MOISTURE MEASUREMENT
USING MICROWAVE TECHNOLOGY

at
DALRYMPLE BAY COAL TERMINAL AUSTRALIA

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1. Microwave Attenuation Analysis

Microwave technology is used in two ways for measuring moisture content of various types of ores, coal and other minerals:

- By reflection or resonance
- Transmission

The technology “by reflection” means that the microwave is emitted into the material bed and the analysis is made on the microwave frequency that is reflected from the material to be measured. The technology is limited to measuring the free or surface moisture of the material. Although some manufacturers claim that bound moisture is also measured, which is only true for materials with a very low attenuation factor such as grain. The reflection technique fails to be a reliable bulk moisture determination for material with a high attenuation since it causes the measured microwaves to only penetrate a thin surface layer of the material. This is especially important for materials such as magnetite where penetration will be at best of the order of a centimetre.

The resonance frequency of the microwave field is detuned and dampened depending on the water content of the material. The changes in the microwave frequency is measured by the receiver antenna and this signal is then evaluated by the microprocessor based control unit. With the measurement of the above parameters and their evaluation, it is possible to determine moisture content and material density separately.

The LFM\textsuperscript{3} uses microwave transmission technology for measurement of online moisture. This technology ensures accurate measurement of all material between antenna pair in difficult applications where vertical material segregation occurs.

The first microwave based moisture content analysers used only one characteristic of the microwave – the attenuation, which gave Thermo Scientific, for a short period of time, a competitive advantage over our competitors.

Nowadays, all competitors are using both; attenuation and phase shift. This is explained in section 1.1 below. The LFM uses low frequency microwaves which enables penetration of much higher material burden than competitor high frequency microwave models.
1.1. **How the technology works**

Microwave moisture analysers work on the principle that water has a very higher dielectric constant compared to most other materials.

When microwaves interact with water molecules within the material they slow down (and hence change phase) and weaken (attenuate) as the energy is transferred to the water.

A low profile antenna transmits a beam through the material on the conveyor belt. The signal is received by a receiver antenna located below the conveyor belt. The received signal is compared to the transmitted signal for phase and amplitude change. See figure below.

![Microwave Transmission technology arrangement. (Figure 1)](image)

Both the change in phase shift and attenuation is measured and processed by the control unit to calculate the moisture content of the material measured.

Since phase shift and attenuation is dependant and influenced by the amount of material to be measured (% moisture by weight), a measurement of the mass loading on the belt is required to compensate or “normalise” the microwave measurements. The mass, profile or height measurement is provided by use of belt weighers, radar level, ultrasonic level, radar scanners etc, or even a combination of these devices. In some cases the density of the material is measured using a Nuclear Type Density Transmitter.
Another technology that is used for online moisture measurement is NIR (Near Infra Red) which is limited in the fact that it only measures surface moisture and does not penetrate the whole burden of material. In Dust Elimination Moisture (DEM) applications where the moisture is measured immediately following sprayers, the moisture reading will be biased to read high moisture which is true for the surface but not for the whole burden of material.

2. Case Study

Dalrymple Bay Coal Terminal (operated by DBCT P/L) is a global coal exporter located in Queensland Australia. Located at the port of Hay Point, 38 kilometres south of Mackay in central Queensland, DBCT P/L is a key player in the world’s global coal export market and is critical to the economic prosperity of Queensland and Australia. Uncompromising dedication to safety of its people and surrounding community with unparalleled persistence has led DBCT P/L to achieve operational excellence. Dalrymple Bay Coal Terminal has been reliably exporting coal to at least 30 countries for more than 30 years.

Over the last 10 years, DBCT has undergone various expansions to meet the unprecedented demand by global markets for Bowen Basin’s premium quality coal. As one of the largest coal export Terminals with the capacity to ship 85Mtpa, DBCT is an impressive facility.

As a result of DBCT’s (Figure 2) most recent expansion, the Terminal now boasts:

- A new third in-loading system including rail loop and dump station.
- Expansion of the stockyard with three additional machinery bunds, two new stockpiles rows and four additional Stacking/Reclaiming machines.
- A third out-loading system feeding the three ship loaders.
- A fourth berth.
- Additional controls to reduce the impact of noise and dust emissions.

![Figure 2](image-url)
DBCT makes significant economic and social contribution to surrounding communities, Queensland and Australia. This includes:

- Employment of approximately 300 employees and 50 Contractors
- Annual injection of more than $100 million into Queensland economy
- Provision of apprenticeships and traineeships
- Community events support

**Figure 3**

Port of Hay Point (Figure 3)

The Port of Hay Point is one of the world's largest coal export ports and is comprised of two separate coal export terminals, Dalrymple Bay Coal Terminal (owned by DBCT M and operated by DBCT P/L) and the Hay Point services Coal Terminal (owned and operated by BHP Billiton Mitsubishi Alliance). North Queensland Bulk Ports (NQBP) is the relevant port authority.

In order to minimize dust pollution DBCT P/L opted, to measure the amount of moisture in the various coal types transported on the conveyors and add measured amounts of water in order to control the dust emission. They choose the Thermo Fisher Scientific Microwave Moisture analyser model LFM³ for this task. DBCT P/L opted to install Moisture Analysers on the incoming and outgoing coal belts as per figure 4. These were all used to ensure optimum coal moistures are achieved for site dust management.
DBCT P/L make use of a closed loop system where water sprays are installed prior to the LFM analyser and in the transfer chutes to ensure penetration of the moisture throughout the material burden to maintain optimum coal moistures and so minimize dust.

The calibration requirements for the Moisture Analysers were arduous and at times seemed impossible. 125 different types of coal were transported on these conveyors and each one had to be measured. Although the LFM is more than 10 times more sensitive to moisture variation than to mineralogy variation, the LFM like any other Microwave based system is prone to inaccuracies due to mineralogy changes in material measured. This was overcome by grouping the coals together with close attention to similar mineralogy to minimize the effect on accuracy with conveying of different coal types.
The end result was each LFM had to be calibrated for 6 different coal groups (representative of 125 coal types) and calibration switching had to be done when the conveyed coal group changed resulting in minimal effect on accuracy. Refer table 1 below.

Table 1: Example of Calibration Accuracy on LFMMA at DBCT:

<table>
<thead>
<tr>
<th>Location</th>
<th>Conveyor No.</th>
<th>Moisture Range of Calibration/s (Ranging from)</th>
<th>Calibration Results (RMSD*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay Point</td>
<td>S1</td>
<td>-</td>
<td>n/a**</td>
</tr>
<tr>
<td>Hay Point</td>
<td>S2</td>
<td>-</td>
<td>n/a</td>
</tr>
<tr>
<td>Hay Point</td>
<td>S11</td>
<td>-</td>
<td>n/a</td>
</tr>
<tr>
<td>Hay Point</td>
<td>L3</td>
<td>8 – 20 %</td>
<td>0.46 - 0.82 wt%</td>
</tr>
<tr>
<td>Hay Point</td>
<td>L13</td>
<td>8 – 21 %</td>
<td>0.32 - 0.67 wt%</td>
</tr>
<tr>
<td>Hay Point</td>
<td>L4</td>
<td>8 – 21 %</td>
<td>0.44 - 0.75 wt%</td>
</tr>
</tbody>
</table>

*RMSD (Root Mean Square Deviation) quoted are at one standard deviation.  
**N/A: as these were calibration transfers from L4. No sampling was available on S1, S2, and S11 to calculate RMSD.

3. Calibration Results & Accuracies
DBCT P/L collected quite a comprehensive set of samples ranging in duration from around 15 minutes to 2 hours. These were taken from their out-loader conveyors using their sampling stations. This enabled good calibration according to our standard sampling regime practice. The challenge with DBCT P/L was the extremely large number of different coal types that are loaded at the Port. With one coal type, the microwave response can be readily linked with moisture content whereas with multiple coal types it is critical to ensure that the calibration is acting on the variation in moisture rather than the differences between coal types. Thus it is necessary to group the coals appropriately, both into groups of similar moisture and similar mineralogy, in order to create a calibration that predicts the moisture (rather than changes in the coal type). The DBCT coal types were allocated to 6 groups and a calibration was created for each group on each of the three out-loading systems.
For development purposes and to test Thermo Scientific's ability to deliver a more streamlined solution to coal loading facilities in the future, the calibrations were mapped over from one out-loading system to the other two in a process called calibration transfer. These transferred calibrations were then tested and optimized using the good quality sample data available on the out-loading systems.

The next stage was to calibrate the three in-loading systems conveyors, for which sampling was not available. The transfer calibration process tested on the out-loading systems was then used to calibrate the in-loading systems. This calibration process leaves an offset that can be removed using a small number of samples. This offset reflects differences in loading and geometry between belts that cannot be accounted for theoretically. However on the in-loading systems, even the small quantity of samples required for offset calculation was not available (this seems to be a typical problem for many sites).

To complete the calibration and remove this offset, a cross site correlation was created, tracking material types from in-loading to out-loading based on time in and out of the facility. Over a long period, this is expected to create a good estimate of the average moisture seen on the in-loading systems and this was used to correct the offset and complete the calibration.

For DBCT, the primary purpose of the LFM moisture measurement is as a process control variable for optimum coal moisture control and also dust suppression. The calibrations created were not as accurate as could be achieved if each coal type was calibrated separately; however DBCT indicated that the accuracy is sufficient to provide the optimum coal moisture control they required. It was also financially more viable than individual calibrations for each coal type.
References / Contributions

Google, DBCT Web Site.

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