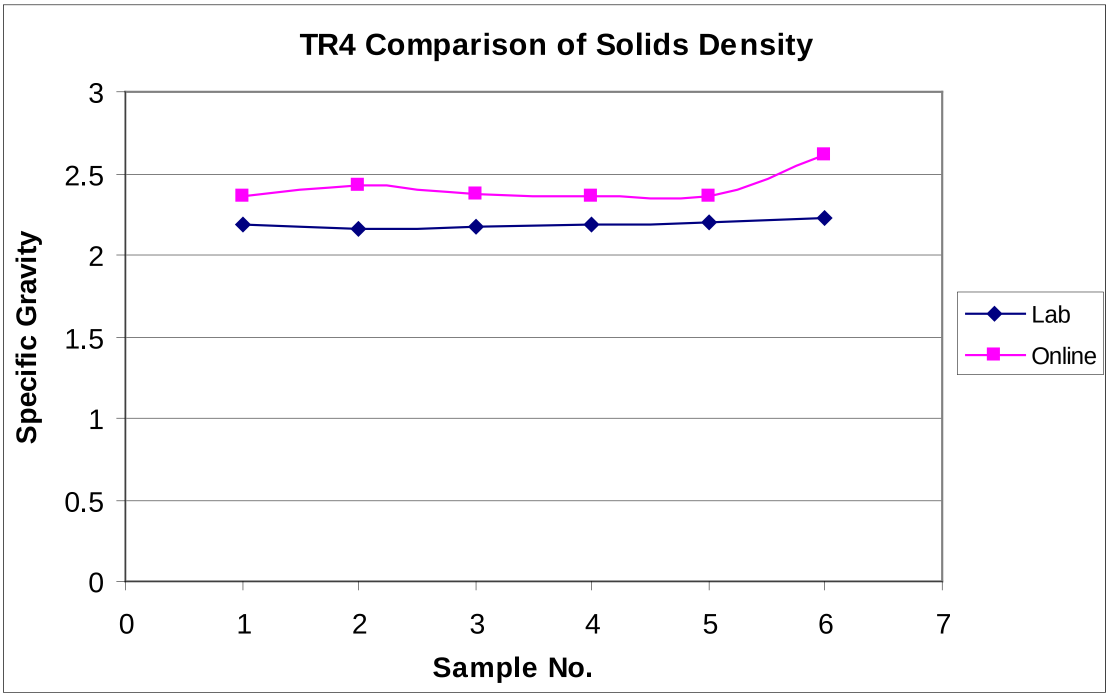
Date	9/02/2005				
Feed Type	BDT Tails			Ash Calcs	
Temp (^oC)	20		0	% ash	1.15
Water sg	0.999		100	% ash	2.7

	Lab Results			Calcs from Lab Results		
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Slurry Density (sg)	Solids Conc(kg/L)
1	2.7	2.19	74.3	1.015	1.016	0.02740202
2	2.5	2.16	74.2	1.014	1.015	0.02534022
3	2.5	2.18	74.1	1.014	1.015	0.02534294
4	2.5	2.19	74	1.014	1.015	0.02534429
5	2.4	2.2	73.6	1.013	1.014	0.02431835
6	1.7	2.23	75.3	1.009	1.010	0.01716091

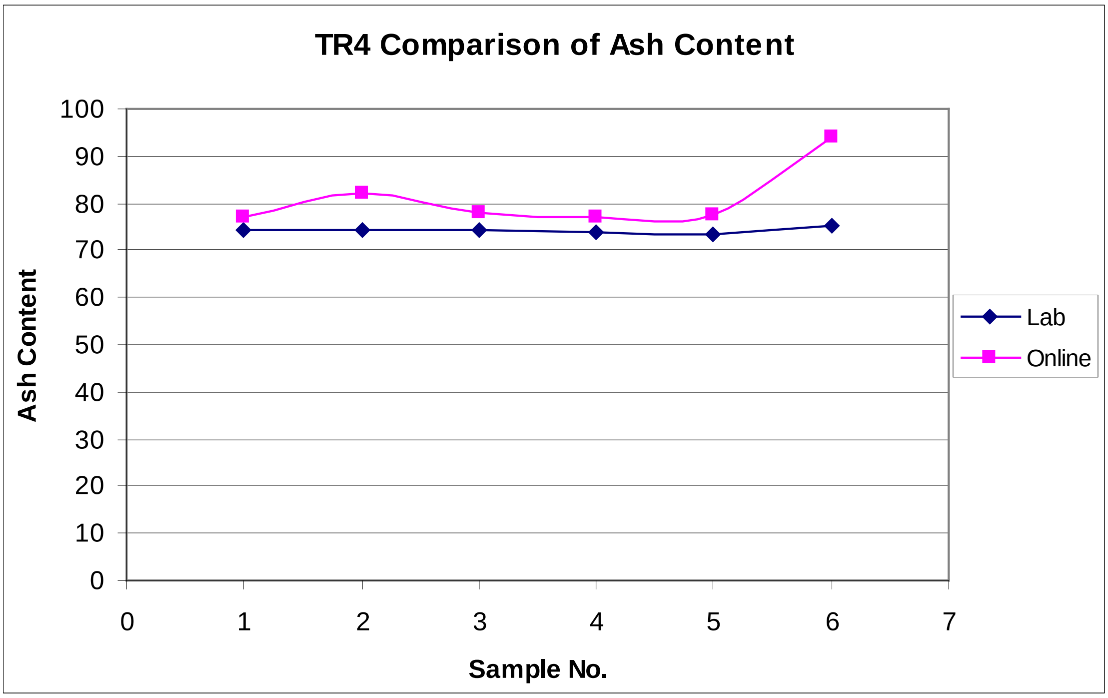
Online Measurements

Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Contin Corrected Solids Conc(kg/L)	Corrected Solids Conc(kg/L)	Contin Calculated Solids Density (sg)	Initial Calculated Solids Density (sg)	Calc Ash (%,ad)
1	1.016	3.305	0.027	0.027	2.35	2.37	78
2	1.015	3.216	0.025	0.027	2.43	2.28	83
3	1.015	2.957	0.025	0.024	2.37	2.51	79
4	1.015	2.968	0.025	0.024	2.35	2.47	78
5	1.014	3.059	0.024	0.025	2.37	2.25	78
6	1.011	1.820	0.017	0.015	2.61	3.40	94

Corrected Slurry Density (sg)	Corrected Calculated Solids Density (sg)
1.016	2.381
1.015	2.461
1.015	2.402
1.015	2.384
1.014	2.397
1.011	2.666



Graph 4.1: Comparison of Solids Density for TR4



Graph 4.2: Comparison of Ash Content for TR4

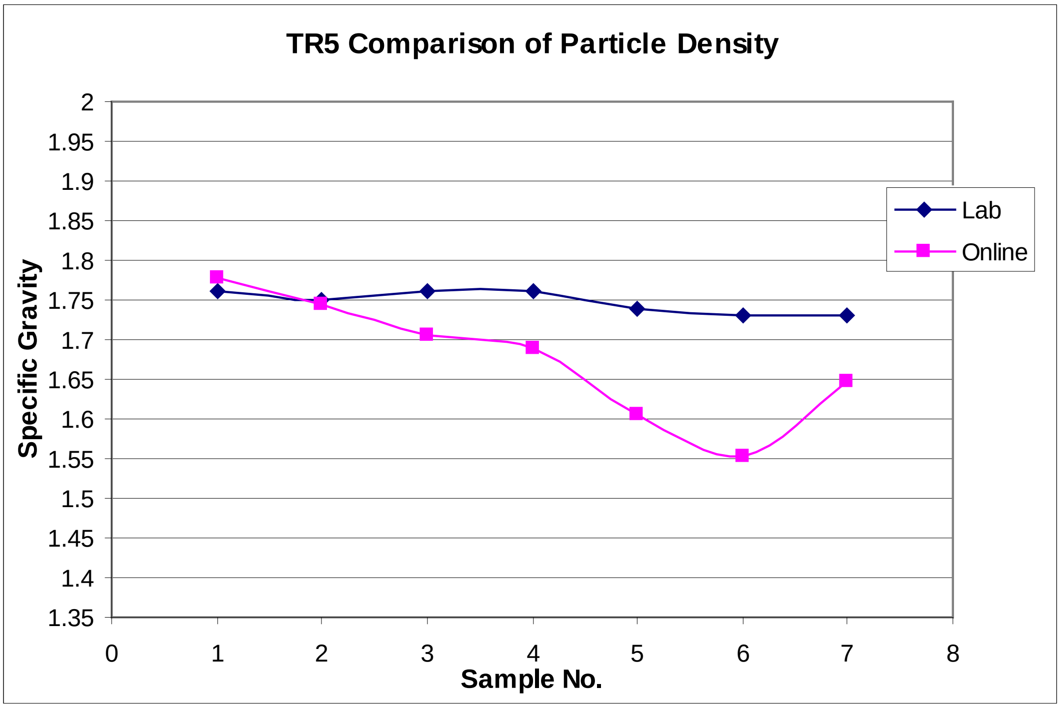
10.3 Trial Run 5

Date	9/02/2005
Feed Type	BDT Tails
Temp (^oC)	20
Water sg	1.005

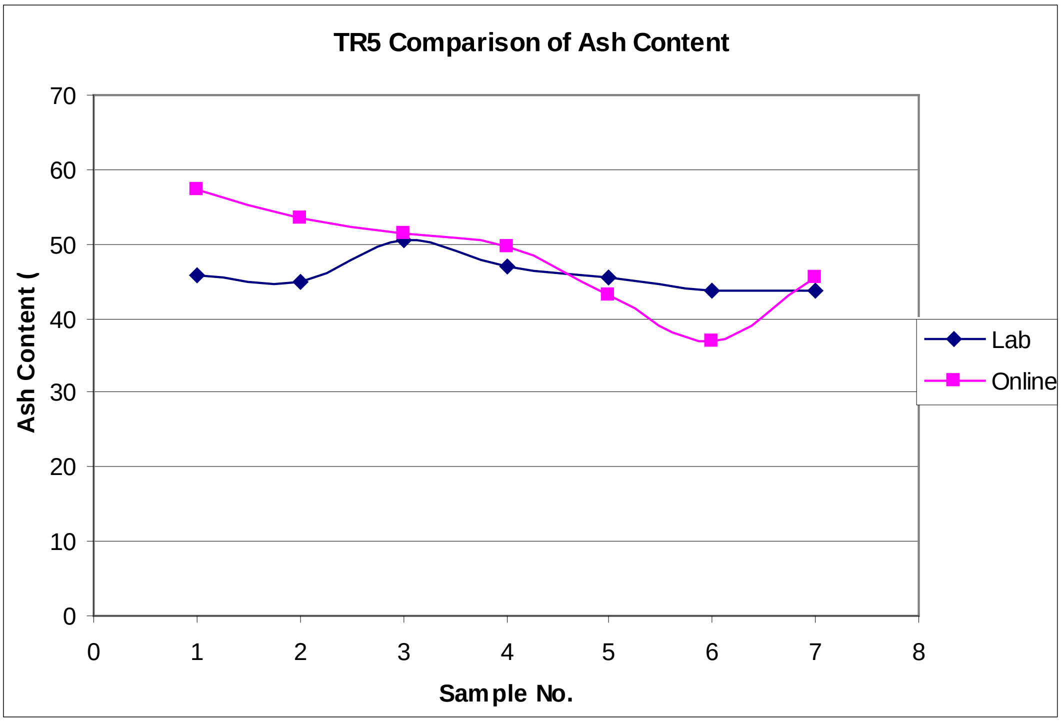
	Lab Results			Calcs from Lab Results		
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Slurry Density (sg)	Solids Conc(kg/L)
1	4	1.76	45.9	1.018	1.013	0.04070305
2	4.2	1.75	45	1.018	1.013	0.04276986
3	4.1	1.76	50.6	1.018	1.013	0.04173897
4	4	1.76	47.1	1.018	1.013	0.04070305
5	4.1	1.74	45.6	1.018	1.013	0.04172759
6	4.2	1.73	43.7	1.018	1.013	0.04275778
7	4.2	1.73	43.7	1.018	1.013	0.04275778

	Online Measurements				
Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Solids Conc(kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.014	3.081	0.03127028	1.7766921	57
2	1.014	3.228	0.03277037	1.74399805	54
3	1.013	3.174	0.03220516	1.70531585	51
4	1.013	3.235	0.03282593	1.6889301	50
5	1.013	3.320	0.03367012	1.60638958	43
6	1.013	3.720	0.0377488	1.55288626	37
7	1.014	3.412	0.03462835	1.64831377	45

	Corrected Online Results				
Sample No.	Slurry Density (sg)	Solids Conc(kg/L)	Solids Conc(kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.019	0.041	0.039	1.91	68
2	1.019	0.043	0.041	1.86	61
3	1.018	0.042	0.040	1.84	58
4	1.018	0.041	0.041	1.81	55
5	1.018	0.042	0.042	1.73	43
6	1.018	0.043	0.047	1.64	32
7	1.019	0.043	0.043	1.76	47



Graph 5.1: Comparison of Solids Density for TR5



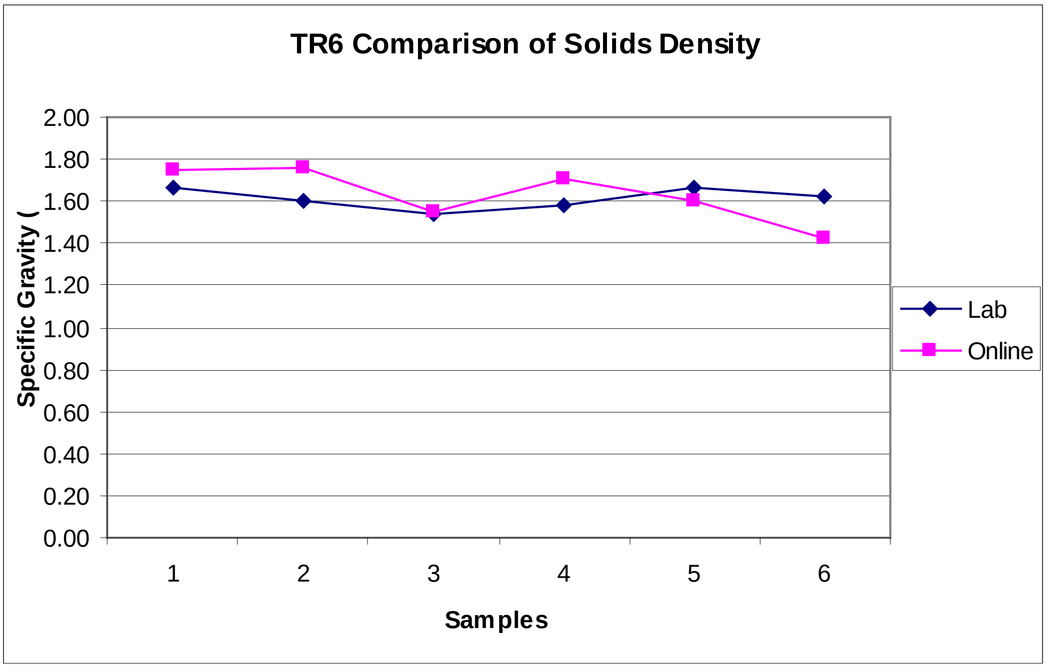
Graph 5.2: Comparison of Ash Content for TR5

10.4 Trial Run 6

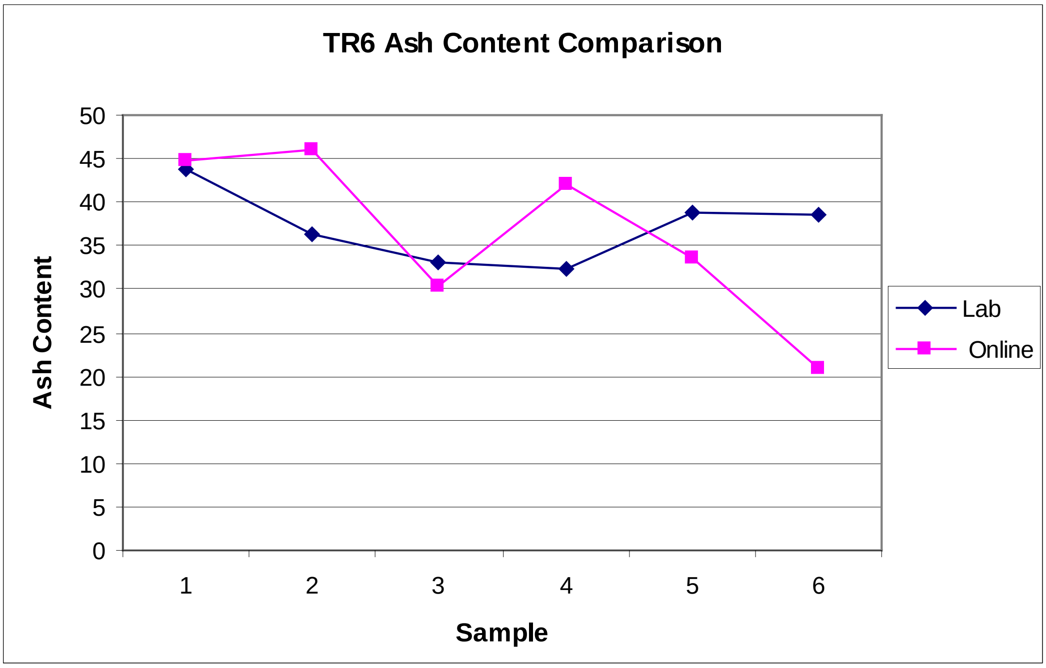
Date	6/09/2005			
Feed Type:	Fresh Feed		Ash Calcs	
Temp (^oC)	21	0	% ash	1.15
		90	% ash	2.35

	Lab Results			Calcs from Lab Results		
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Solids Conc(kg/L)	conc correction number
1	7.8	1.67	43.7	1.032	0.08051974	2.21E-02
2	7.7	1.60	36.2	1.030	0.07928948	
3	8.4	1.54	33.1	1.030	0.08654927	
4	7.3	1.58	32.4	1.028	0.07501008	
5	7.2	1.67	38.8	1.030	0.07414167	
6	8.5	1.62	38.6	1.034	0.0878581	

	Online Measurements				
Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Corrected Solids Conc (kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.034	3.651	0.0805	1.75	44.8
2	1.032	3.313	0.0731	1.76	46.1
3	1.030	3.781	0.0834	1.55	30.3
4	1.030	3.282	0.0724	1.71	42.1
5	1.032	3.854	0.0850	1.60	33.7
6	1.032	4.805	0.1060	1.43	20.9



Graph 6.1: Comparison of Solids Density for TR6



Graph 6.2: Comparison of Ash Content for TR6

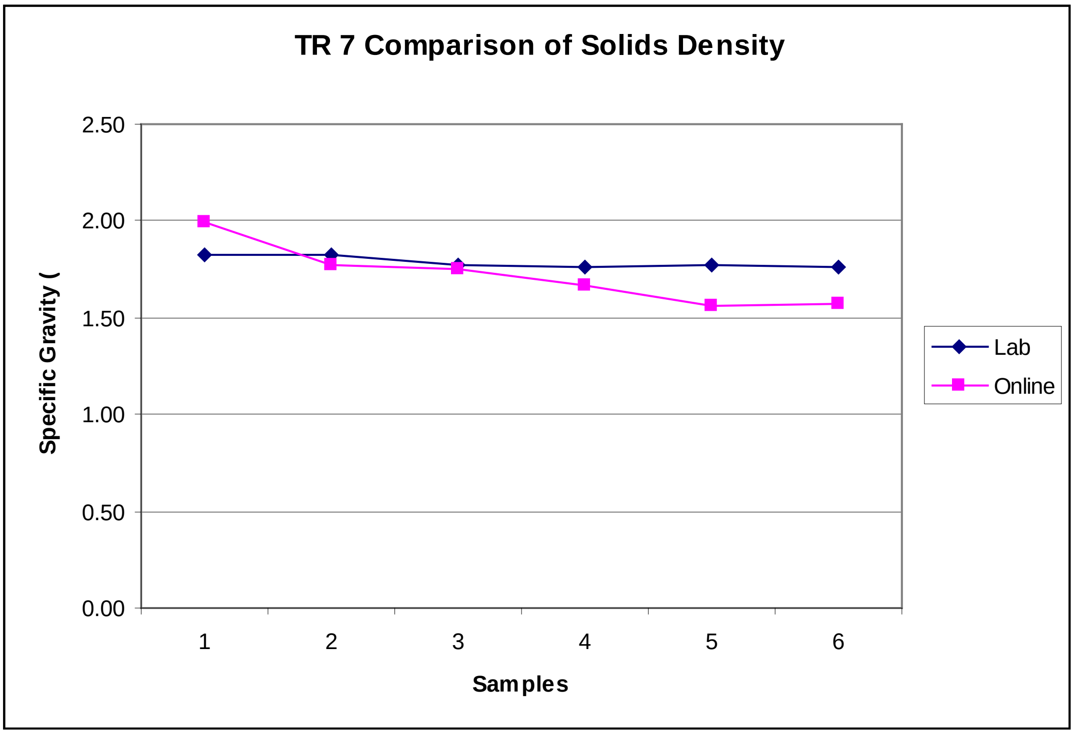
10.5 Trial Run 7

Date	7/09/2005			
Feed Type:	Fresh Feed		Ash Calcs	
Temp (°C)	21	0	% ash	1.15
		90	% ash	2.35

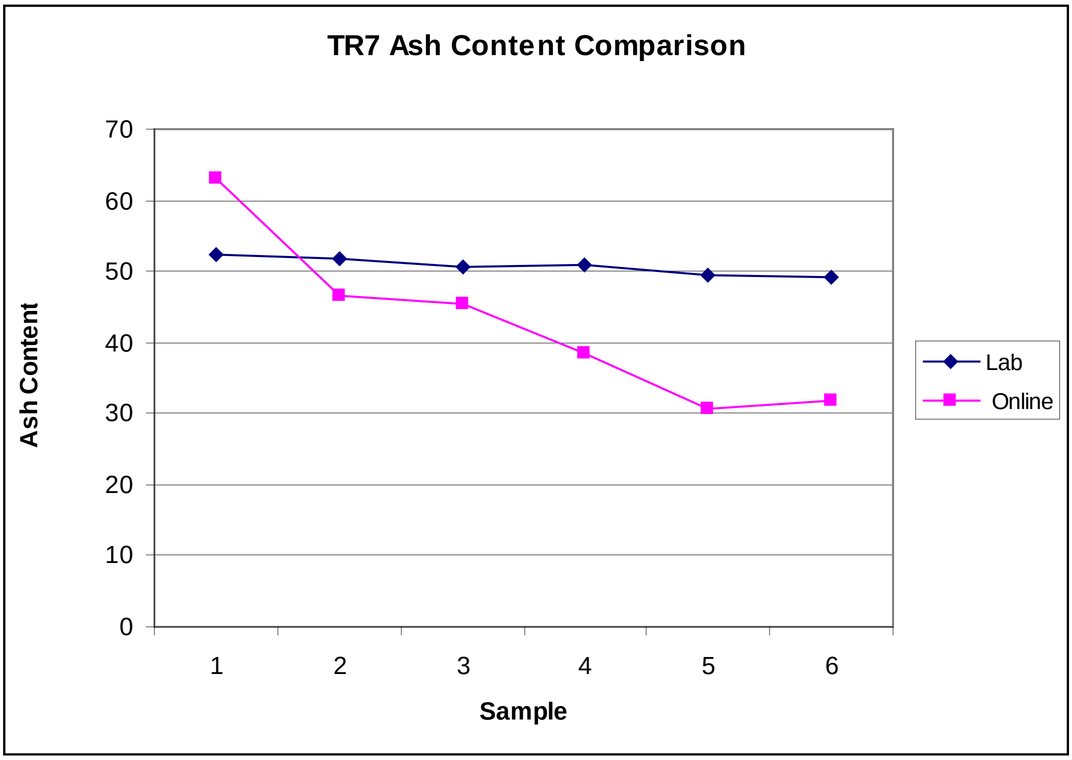
conc correction number
1.55E-02

	Lab Results			Calcs from Lab Results	
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Solids Conc(kg/L)
1	4.4	1.82	52.5	1.020	0.04488991
2	4	1.82	51.8	1.018	0.04073411
3	3.7	1.77	50.6	1.016	0.0376053
4	3.5	1.76	50.8	1.015	0.03553709
5	3.6	1.77	49.4	1.016	0.03657277
6	3.5	1.76	49.3	1.015	0.03553709

	Online Measurements				
Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Corrected Solids Conc (kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.022	2.891	0.0449	1.99	63.0
2	1.021	3.160	0.0491	1.77	46.6
3	1.020	2.982	0.0463	1.76	45.4
4	1.019	3.006	0.0467	1.66	38.6
5	1.018	3.184	0.0494	1.56	30.7
6	1.017	3.061	0.0475	1.57	31.8



Graph 7.1: Comparison of Solids Density for TR7



Graph 7.2: Comparison of Ash Content for TR7

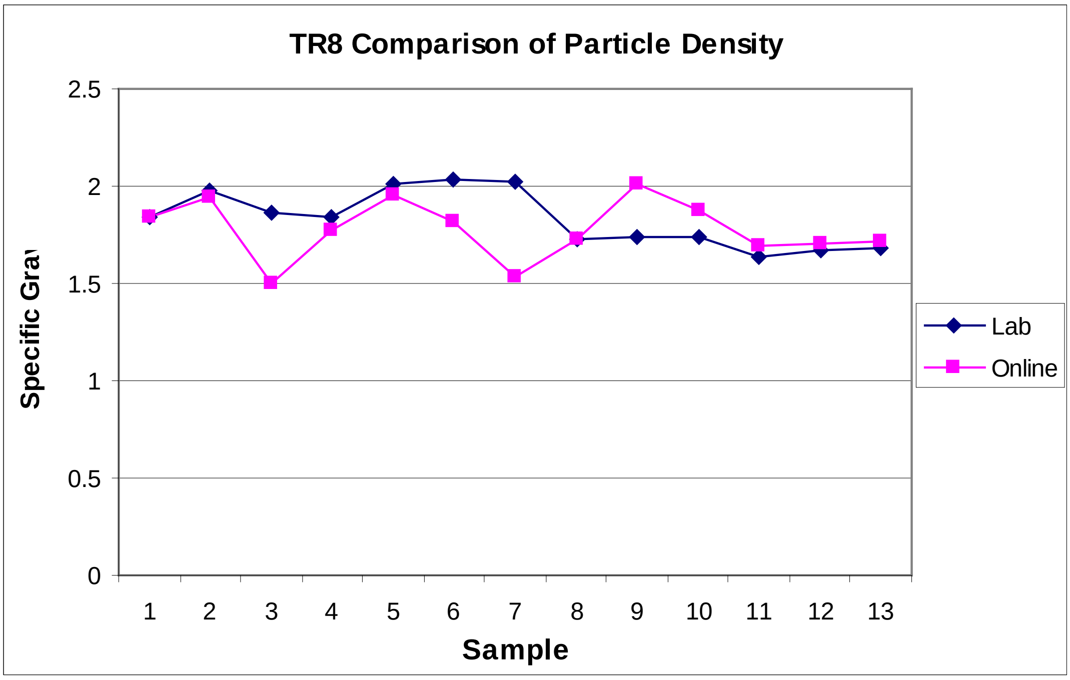
10.6 Trial Run 8

Date	9/12/2005				
Feed Type:	Fresh Feed		Ash Calcs		
Temp (^oC)	15.1	0	% ash	1.15	
		90	% ash	2.35	

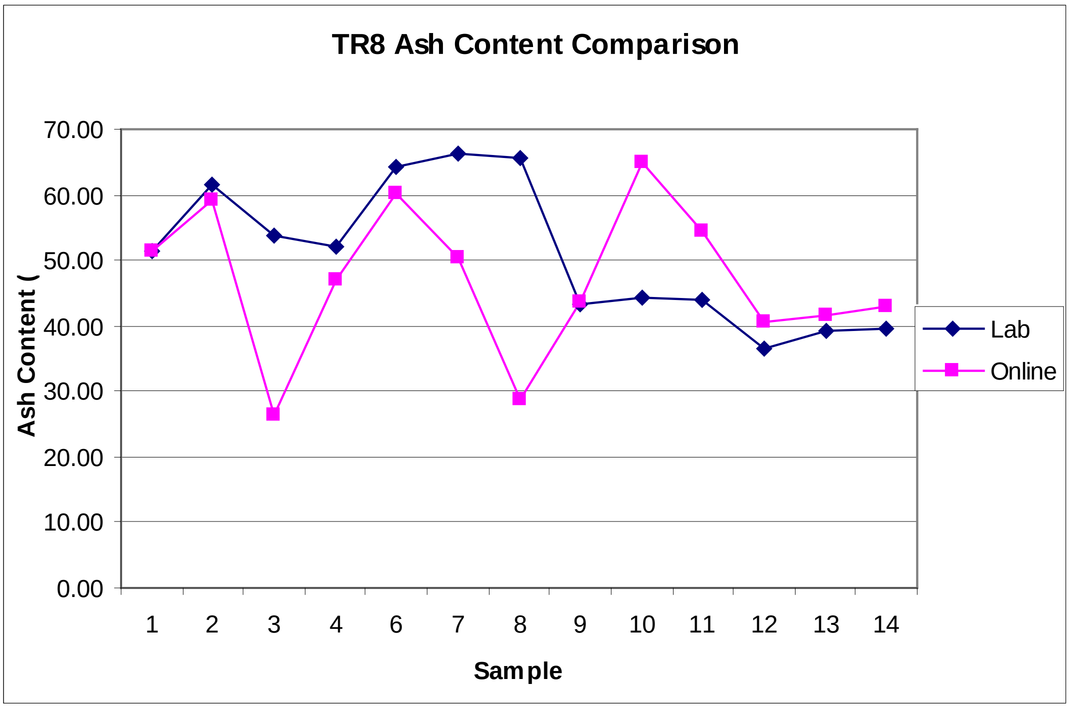
	Lab Results			Calcs from Lab Results	
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Solids Conc(kg/L)
1	5.3	1.835333	51.40	1.025	0.05431009
2	4.9	1.972667	61.70	1.025	0.05021318
3	3.6	1.868667	53.9	1.017	0.03661271
4	4.9	1.844667	52.1	1.023	0.05012464
5			No sample taken		
6	3.1	2.006	64.2	1.016	0.03148955
7	2.6	2.034	66.3	1.013	0.02634825
8	1.8	2.026	65.7	1.009	0.01816559
9	5.9	1.727333	43.3	1.025	0.0605031
10	6	1.740667	44.3	1.026	0.06157196
11	5.9	1.735333	43.9	1.026	0.06051287
12	6.4	1.638	36.6	1.026	0.06563618
13	6.3	1.672667	39.2	1.026	0.06463763
14	6.8	1.676667	39.5	1.028	0.06991881

conc correction number
1.03E-02

	Online Measurements				
Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Corrected Solids Conc (kg/L)	Solids Density (sg)	Ash (%,ad)
1	1.025	5.297	0.0543	1.84	51.4
2	1.025	4.982	0.0511	1.94	59.3
3	1.017	4.973	0.0510	1.50	26.3
4	1.023	5.116667	0.0525	1.78	47.1
5			No sample taken		
6	1.016	3.160909	0.0324	1.95	60.0
7	1.013	2.9	0.0297	1.82	50.2
8	1.009	2.576667	0.0264	1.53	28.8
9	1.025	5.881818	0.0603	1.73	43.6
10	1.026	5.068	0.0520	2.02	65.0
11	1.026	5.361	0.0550	1.87	54.3
12	1.026	6.096	0.0625	1.69	40.7
13	1.026	6.133	0.0629	1.70	41.6
14	1.028	6.572	0.0674	1.72	42.8



Graph 8.1: Comparison of Solids Density for TR8



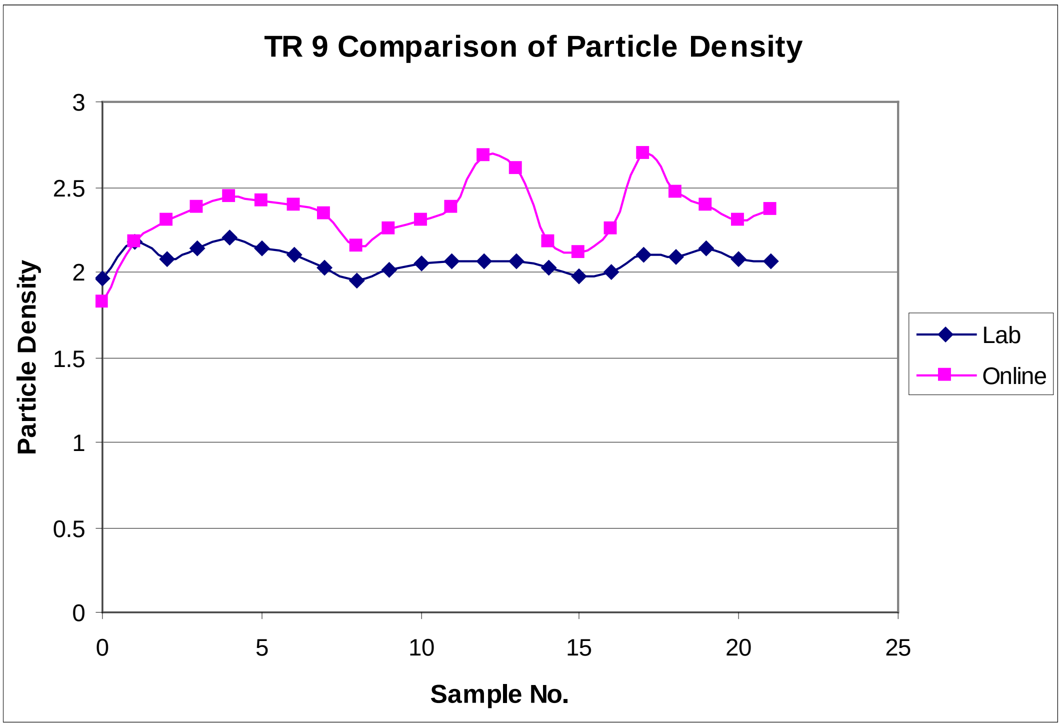
Graph 8.2: Comparison of Ash Content for TR8

10.7 Trial Run 9

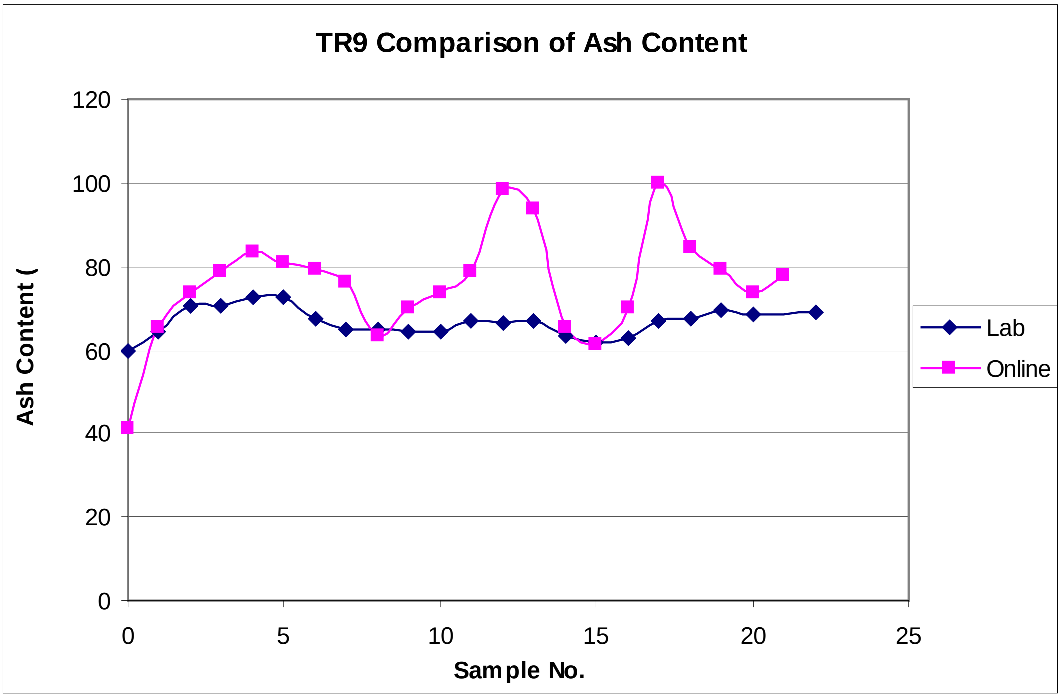
Date	13/09/2005
Feed Type:	BDT Feed
Temp (^oC)	20
Water sg	0.998

	Lab Results			Calcs from Lab Results		
Sample No.	Solids conc (%,w/w)	Solids Density (sg)	Ash (%,ad)	Slurry Density (sg)	Slurry Density (sg)	Solids Conc(kg/L)
0	3	1.96	59.9	1.015	1.017	0.030
1	2.5	2.18	64.6	1.014	1.016	0.025
2	2.5	2.07	70.8	1.013	1.015	0.025
3	2.6	2.14	70.4	1.014	1.016	0.026
4	2.5	2.2	72.5	1.014	1.016	0.025
5	2.3	2.14	72.4	1.012	1.014	0.023
6	2.1	2.1	67.3	1.011	1.013	0.021
7	2	2.03	65	1.010	1.012	0.020
8	2.1	1.95	64.8	1.010	1.012	0.021
9	2.1	2.01	64.3	1.011	1.013	0.021
10	2.1	2.05	64.3	1.011	1.013	0.021
11	2.3	2.06	66.7	1.012	1.014	0.023
12	2.1	2.06	66.6	1.011	1.013	0.021
13	2.2	2.06	66.8	1.011	1.013	0.022
14	3.9	2.02	63.5	1.020	1.022	0.040
15	5.4	1.97	61.9	1.027	1.029	0.055
16	4.5	2	62.9	1.023	1.025	0.046
17	3.4	2.1	67	1.018	1.020	0.035
18	3.2	2.09	67.4	1.017	1.019	0.033
19	3	2.14	69.6	1.016	1.018	0.030
20	3.1	2.08	68.5	1.016	1.018	0.032
21	2.9	2.06	68.8	1.015	1.017	0.029

		Ash Calcs				
	0	% ash	1.2			
	100	% ash	2.7			
	Online Measurements					
				Corrected	Corrected	Calculated
Sample No.	Slurry Density (sg)	Solids conc (%,w/w)	Solids Conc(kg/L)	Solids Conc(kg/L)	Solids Density (sg)	Ash (%,ad)
0	1.014	7.500	0.030	0.030	1.82	41
1	1.014	8.705	0.025	0.035	2.18	66
2	1.014	8.516	0.025	0.035	2.30	73
3	1.015	7.755	0.026	0.031	2.38	79
4	1.015	7.305	0.025	0.030	2.45	83
5	1.014	6.660	0.023	0.027	2.41	81
6	1.012	7.380	0.021	0.030	2.39	79
7	1.012	7.133	0.020	0.029	2.35	76
8	1.011	7.038	0.021	0.029	2.15	63
9	1.012	6.614	0.021	0.027	2.25	70
10	1.012	6.455	0.021	0.026	2.30	74
11	1.014	6.676	0.023	0.027	2.38	79
12	1.013	6.835	0.021	0.028	2.68	99
13	1.014	6.907	0.022	0.028	2.61	94
14	1.022	5.544	0.040	0.023	2.18	65
15	1.029	5.087	0.055	0.021	2.12	61
16	1.026	4.871	0.046	0.020	2.25	70
17	1.022	5.132	0.035	0.021	2.70	100
18	1.019	5.132	0.033	0.021	2.47	84
19	1.018	5.199	0.030	0.021	2.39	79
20	1.018	5.824	0.032	0.024	2.31	74
21	1.017	6.200	0.029	0.025	2.37	78



Graph 9.1: Comparison of Solids Density for TR9



Graph 9.2: Comparison of Ash Content for TR9