paper C1

Horizontal Vacuum Belt Filter Control Using On-line Moisture Analysis at Gregory Coal Mine

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Abstract

The paper summarises the recent ACARP project C14061 where a microwave moisture analyser was fitted across a horizontal vacuum belt filter at the Gregory coal preparation plant. The horizontal vacuum belt filter dries fine coal slurry which is typically 20% solids to a cake of 20-40% moisture. On-line analysis on the belt filter gives the opportunity for feed back control and minimal delay time.

The purpose of this project was to gain a better understanding of belt filter control by examining the moisture on-line. The integration of a moisture result into the control loop may provide a cake of more consistent moisture as the drying time can be adjusted real-time to maintain a desired outlet moisture range.

After determining the accuracy of the analyser was 1.0% to 2% at 2 standard deviations (depending on the range) it was possible to monitor moisture online. It was found that the moisture analyser proved very useful to optimise process parameters such as flocculant addition and belt speed for a desired filter cake moisture.

Introduction

Horizontal vacuum belt filters are a common dewatering technique for fine coal applications in Australian coal mines. Through the use of these filters, material as coarse as spiral product or as fine as froth flotation concentrates can be dewatered effectively.

Horizontal vacuum belt filters work by applying vacuum below a filter media. As the name implies the filter is horizontal in the zone where the vacuum is applied. The filter media is therefore flat and, for continuous separation to occur, the media must also be moved continuously. Generally the horizontal vacuum belt filter is designed to allow about one-third of the conveyor length for drainage of free moisture and the remainder for drawing air through the drying zone. Whilst there are a number of controls to adjust the performance of horizontal vacuum belt filters such as belt speed, cake depth, flocculant addition, and vacuum control, to optimise the process requires extensive laboratory sampling to observe a parameter's effect on the output moisture. Figure 1 below displays a cross sectional view of a typical horizontal vacuum belt filter, the slurry is deposited on top of the cloth on the left side, and dropping off the right side of the belt as dewatered product.

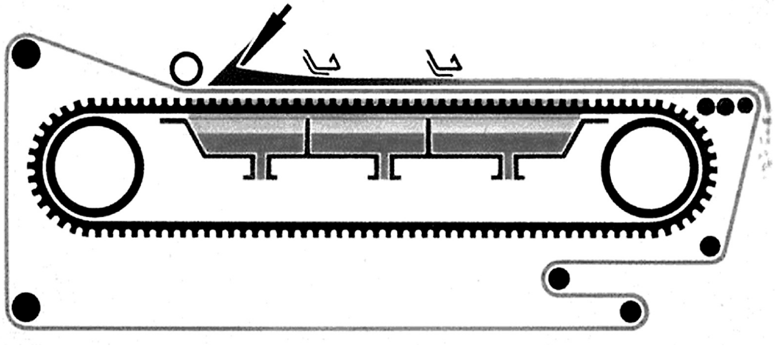

Figure 1 Cross-section of a Horizontal Vacuum Belt Filter

This project examines the installation of an on-line instrument to measure moisture in real-time. If proven successful, this will allow operators and process engineers to accurately adjust process parameters to meet the desired product moisture. It would also eliminate the costly need to manually sample the filter belts, which in many cases are performed only every two hours.

In the early stages of this project Callidan Instruments undertook to develop a microwave based moisture analyser which would predict the moisture content of the fine coal bed across the conveyor belt. The analyser was designed to independently determine the percentage moisture at three different locations across the conveyor belt. For each location a microwave transmitter was located below the conveyor and an opposing microwave receiver located above the conveyor and filter cake product. One of the major design concerns for this application was to develop the correct microwave operating parameters to cater for approximately 20-40 mm of filter cake which could vary in moisture from 20% to 50%.

Project Objectives

The objectives of this project were to:

- Design, develop and supply an on-line microwave moisture analyser with 3 measurement heads across a horizontal vacuum belt filter, and outputting three moisture results simultaneously.
- Install commission and calibrate the analyser at the Gregory CHPP.
- Evaluate and determine the accuracy of the moisture result.
- Provide a report on the accuracy and effectiveness of the installed instrumentation and the resultant improved effect upon belt filter control.
- Identify control strategies for belt filter control using an on-line moisture analyser.

Project Stages and Outcomes

Stage 1 – Design and Development of an On-line Moisture Analyser for a Horizontal Vacuum Belt Filter

The first objective of this project was the design and development of a microwave moisture analyser which would be capable of accurately predicting the moisture content at three independent points across the 5m span of the filter cloth. Whilst there are a number of techniques available for the determination of moisture in material such as fine coal, it was decided to use a microwave transmission technique. This technique passes a microwave signal from below the conveyor fabric, through the filter cake bed and is detected by the microwave receiver. By using statistical analysis tools (chiefly linear regression) on both the measured microwave attenuation, phase shift, and the filter cake depth an algorithm was determined which could predict the total moisture content of the filter cake.

The analyser needed to be designed such that three independent readings of moisture could be obtained from the analyser, hence three pair of sensors where equally placed across the conveyor. The analyser then needed to accept the filter cake depth signal from the already installed ultrasonic sensor. Typically ultrasonic depth sensors would be provided for each microwave sensor, however due to financial and complexity constrictions, the single ultrasonic was used and the thickness across the belt was assumed to be uniform.

In addition to the sensor heads and measurement techniques of the analyser, the analyser needed to incorporate an integral processor, user display, and industry standard analog, digital and serial outputs.

Over a period of approx 2 months the analyser design specification was established, the necessary components ordered and the analyser assembled and tested with Callidan Instruments R&D facility in Mackay. Figure 2 and Figure 3 below shows the analyser being manufactured in Mackay and the sensor head.

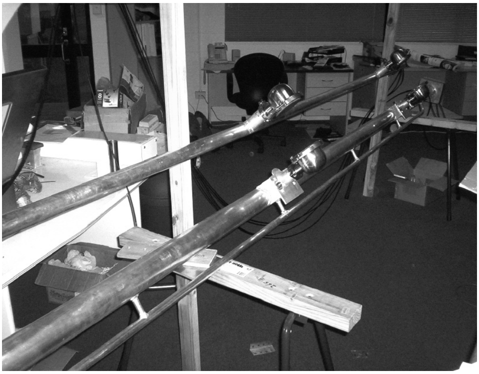

Figure 2 Manufacture of Analyser

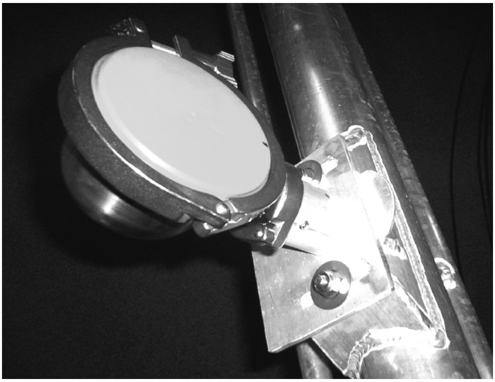

Figure 3 Sensor Head

Stage 2 – Installation and Commissioning

The second objective of this project was the installation, commissioning and calibration of the analyser. The analyser was installed at Gregory in June 2005. The installation of the analyser needed to occur during a routine shutdown period of the Gregory coal handling and preparation plant. The necessary safety requirements for both the mechanical and electrical installation were considered. Mechanical and electrical installations were then conducted safely and without any difficulties.

The unit consists of the conveyor frame which supports the 3 pairs of transmitters/sensors. Located within 5m is the control cabinet which is designed to operate from a standard 110v or 240v power supply.

The analyser automatically begins reporting moisture when the filter cake reaches a pre-determined minimum depth which was found to be 10mm. The results of the analyser can be supplied to the control room via analog, serial, or Ethernet, enabling moisture trends to be displayed for the benefit of the operators. The analyser can supply an instantaneous (1 second) or a configurable rolling average moisture result at each sensor location or alternatively an average of the 3 results.

The microwave transmitters located beneath the cake emit RF energy at less than 5mW or +3dBm. For comparison a mobile phone emits between 50mW and 800mW of RF energy.

Figure 4 and Figure 5 show the analyser location prior to the analyser being installed and after the installation.

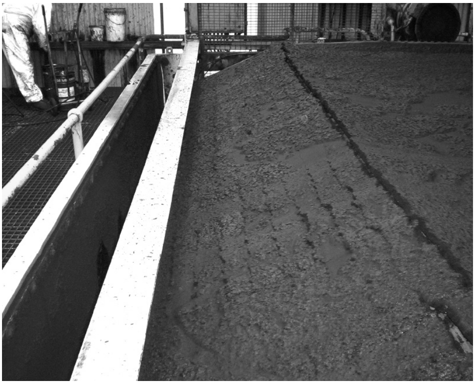

Figure 4 Discharge End of Conveyor Prior to Installation

Figure 5 Installation of Sensor Heads During Shutdown Period

Stage 3 – Moisture Analyser Calibration

The analyser was calibrated by sampling filter cake directly from the discharge conveyor. A sample of approx 5kg was collected next to each sensor over a period of approx 10 seconds and samples were collected 10 minutes apart. The collected samples were analysed for total moisture content. In total 60 samples were taken for the purpose of calibration, 20 samples per sensor. The analyser moisture result was also averaged over the same 10 second period.

It is important to understand the analyser carries out the on-line determination of moisture by measuring the microwave response through the filter cake, however for this to occur independently from the depth of filter cake the depth signal must be used. For this particular filter belt it was assumed that measuring the cake depth at one location (i.e. the only existing ultrasonic sensor in line with sensor 1) would be sufficient for all three measurements as ultrasonics could not be provided for each sensor.

Figure 6 below highlights the calibration performance of the first sensor.

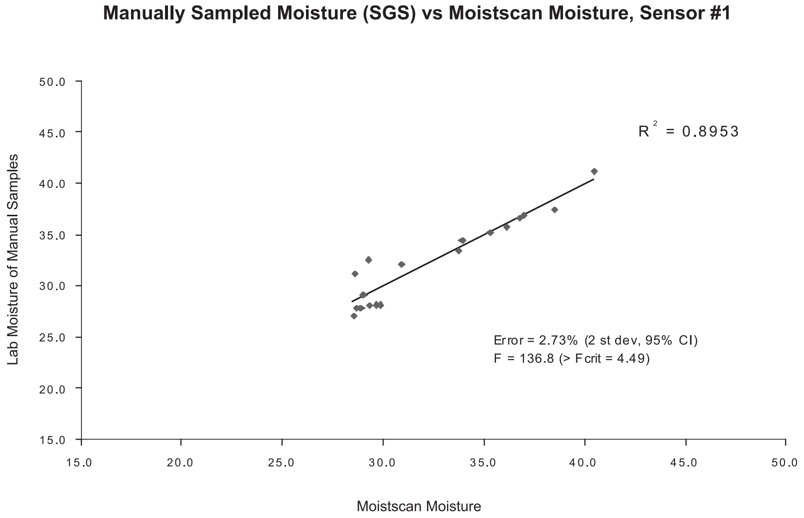

Figure 6 Sensor 1 Sampling Data

The results from Sensor 1 indicated that the analyser could operate to an accuracy of better than 2.7% (2 std dev) moisture over a range of 25% – 45%. Sensors 2 & 3 did not achieve this level of accuracy and are included below. However for all data sets the F statistic for the data is greater than the critical value indicating that there is a relationship between analyser and lab results, and that this relationship did not occur by chance. For the F statistic calculation, the probability of erroneously concluding a relationship or alpha value was set at 0.05.

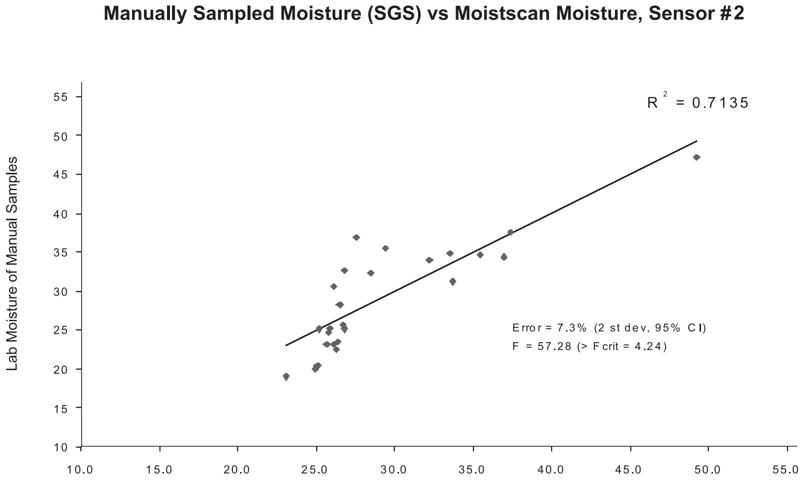

Figure 7 Sensor 2 Sampling Data

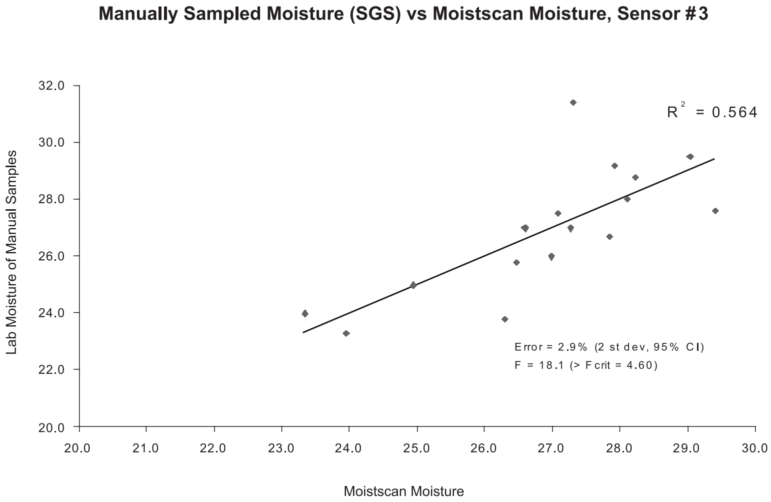

Figure 8 Sensor 3 Sampling Data

The correlations and significance of the Moistscan versus laboratory samples for sensors 2 and 3 are not as good as those for sensor 1.

The calibration for sensor 2 yields a good correlation, assisted heavily by the 50% moisture sample. The error is quite high at 7.3% (2 std dev) this is due to a number of outliers at ~35% moisture.

The calibration for sensor 3 above yields a poor correlation, though a surprisingly small error of 2.9%. The reason for this small error is the narrower range of sample moistures compared to the calibration results of the other two sensors. There are 2 points that could be considered as outliers whose removal would improve the statistics, these are at 24% and 31%.

The calibration data was certainly good for sensor 1 and poor for sensors 2 and 3. The reason for this is likely the assumption of consistent bed depth across the filter. Given that the cloth was quite old and prone to blinding, this assumption is unlikely to be true for cases where this is occurring. Unfortunately due to time constraints, cost, system complication and limited downtime, additional ultrasonics were not fitted for the other 2 sensors.

Stage 4 – Accuracy Determination

1 week after calibration, this project attempted to determine what the actual accuracy of the analyser is via the operation of a "Grubbs estimator" approach. The Grubbs estimator approach consists of taking two independent samples from the discharge end of the conveyor at sensor 1 and then comparing these with the average Moistscan result for the same sensor over the same time period. This Grubbs estimator sampling program was only conducted for Sensor 1 due to the depth measurement being in line with this sensor and not the others.

The results of the sampling program indicated an Analyser error of approx 2.0% at 2 standard deviations. Figure 9 below highlights a tracking plot of the analyser, sample 1 (Lab1), and sample 2 (Lab2).

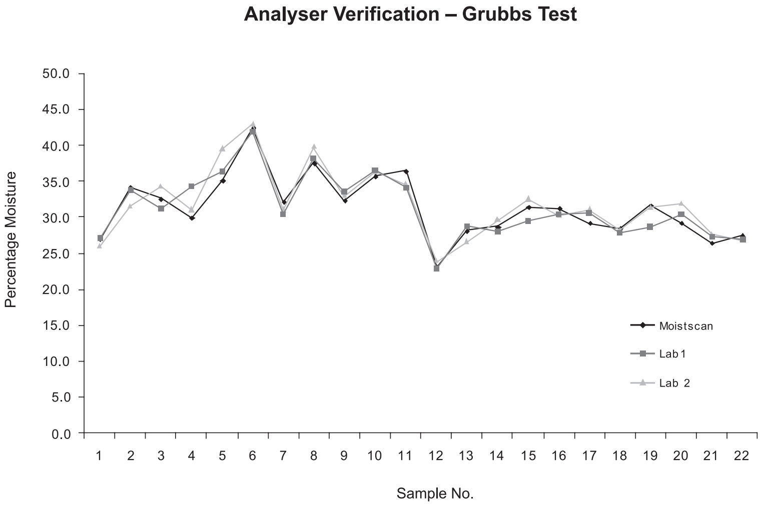

Figure 9 Trends of Moisture Analyser and Laboratories

When applying the 3 data sets to the Grubbs Estimator program it can be determined that the analyser error is approx 1.0% moisture at a 95% confidence level whilst the two sampling techniques yield a slightly greater error (approx 1.1% and 1.2%). Figure 10 below shows the resultant Grubbs calculated instrument and laboratory techniques.

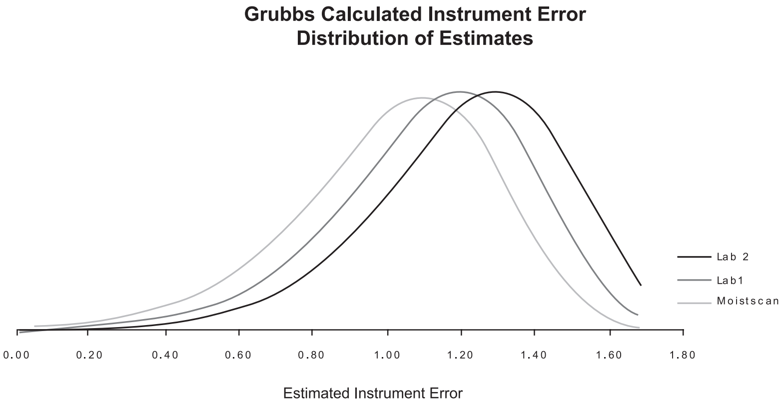

Figure 10 Grubbs Estimator Reporting of Instrument and Laboratory Errors

Stage 5 – Investigation into Control Mechanisms and their Optimisation

The horizontal vacuum belt filter used for this trial unfortunately had some serious maintenance concerns. The filter belt was scheduled for replacement in late September as the current belt was fouling and partially "blinded". In addition the spray bar nozzles at both the front end of the belt filter (prior to slurry addition) and mid way along the belt filter were partially inoperative.

The result of this poorly performing belt filter was that a large variation in moisture was experienced across the width of the belt filter. Typically sensor 1 & 2 experienced extremely high moisture variations and variable depth of product. Sensor 3 experienced much more stable cake depths which resulted in a much more consistent moisture reading. Figure 11 below highlights the vastly differing moisture readings experienced over a 2 hour period.

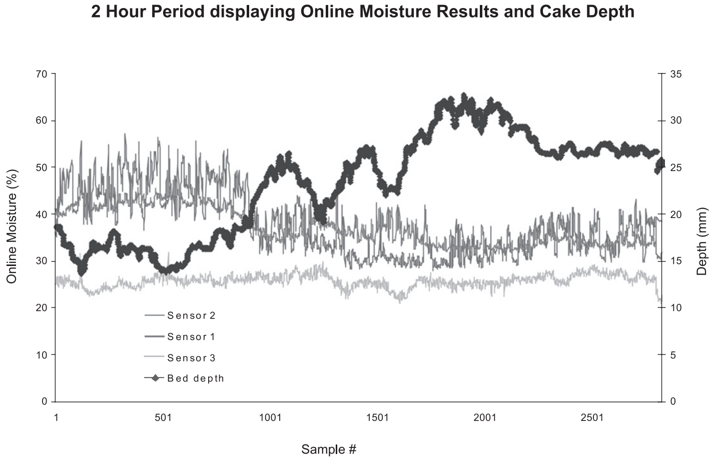

Figure 11 Two Hour Trend of Moistures and Cake Depth

What can be observed from this data is the clear relationship the cake depth has with moisture content. Considering that the depth measurement only occurs near Sensor 1, it is interesting to observe the relationship between the two below in Figure 12.

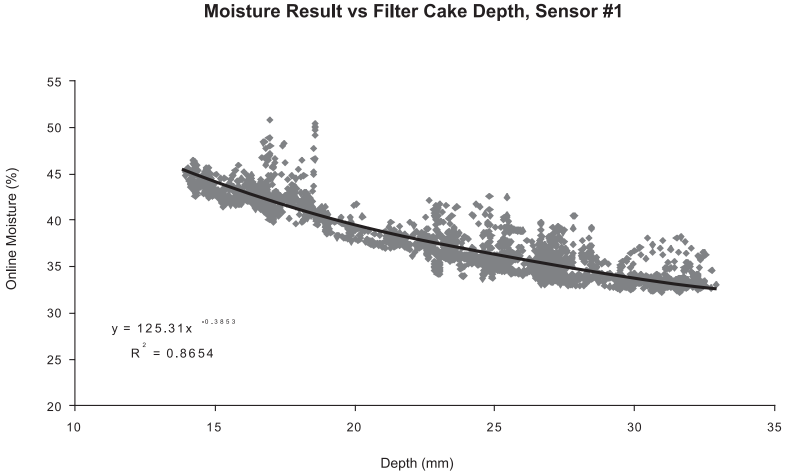

Figure 12 Analyser Moisture vs Filter Cake Depth

Whilst depth of filter cake is only a part of the complexity of controlling moisture it can be observed from Figure 12 that typical performance plots for moisture control can be now easily obtained using the calibrated and verified moisture analyser where previously this exercise required extensive sampling and analysis.

After the bed depth trial above, the filter cloth was replaced and no more data was collected for 2-3 months. With the installation of the new filter cloth the filter cake profiles appeared much more consistent and of much lower moisture content.

Figure 13 displays an example of the effect of belt speed on the on-line moisture result. Typically the plant operators run the belt speed at 0%, however during this test the belt speed was incrementally adjusted up to 50%. A speed of 0% simply represents the minimum belt speed of 30mm/s whilst 100% represents the belts maximum belt speed of 200mm/s or 60t/h. It can be observed that as the belt speed approaches 35% of its maximum speed the moisture content begins to rise rapidly.

Whilst this graph clearly displays a relationship between belt speed and moisture it should be understood that the belt speed is not the only contributor to the change in filter cake moisture. It was observed during the test that as the belt speed increases the bed depth decreases, hence two effects are contributing together during the this test.

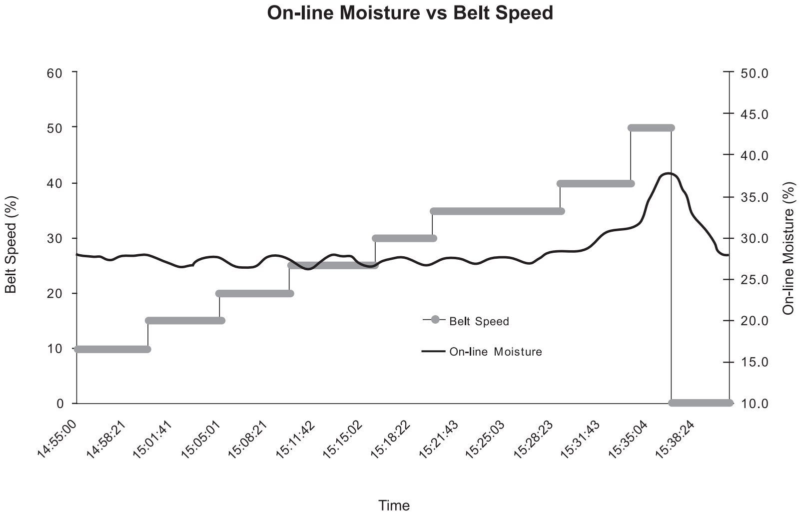

Figure 13 Analyser Moisture vs Belt Speed

The effect of flocculant on on-line moisture was tested (Figure 14). Plant operators typically operate the belt filter with an addition of 100% flocculant, meaning the flocculant pump is operating at 100% of its capacity. Figure 14 indicates that flocculant addition could be reduced to 80% before any appreciable change in moisture was observed on that occasion.

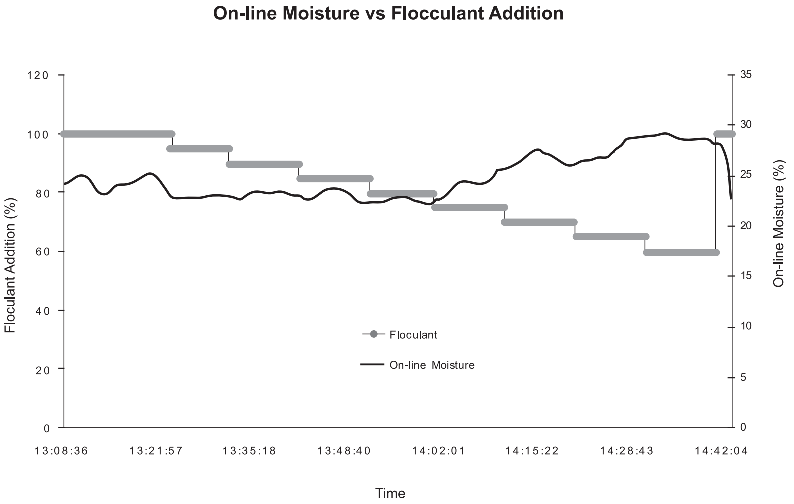

Figure 14 Analyser Moisture vs Flocculant Addition

Typically operators run belt filters for good discharge and adjust the "right" bed thickness to achieve this. There is currently no easy way of knowing what the best approach for moisture control should be. Traditional practices usually involve a manual sample being taken directly from the belt discharge every two hours. Not only is this sample indicative of perhaps a snapshot of 2-3 seconds of belt filter operation the analysis results can take up to 4 hours to be received by the operator. By this time the operation of the belt filter can and usually does change considerably.

This project demonstrates the value of an instrument measuring belt filter moisture online so that effective control strategies can be implemented. It is the author's belief that the accuracy achieved from the analyser would clearly add benefit to strategies for belt filter control. Having an instrument reliably provide direct on-line information to an accuracy of better than 1.0% moisture would be a clear advantage over previous labour intensive sampling practices.

The control strategies for optimum belt filter control will vary considerable depending upon the objectives of each operation. Not all plants may require the lowest moisture possible as some operations will consider throughput and flocculant usage as equally important parameters. There may even be the case of wanting the product to be of higher moisture content to meet client specifications. Regardless of plant objectives, there is little debate that the use of an accurate and reliable on-line moisture result will enable plant operators to tune the belt filter for their own objectives.

The findings of this project suggest there is opportunity for this type of analyser in almost every belt filter application world wide. The analyser could be used in industry for more effective means to monitor product quality and efficient use of flocculant.

Conclusions and Recommendations

The author's feel they met the majority of the project objectives and conclude that the design, development and implementation of the analyser were very successful. Due to the age of the cloth and the serious blinding effect on some of the sensors, the plant condition variations caused flooding on the belt, the result of which was that some of the collected data for sensors 1 and 2 was invalid. The effect of belt speed, cake depth and flocculant levels were measured. It can be clearly seen that using the moisture analyser as a process tool would allow operators to confidently adjust belt filter parameters to achieve the plant objectives.

Monitoring the validity of the calibration is the only regular maintenance for the analyser. It is suggested that the analyser moisture be compared to shift moisture results or failing that monthly spot checks to determine whether recalibration is required to ensure accurate on-line moistures are produced.

Further research into the ability to take the same technology into other coal processing applications such as filter presses, drum filters, centrifuges, and other dewatering techniques is recommended.

Technology Transfer Issues

Whilst this project creates an opportunity to introduce existing technology into a new application, it is the project team's belief that there is insufficient novelty in this concept to warrant patentability. Callidan Instruments currently hold a patent for their microwave technology, which constitutes measuring attenuation and phase shift of a received microwave signal for a swept frequency range through a material to determine the moisture of the material. This project merely explores another avenue to apply the currently patented technology.

Acknowledgments

The project team would like to acknowledge the efforts of the Gregory CHPP staff who assisted with the installation and commissioning of the analyser and also allowed process changes to occur upon their belt filter for the purposes of the project.

Annexes

Microwave Emission Information

The MOISTSCAN Moisture Analyser is designed to use low level non-ionizing microwave radiation. The microwave power emitted from the MOISTSCAN is less than 10mW (10dBm). This complies with AS/NZS 4268 which specifies the maximum Equivalent Isotropically Radiated Power (EIRP) for short range radio equipment.

This radiation level exists directly between the two antennas, which in almost all cases is inaccessible due to the conveyor belt. Microwave radiation further than 1m from the analyser is virtually undetectable.

References

[i] Edward, D and Clarkson, C., 1999, '**Sampling Statistics Toolkit**', *ACARP Project C3090*, Australian Coal Research Pty Ltd.