PROCESS IMPROVEMENT THROUGH REAL-TIME ANALYSIS*

Luke A. Balzan[1]
Andrew R. Harris[2]
Zoran Bauk[3]

Abstract

Access to information is a key component for making improvements to any process. This is particularly true for all aspects of the iron mining and steelmaking process. The ability to make rapid control decisions can significantly influence process outcomes, including ensuring product specification, mining quality, transportation limits, upgrade factors, waste bypass and direct shipping, among many others. While traditional laboratory methods provide feedback for such processes, having access to analysis results in real-time can lead to positive reactive and predictive control decisions to be made rapidly, leading to significant improvements throughout the process. Scantech has been designing, manufacturing and supplying technological products to the minerals industry since 2002 to enable the availability of such real-time information to a mine or plant, with the benefits being enjoyed by a wide range of operators. This paper provides a summary of the available technologies used in the iron ore and steel industries, as well as providing a case study of their use at an Australian site, and a description of the potential benefits of a range of analysis equipment.

Keywords: On-belt analysis; Geoscan; Moisture; Real-time analysis.

---

[1] *Ph.D, B.Eng (Hons) Electrical & Electronic, Technical Consultant, Scantech International Pty Ltd, Camden Park, SA, Australia.*

[2] *B.Sc (Hons) Physics, Operations Manager, Scantech International Pty Ltd, Camden Park, SA, Australia.*

[3] *B.Eng (Hons) Electronic, Product Optimisation Manager, Scantech International Pty Ltd, Camden Park, SA, Australia.*

1 INTRODUCTION

Access to information is critical for any process, and is a fundamental component for making process control decisions. In order to yield effective processing outcomes, it is important for that information to be readily available, preferably as quickly as possible, and to be as accurate as possible. While speed and accuracy are often traded off against each other, there are numerous technologies available in a processing environment that allow for both rapid flow of information and a high level of accuracy. The use of on-belt analysis equipment has a long trusted history of use in a number of mining and processing environments and industries, providing information such as elemental composition and grade of conveyed materials, moisture content, waste proportion and energy information. Australian company Scantech has been a provider of such equipment since 1981, and has become an industry leader in both the supply and development of on-belt analysers across a range of industries.

Having developed a large installation base in coal, cement and minerals industries, Scantech recognised the potential for the use of its equipment in iron ore, and became the first supplier of on-belt analysis equipment to this industry in 2002. Since that time, Scantech has supplied over 40 of its Geoscan on-belt elemental analysers to the sector, and more than 50 of its through-belt moisture (TBM) analysers. In addition to its use in iron ore and steelmaking, the equipment is widely used in manganese, base metals, phosphates, and numerous other industries. The benefits of having access to information about the elemental composition of material on a conveyor belt in real-time became quickly apparent to users of the equipment [1, 2], with results applied in both feed-forward and feedback control systems. Gains in efficiency and processing performance were also quickly recognised and documented [3, 4, 5], with the benefits of being able to make rapid decisions and process control changes in real-time translated to a range of different industries [6, 7]. Users of the equipment have continued to discover new and innovative uses as a result of having access to real-time information [8], and have been enthusiastic in praising the use of the equipment [9]. As well as elemental analysis from its Geoscan, Scantech also has a solution for on-belt moisture analysis with its TBM, which has been equally acknowledged for its success in the iron ore industry [10]. Moisture analysis is becoming critically important in relation to ore transportation, especially in Brazil. Ore needs to maintain a moisture level greater than the dust extinction moisture (DEM), but be less than the transportable moisture limit (TML) for shipborne transport. Accurate real-time moisture analysis from a TBM is clearly important in being able to control the moisture within such limits.

It is clear that access to the information provided by the equipment yields benefits for its users, and this paper seeks to provide a summary of the technology that enables access to this information, as well as giving an overview of results achieved in iron ore and steel industries, and finally giving a case study description of Geoscan and TBM usage by an Australian iron ore mine and how the equipment is utilised for process control, concluding the paper.

2 ON BELT ANALYSIS TECHNOLOGY

To be able to benefit from having real-time information about conveyed materials in a process, it is important that the information is a true representation of the material being observed. This is a key objective of good analysis technology, and requires that the analysis technique is accurate and repeatable, and that the measurement being provided is a good estimator of the full material stream. There has been significant research looking at segregation, separation and migration of material on a moving conveyor, suggesting that observing only the surface of the conveyed material or a small section will lead to strong biases in the results. For iron ore, this is particularly important for material streams with a wide particle size distribution, where fines and lump particles constitute different qualities of ore, and for moisture as it migrates as a result of the belt motion.

With a large amount of experience in mineral analysis, Scantech recognises the importance of full material stream and full bed depth analysis, and focuses on technologies that enable fully representative analyses to be obtained in an accurate and repeatable way. Coupled with Scantech's unique tailored calibration methods, designed specifically for a sites' individual requirements, including minimising impacts on production, has allowed Scantech to become a market leader in on-belt analysis for iron ore [5, 8].

This section highlights two of the key technologies used in the iron ore and steelmaking industries and what results can be produced to allow for enhancements in process control.

2.1 Geoscan Elemental Analysis

Scantech's Geoscan on-belt analysers utilise thermal neutron capture technology to determine the elemental composition of conveyed bulk materials in real-time. Conveyed material passes through the tunnel of the Geoscan, while a californium-252 radioactive source located within the Geoscan below the belt passes neutrons through the material. The neutrons are captured in the nuclei of the atoms in the material on the belt, which instantaneously outputs gamma-rays that are energy-specific to the element. The gamma-ray spectrum is captured by an array of detectors located at the top of the Geoscan, where Scantech's signal processing algorithms resolve the signal into a set of elemental results.

The measurement technique is completely penetrative and allows for analysis of the full material stream, full bed-depth and full belt-width. It is also independent of particle size and ore mineralogy, allowing for fully representative analysis of the conveyed material. In this way, it does not suffer from sampling errors, such as if a top surface only measurement was taken. Results are produced for a suite of elements calibrated for the specific requirements of the end user, with emphasis on their key elements of interest. The calibration is tailored for their requirements, including incorporation of variation due to changes in the belt load and material composition.

For iron ore and steelmaking the typical elements of interest include Fe, Mn, and oxides of Si, Al, Ca, and K. Different sites will have varying requirements and may make control decisions based on various criteria; decisions may be made on whether to upgrade or direct-ship or even discard material based on Fe grade, or may make alterations to how the process acts on the material based on the Al content. In steelmaking, the sinter feed is often monitored, with basicity ratios of Ca, Si, Al and Mg observed and lime dosing controlled based on the ratios. Scantech works closely with the end users to ensure a tailored solution for each installation.

2.2 Through-Belt Moisture TBM Analysis

The underlying principle of moisture measurement requires the transmission of a microwave signal from a transmitting antenna, through the material to be measured, and subsequently received at a receiving antenna. The transmitted signal is known and controlled, and metrics relating to how the signal changes as it passes through the material are observed, subsequently inferring a moisture measurement. Scantech's TBM utilises two orthogonal signal transformation metrics in order to determine the moisture content. A solid understanding of the principles of how the signal is transformed through the material allows the TBM to produce moisture measurements with a high degree of accuracy.

One metric that is observed is the change in signal power as it passes through the material, conveyor belt, and air between transmitting and receiving antennas. The signal power is attenuated by solid materials in the transmission path, with different materials affecting the signal power to different degrees. It is well known that microwave signals induce oscillations in free water molecules as they transmit through a medium. The oscillation of the water molecules results in signal power loss. Therefore, there is a strong linear relationship between the change in signal power and the amount of moisture in the material.

The second metric that is observed relates to the velocity of the microwave signal as it transmits through different materials. The velocity of microwaves through a medium is inversely proportional to the square root of the complex dielectric constant of the material. For a medium comprising a variety of minerals plus water, the complex dielectric is a combination of the individual dielectrics of the various materials. The fact that for many bulk solids, the dielectric constant is small compared to that of water means that the complex dielectric is a key indicator of the moisture content in the material. The velocity of the microwave transmission through the material is linearly related to the moisture content of the material. The velocity variation is measured by observing the signal delay as it passes through the full bed-depth of material.

These two metrics are independent and orthogonal measurements of the processed microwave signal. By accounting for other effects such as changing material depth and density, the two metrics can be combined to produce an accurate measurement for moisture.

As well as microwave measurement instruments, there are also surface-measurement devices, using techniques such as near-infrared (NIR), but these do not measure the full bed-depth of material, and are thus potentially subject to inherent inaccuracies in a surface-only measurement. Moisture migration of conveyed materials is a widely known phenomenon, and thus surface-only measurement techniques are not able to accurately measure the true moisture content of conveyed materials.

The use of microwave technology for moisture measurement is well established and accepted in the coal and other industries, though the uptake in the iron ore sector is less mature and has been obscured by devices that do not meet customer expectations. Despite the inherent difficulties of real-time moisture measurement in iron ore, Scantech has been widely successful in providing the TBM device to match every expectation in a large number of installations.

3 TYPICAL ANALYSIS RESULTS

To determine the accuracy of Geoscan results, for both calibration and verification purposes, the Geoscan data is compared to conventional laboratory data. As discussed above, calibrations are tailored for individual customers, such that the results being produced apply well to a specific customer's needs. This includes the suite of elements reported, the ranges for those elements, and also incorporates normal dynamic operating conditions. It is not enough for calibration and verification to be performed under controlled static conditions [2, 6, 7, 8, 9]; not only does this methodology require significant stopped belt time, it also fails to capture any effects of normal operation, including but not limited to variation in belt load, variation in material quality, variation in mineralogy, etc. To ensure minimal interruption to production, Scantech works closely with its customers to ensure an effective means and method of dynamic calibration and verification is determined and utilised. Often, this includes the use of conventional sampling data, but if this is not available, alternatives are selected.

3.1 Typical Geoscan Results

Figures 1—4 show a series of results from active iron ore operations that have utilised a variety of dynamic sampling methodologies. All results incorporate the inherent Geoscan precision, as well as external errors including laboratory, sampling and handling errors. Despite this, these true dynamic results demonstrate the effectiveness of the Geoscan for producing results relevant to the iron ore industry.

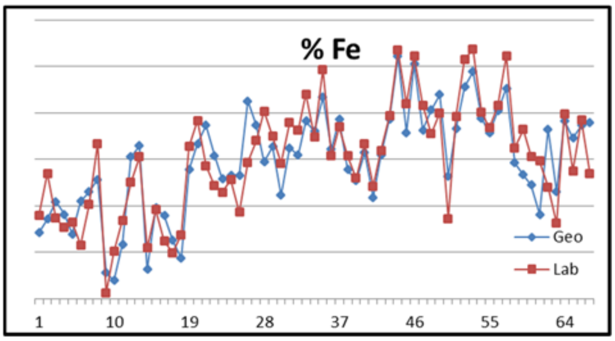

Figure 1. Comparison of Geoscan (blue) to laboratory (red) trend for iron

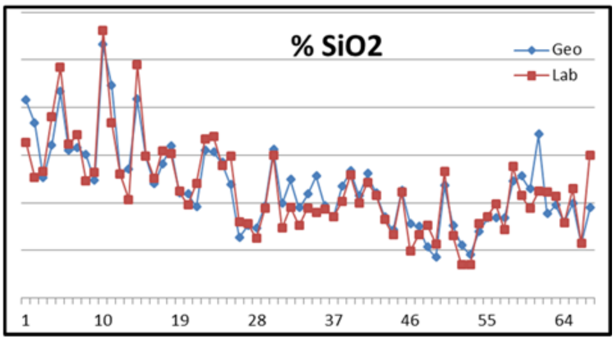

Figure 2. Comparison of Geoscan (blue) to laboratory (red) trend for silica

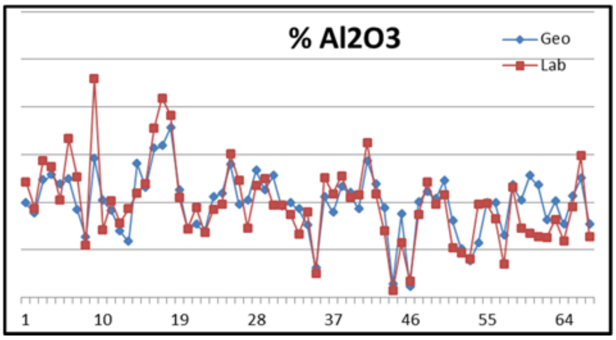

Figure 3. Comparison of Geoscan (blue) to laboratory (red) trend for alumina

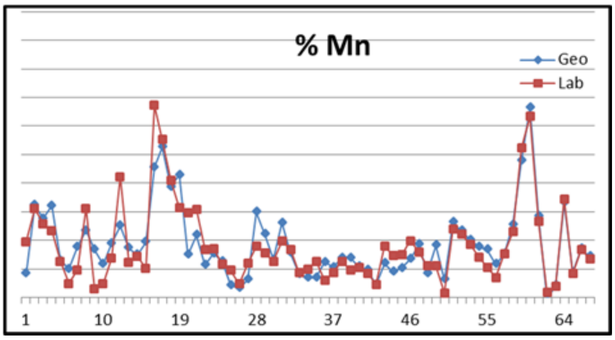

Figure 4. Comparison of Geoscan (blue) to laboratory (red) trend for manganese

3.2 Typical TBM Results

Figure 5 shows TBM results for moisture analysis on iron ore. Again, the TBM results are compared to conventionally collected laboratory analysis samples, with the error incorporating the inherent TBM precision along with errors associated with laboratory, sample collection and handling. With moisture laboratory analyses, handling error becomes important due to the potential for evaporation or moisture addition due to rain and humidity. Despite such sources of error, the results obtained show very good agreement.

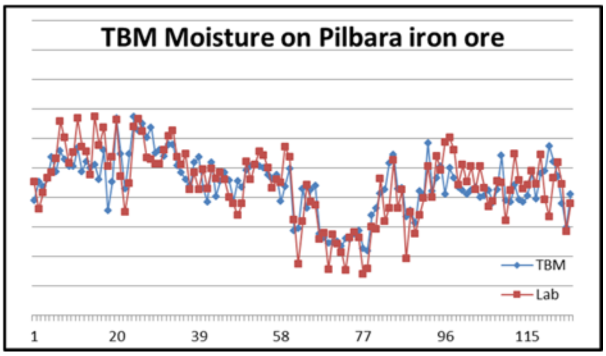

Figure 5. Comparison of TBM moisture (blue) to laboratory (red) for Pilbara iron ore

4 CASE STUDY GEOSCAN RESULTS

In this section, two case studies are presented for widespread Geoscan usage. The first site, located in South Africa uses a large number of Geoscans at various stages of their process. The second site, in the Pilbara in Australia uses three Geoscans in their process. The South African site is described below, and the Pilbara site, including a series of results, is described subsequently.

4.1 South African Site

Geoscan usage in South Africa is very wide spread. A number of operators have been very quick to adopt Geoscan usage, with sites typically having a large number of Geoscans throughout their operations. One site utilises a very large number of Geoscans, where virtually every stage of their process is monitored [2]. At this site, Geoscans are located at the run of mine (ROM), at the feeds to various jig processing facilities, to separation plants, and of course, on the products. A key feature is that the Geoscans are used to provide a bulk sorting function, where material of a particular grade or above can be diverted away from the main processing facilities to a direct shipping stockpile. Material less than this quality is allowed to be processed as normal. This frees capacity within the processing facility to enable only material that requires upgrading to be processed. The net result is that a higher plant throughput can be obtained with less resource and for less cost. The adoption of the Geoscan technology on site has allowed for operators to become very comfortable with having access to real-time data, such that the Geoscans form a critical aspect of the operation.

4.2 Pilbara Site

A final series of results from a particular site in Western Australia's Pilbara region is used to demonstrate the effectiveness of Geoscan results in a real live mining environment. Similarly to the South African site, this site utilises Geoscans throughout their process. Two installations will be discussed here: their ROM Geoscan and their Products Geoscan. The two represent the two ends of the mining process. Figures 6—17 highlight results from the ROM Geoscan, the products Geoscan, and a comparison of the two Geoscans for the elements of interest.

4.2.1 ROM Geoscan

The ROM Geoscan, with results shown in figures 6—9, is observing primary crushed material, and experiences significant variation in belt load and material quality. It is clear to see the two distinct grades of material being fed into the plant in these figures. There is no sampler present on the ROM belt, so alternative sample collection and comparison methods have been employed

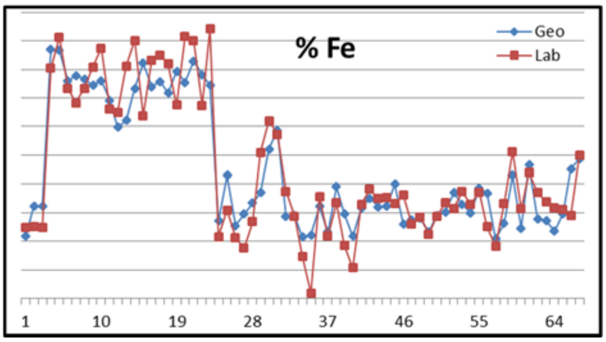

Figure 6. Comparison of Geoscan (blue) to laboratory (red) trend for iron

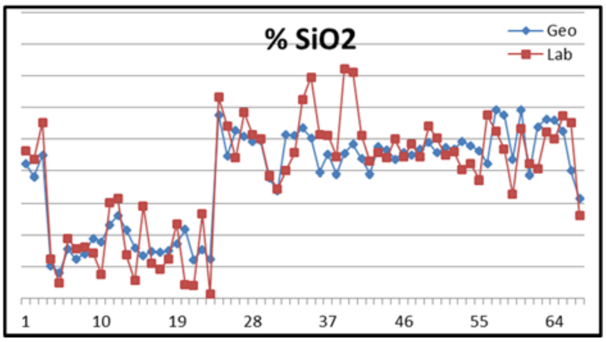

Figure 7. Comparison of Geoscan (blue) to laboratory (red) trend for silica

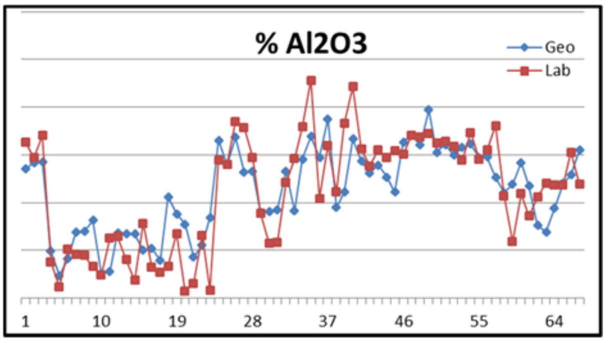

Figure 8. Comparison of Geoscan (blue) to laboratory (red) trend for alumina

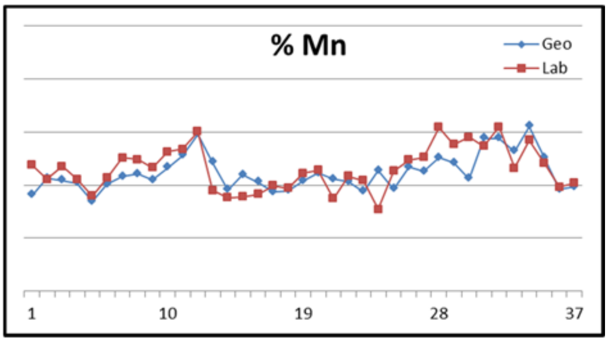

Figure 9. Comparison of Geoscan (blue) to laboratory (red) trend for manganese

4.2.2 Fines Product Geoscan

The fines product Geoscan is observing the output of the plant prior to shipping, and shows the results of comparison to samples collected at ISO standards. The results are observed in figures 10—13.

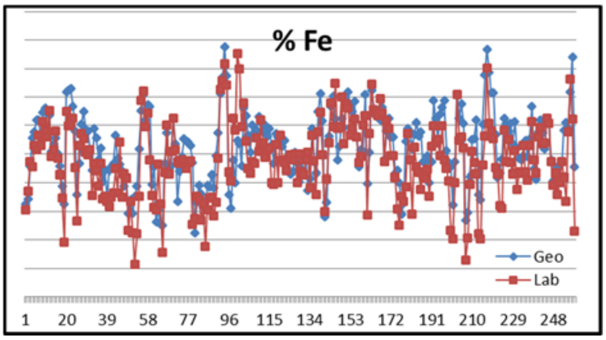

Figure 10. Comparison of Geoscan (blue) to laboratory (red) trend for iron

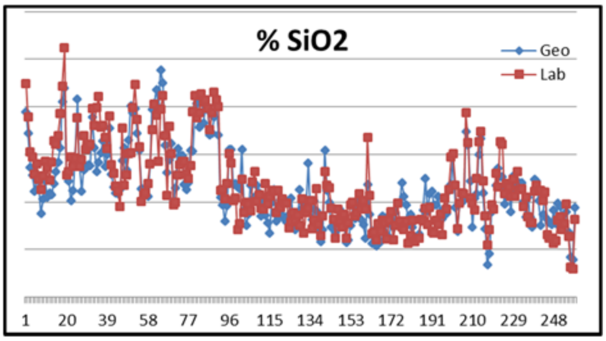

Figure 11. Comparison of Geoscan (blue) to laboratory (red) trend for silica

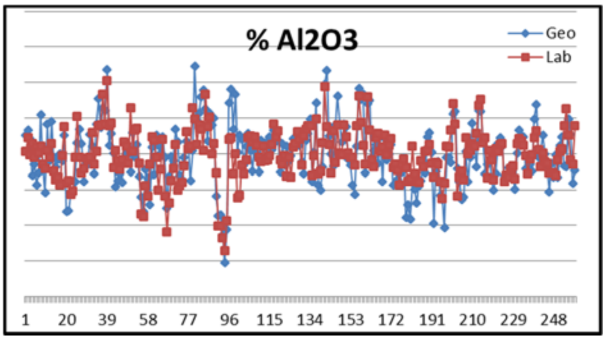

Figure 12. Comparison of Geoscan (blue) to laboratory (red) trend for alumina

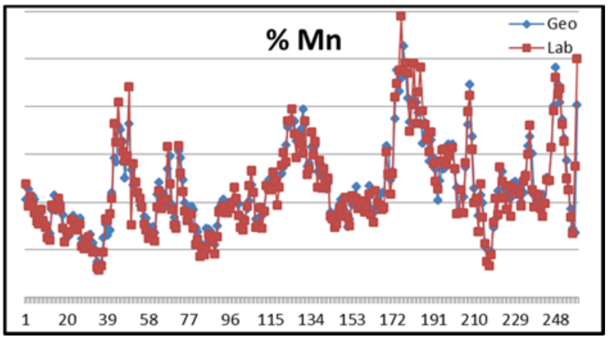

Figure 13. Comparison of Geoscan (blue) to laboratory (red) trend for manganese

4.2.3 Comparison of Results

As mentioned above, two different comparison methods are employed to compare the ROM and products Geoscans. To validate the comparison method, a comparison between the two Geoscans was made for a period where the ore processing facility was known to be offline for maintenance purposes. This had the effect of having both ROM and fines product Geoscans measuring the same material (with a delay). By comparing the Geoscan results to each other for this period and observing the excellent agreement in results, the calibration methods are validated as well as providing an additional reference to ascertain the quality of the Geoscan results. These results are seen in figures 14—17.

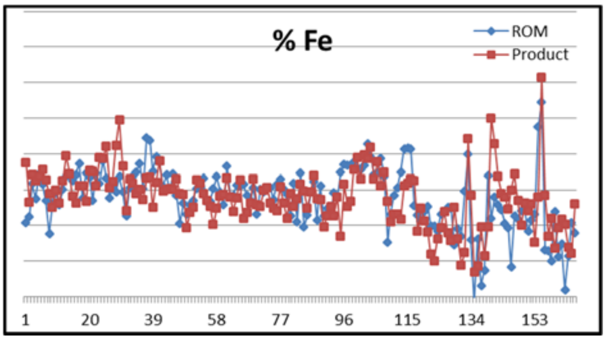

Figure 14. Comparison of Geoscan (blue) to laboratory (red) trend for iron

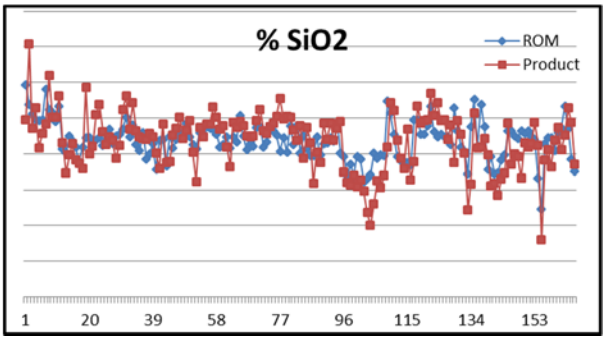

Figure 15. Comparison of Geoscan (blue) to laboratory (red) trend for silica

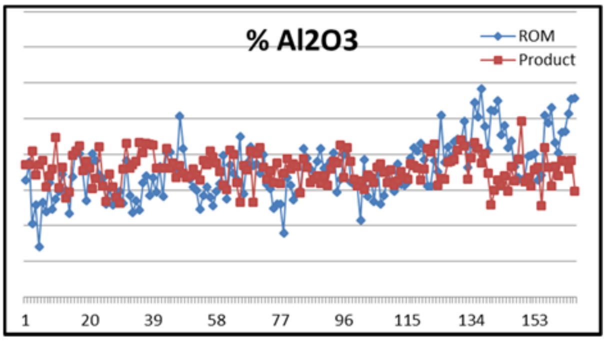

Figure 16. Comparison of Geoscan (blue) to laboratory (red) trend for alumina

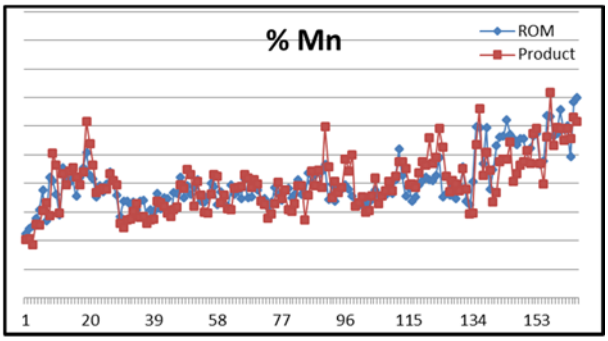

Figure 17. Comparison of Geoscan (blue) to laboratory (red) trend for manganese

5 CONCLUSION

This paper has provided a summary of some of the real-time analysis equipment that is widely used within the iron ore and steelmaking industries. A discussion of the underlying technologies for elemental analysis and moisture analysis has been provided, along with a technical description of the Geoscan and TBM instruments. Examples of typical results obtained from such equipment have been detailed, as well as two case studies of site installations across different continents. Analysis performance data has been included, demonstrating the suitability of this equipment for use within both the iron ore and steel industries.

REFERENCES

1 Arena T, McTiernan J. On-belt analysis at Sepon copper operation. Proceedings MetPlant. 2011; 527-535.
2 Matthews D, du Toit T. Real-time online analysis of iron, validation of material stockpiles and roll out for overall elemental balance as observed in the Khumani Iron Ore Mine South Africa. Proceedings Iron Ore. 2011; 297-305.
3 Harris A, Smith K, Rossi F. On-belt analysis breakthrough. International Cement Review. 2005; October: 62-66.
4 Ortiz C, Harris A. Raw mix control. World Cement. 2002; February: 46-49.
5 Kurth H. Real time on-belt elemental analysis for advanced process control in iron ore. Proceedings 43rd Ironmaking and Raw Materials Seminar, 12th Brazilian Symposium on Iron Ore and 1st Brazilian Symposium on Agglomeration of Iron Ore. 2013; 364-373.
6 Balzan L, Harris A. Adaptation and performance of Geoscan on-belt analysers for manganese ore at Assmang Black Rock. Proceedings Africa Australia Technical Mining Conference. 2015; 125-130.
7 Patel M. On-belt elemental analysis of lead-zinc ores using prompt gamma neutron activation analysis. Proceedings XXVII International Mineral Processing Congress. 2014; chapter 17.
8 Balzan L, Jolly T, Harris A, Bauk Z. Greater use of Geoscan on-belt analysis for process control at Sepon copper operation. Proceedings XXVIII International Mineral Processing Congress. 2016; accepted.
9 Balzan L, Beven BJ, Harris A. Geoscan online analyser use for process control at Fortescue Metals Group sites in Western Australia. Proceedings Iron Ore. 2015; 99-105.
10 Balzan L, Harris A. Real-time through-belt moisture analysis for iron ore. Proceedings Iron Ore. 2015; 539-542.