GEOSCAN ELEMENTAL ANALYZER FOR OPTIMISING PLANT FEED QUALITY AND PROCESS PERFORMANCE

*H. Kurth[1]

[1]*Scantech International Pty Ltd,*
Unit 14, 2994 Logan Rd,
Underwood QLD 4119, Australia.
*(*Corresponding author: h.kurth@scantech.com.au*)

GEOSCAN ELEMENTAL ANALYZER FOR OPTIMIZING PLANT FEED QUALITY AND PROCESS PERFORMANCE

ABSTRACT

Geoscan (using PGNAA) is used for multi-elemental analysis of conveyed bulk materials in real time measuring continuously through the full bed depth, and unaffected by belt speed, particle size, layering and dust levels. Tonnage weighted results are used to monitor quality, divert increments (bulk sorting), ore blending, and feed forward control to optimize downstream processes. Advance warning of compositional variability enables appropriate and timely reactions prior to processing. This may include modifying feed rate, changing feed blend, or modifying the treatment regime in anticipation of a change in feed quality or mineralogy. Major benefits have been achieved at existing operations.

KEYWORDS

Geoscan, elemental analysis, PGNAA, mine to mill, real time

INTRODUCTION

As operators of process plants strive to remain competitive and increase productivity, more focus has been directed at incremental performance improvements at incremental cost rather than major expansions to increase output. The philosophy of working smarter allows plants to adopt technologies proven in other industry sectors to minimize risk. This paper discusses one such technology that the minerals sector has found to be safe, reliable and accurate with paybacks of weeks in most applications. New applications continue to be developed and major benefits realized at various stages in the processing and handling of ores and products.

Real time analysis of conveyed materials at mining and mineral processing operations has enabled a significant improvement in process control as the real time data allows immediate feedback to upstream operations and feed forward of data on material quality to downstream processing operations. The real time measurement of multi-elemental and moisture content provides opportunities for process improvement through the availability of good quality analysis of conveyed increments. These increments, which can represent fewer tonnes than a haul truck, can be appropriately handled based on their composition. Plant response depends on the key parameters measured or indicated and on the potential impact of the composition or its variability on downstream processes.

The technology is intended as a process control tool and not to replace all sampling. The turnaround time for results from sampling systems, sample preparation, and laboratory analysis do not allow for effective real time control. Routine sampling of conveyed flows can be significantly reduced and this can justify an analyzer alone in some cases. Utilising an effective and representative real time sensor technology for grade management has been particularly necessary in the “mine to mill” stages as this area has the potential for significant improvements to the processing operations at relatively low cost. It is also the section of the process where implementation of representative sampling processes and equipment is most problematic due to large particle size and large flow rates necessitating large and expensive installations with high maintenance requirements. Benefits of implementing a real time elemental analysis technology are dependent on a good understanding of grade variability and the relationship of ore components, their effect on processing, and the measureable elemental composition.

BACKGROUND

Real time sensing technologies have been developed for many mining applications; for down-hole probes during exploration, handheld qualitative measurements systems, truck scanners, and image analysis for particle sizing. The most commonly adopted technologies for measuring material quality in process plants for control are found in flotation circuits where slurry analyzers have been used for decades.

Technologies that have been developed for conveyed bulk material composition analysis include adaption of those used in laboratory analysis, such as XRF (X-Ray Fluorescence), LIBS (Laser-Induced Breakdown Spectroscopy), NIR (Near Infrared), LIF (Laser-Induced Fluorescence), multispectral scanning and others. PGNAA (Prompt Gamma Neutron Activation Analysis), or thermal activation, has proven to be representative irrespective of particle size, belt speed, mineralogy, layering on the belt, high dust levels, and variable moisture content. It is penetrative and continuously measures through the full cross section of the conveyed load. This is in contrast to technologies used in particle sorters which are focussed on particles within a limited size range and generally applied to a mono-layer so each particle can be individually interrogated. This limits throughput to a few hundred tonnes per hour, hence the PGNAA technique used in the Geoscan has become the technology of choice for real time bulk material conveyed analysis.

The Geoscan uses PGNAA which involves the generation of neutrons from a Californium-252 source located beneath the conveyor belt. Neutrons absorbed by elemental nuclei in the conveyed material result in gamma rays being emitted. The energy level of each gamma ray is used to identify the element from which it is emitted. The Bismuth Germanate detector array and digital multi-channel analyzers above the conveyor detect the energy levels of the gamma rays received and over a short time frame spectral data are accumulated which are representative of the conveyed load's composition. Elements typically measured are those within in the sodium and potassium rows in the periodic table.

Belt weigher and adjacent moisture monitor inputs allow tonnage weighted dry weight per cent for each element above a minimum and reliable detection level to be reported to a control system every few minutes (typically one to five minutes) for any ore, concentrate or intermediate conveyed flow, enabling operators to respond accordingly to each result or trend. As a process control tool absolute accuracy is not essential, however, enhanced calibration techniques have enabled very good measurement accuracies to be achieved for most elements of interest in mineral processing operations.

Real time elemental analysis has been used in the coal industry since the early 1990s. It was adopted in the cement industry when it was found that control using real time elemental analysis reduced product quality variability to half that achieved using sampling and laboratory analysis. It was adopted in the minerals sector once parallels in processing operations and control philosophies were recognized and it was considered low risk as the technology had been proven in other sectors over a considerable time frame. Since 2003 the Geoscan has been used successfully in minerals applications initially in the iron ore and manganese industry, then copper, and more recently into zinc-lead and phosphate applications. There are in excess of 50 successful Geoscan installations worldwide in the minerals sector.

APPLICATION HISTORY

For conveyed applications, studies indicated potential for PGNAA suitability for bauxite measurement (Beurton, Ledru, & Letourneur, 1995). Tran and Evans (2001) concluded there was no equivalent technology to PGNAA in terms of material penetration power and that the technology was suitable for the cement industry. Nelson and Riddle (2003) evaluated PGNAA for possible use in the phosphate industry and recommended its use for characterisation of a mine's various ore types to improve stockpile allocation and grade control. Cottle (2007) discussed factory test work on a potential sinter application and Delwig, Fettweis, Schnitzler, Wienstroer, Ferguson, and Noble (2011) described the successful installation in 2009 and subsequent successful performance of PGNAA for base-to-acid ratio control in sinter feed with analyzer output used to control lime addition.

Geoscan has been indicated by Minnett (2010) to work very well on iron ore and "seem to improve control over what is happening in the plant" (p. 42) and that "comfort that the product overall is on-spec" (p. 42). PGNAA is not yet used in the minerals sector for tariff purposes as has occurred since 2000 with Coalscan (PGNAA) in coal (Minnett, 2010). Kurth (2007) and Kurth and Edwards (2008) discuss the applications of the technologies for measuring mine output in terms of process control for both the mine and the processing operations. Matthews and Du Toit (2011) explained the benefits available from the application of multiple Geoscan units in iron ore for:

- grade allocation,
- identifying ore types based on major and minor elements and elemental ratios,
- bulk sorting to bypass beneficiation for product quality ore,
- measuring jig feed and product flows to maximize quality upgrade,
- measuring product and discard flows for site wide elemental balance,
- measuring flows to and from stockpiles to quantify stockpile quality, and
- measuring train load out grade to manage stockpiling at the port before shipment.

Arena and McTiernan (2011) outlined benefits in measuring and controlling feed grade and mineralogy blending in a copper operation while Patel (2014) discussed the benefits of a Geoscan in measuring zinc-lead ore quality to improve heavy medium plant recovery/reject control. Balzan and Harris (2015) outlined the Geoscan performance achieved in manganese ore applications for underground and surface control of stockpile quality and blending. Kurth (2015) discussed suitability of Geoscan for applications in mine to mill stages of ore processing including the use for feed forward control related to grinding and flotation circuits.

GRADE CONTROL APPLICATIONS

Measuring conveyed flow continuously enables a real time quality determination to be assigned to a short conveyed tonnage increment (e.g. two minutes). This tonnage increment can be tracked through a series of handling stages. The lag time between the measurement point (analyzer) and a control point is used to enable monitoring and control of the composition. Greatest benefits of real time analysis occur where there is quality variability, which is usual in geological environments. Process plants are typically designed using an average ore quality value or relatively narrow range. In reality the plant may not see the average grade often and must constantly adjust its operations to address variation in feed quality. When plant upsets occur due to major feed quality variations, significant periods of sub-optimal performance can occur which result in lower metal recoveries. This presents opportunities for improvement. Figure 1 indicates typical analyzer performance for run of mine iron ore from a Western Australian iron ore operation.

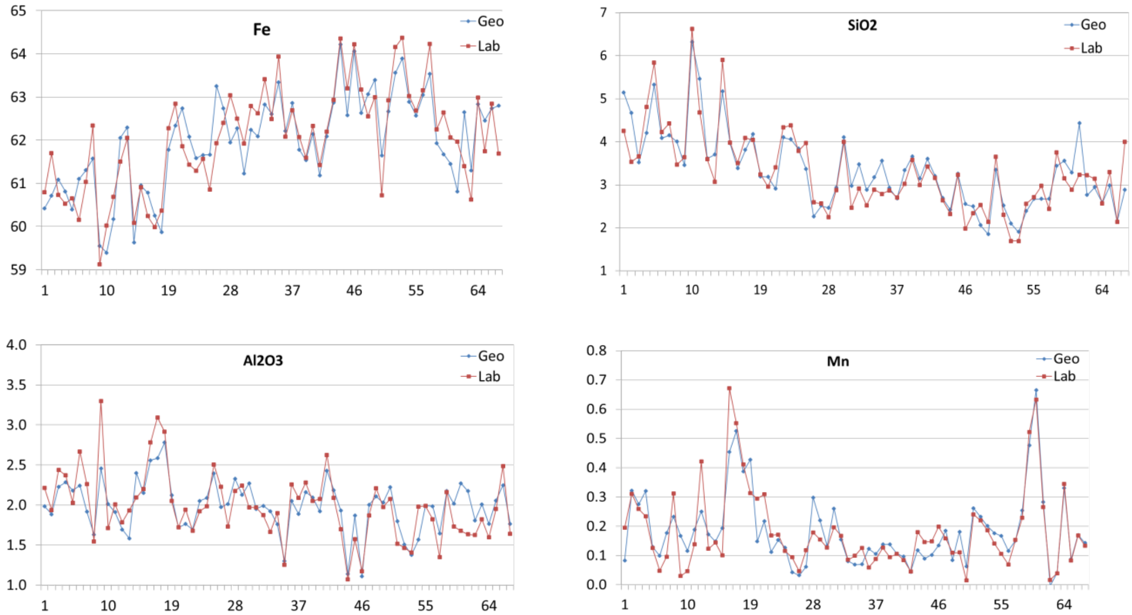

Figure 1 – Comparison of daily average Geoscan and laboratory analyses for iron ore

The main applications of the Geoscan discussed below are to measure the composition to determine variability and enable control to be implemented to either benefit from the variability or minimize it. Prior knowledge of the relationship between the elemental content and the key process performance parameters is essential for effective implementation, although some of this can be developed over time after implementation by relating effects in the process to causes due to feed composition characteristics.

Monitoring

Measurement of increments to determine composition is most beneficial when there is an opportunity to respond to a change in composition. Simply monitoring the composition of a conveyed flow may be useful for feedback, such as an ore flow from a mine or product flow onto a ship, to confirm that the quality meets expectations or a specification. While useful for metal accounting or reconciliation, it has proven to be difficult to justify the purchase of an analyzer based purely on such applications, except where the measurement can prevent penalty payments or rejection of the shipment where material quality is clearly not to specification.

Monitoring a mine's ore production can be a useful measurement for key performance indicator evaluation. If the measurement is only used by the mine for ore reconciliation against the mine plan or schedules then it will not be as beneficial as if that same information is used to advise the process operations of the ore quality they should expect to receive. A simple feedback and feed forward process is illustrated in Figure 2.

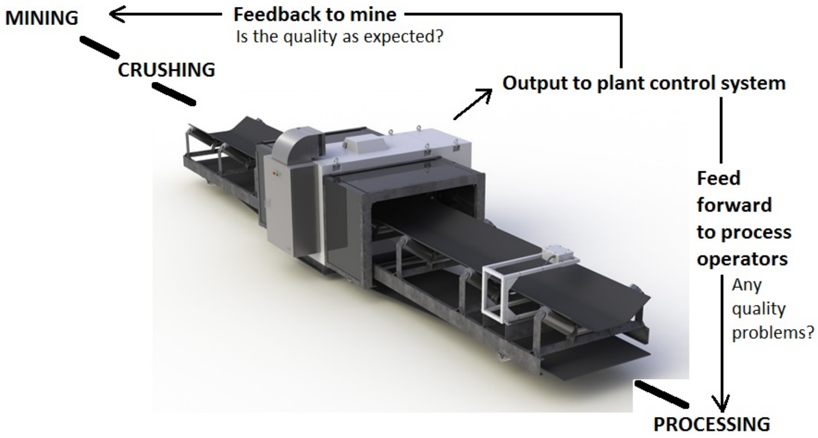

Figure 2 - Simple feedback and feed forward of real time analyzer information for quality monitoring

In the phosphate industry, for example, the chemical composition of phosphate rock is measured as it is fed to an acid reactor. The acid reactor takes phosphate rock and sulphuric acid as inputs. The real time analysis is used to measure the calcium and phosphate levels in the rock to control the acid addition to optimize the reaction process which ensures maximum calcium capture to gypsum (main waste product) and prevent calcium recovery to phosphoric acid (main product).

Input-Output Measuring

Measuring the feed and product (and/or discard) from a process may allow that process performance to be effectively optimized. The feed and product flows will provide information on the efficiency of that process stage, be it a complete beneficiation circuit (Figure 3) or one process step, such as a jig. The information can be used to fine tune the recovery as feed quality changes. The measurements also allow calculation of performance parameters for that process where other measurement opportunities may not exist, such as dry processing where slurry analysis methods are not applicable.

The same applies to stockpiles where measurement of the feed flow and the reclaimed flow allow a reasonable average stockpile quality to be continuously monitored, enabling decisions on that stockpile to be made affecting what is delivered to it or removed from it. This also benefits the reconciliation and mass balancing processes where stockpile tonnes and grade can have a major impact.

Bulk Sorting

This process refers to applications where different qualities of material would ideally follow different process paths. The lag time between the measurement and a diversion point is used to ensure correct allocation of that increment to a process path, such as a stockpile or a processing stage, depending on the composition. This involves the use of a diverter chute, flop gate or belt tripper to ensure the increment is selected and diverted as completely as possible.

Diversion can occur within the pit where in-pit crushing and conveying is used, or more typically after a primary crusher where ore is trucked and dumped prior to further processing. Another appropriate application is in the measurement of pebble circuit quality to ensure only increments with acceptable quality are recirculated to the grinding mill feed.

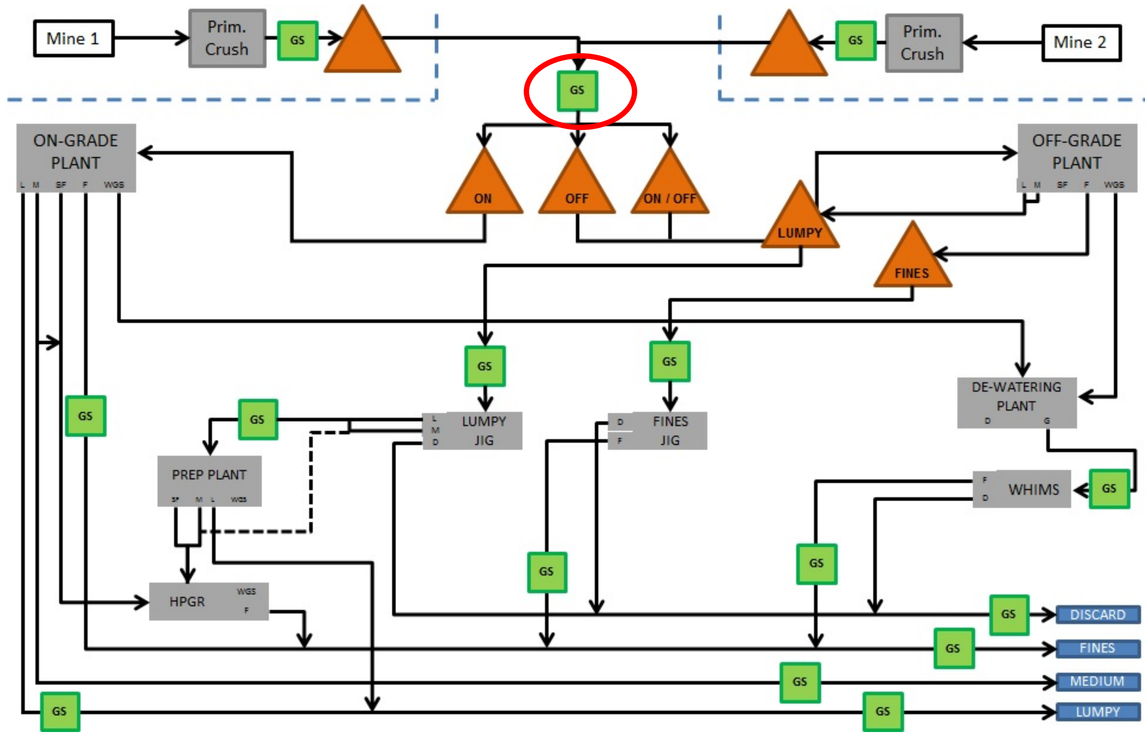

Figure 3 - Geoscan analyzers (GS) in an iron ore operation in South Africa with the bulk sorting analyzer circled (after Matthews & Du Toit, 2011)

The most beneficial application is in the removal of waste increments being conveyed to prevent unnecessary treatment of feed material which is uneconomic to process. Processing waste provides no benefit and consumes plant capacity, energy, grinding media, water, reagents, and tailings capacity. If waste can be removed at this stage then some 80-90 per cent of the treatment cost in a plant using a flotation circuit, for example, can be saved for this material. Figure 4 indicates where analyzers can be utilized to divert increments to waste dumps or further processing stages. Ore can replace diverted waste in the feed flow resulting in higher average feed grade, increased plant output for the same throughput rate, improved metal recoveries and more efficient process plant operation.

The diversion of low grade material can also be beneficial to "high grade" the process operation and generate a faster payback on the project. An analyzer has been designed into a process plant upgrade to perform this role at a base metal operation in Australia. Low grade material can be stockpiled for later processing when high grade material is in short supply, be diverted to particle sorting technologies for upgrading, or blending back into the feed flow to improve grade consistency.

Sorting ore onto stockpiles based on composition allows controlled reclaim of the stockpiles to occur downstream. High and low quality stockpiles provide flexibility in managing quality to the next process stage. Ore quality material with high deleterious content can be separately stockpiled to avoid plant upsets. This could be high pyrite, talc, arsenic, or other element which detrimentally affects processing. Such stockpiles may be blended with better quality material to reduce the effect of these components.

In direct shipping ore (DSO) applications in iron ore, bauxite and other commodities, product quality ore can be diverted to bypass beneficiation processes to ensure unnecessary processing and its associated costs are avoided. In a South African iron ore operation one Geoscan reduces beneficiation costs by approximately AUD $7-8 million per year in this application. Diverted "product quality" ore does not incur the cost of full beneficiation and therefore in excess of $1 per tonne in treatment costs is saved. Up to

5 million tonnes per year of the conveyed iron ore bypasses the jigs. This ore incurs only minor crushing and screening costs. Figure 3 also shows how the Geoscan in the plant flow sheet is used to achieve this.

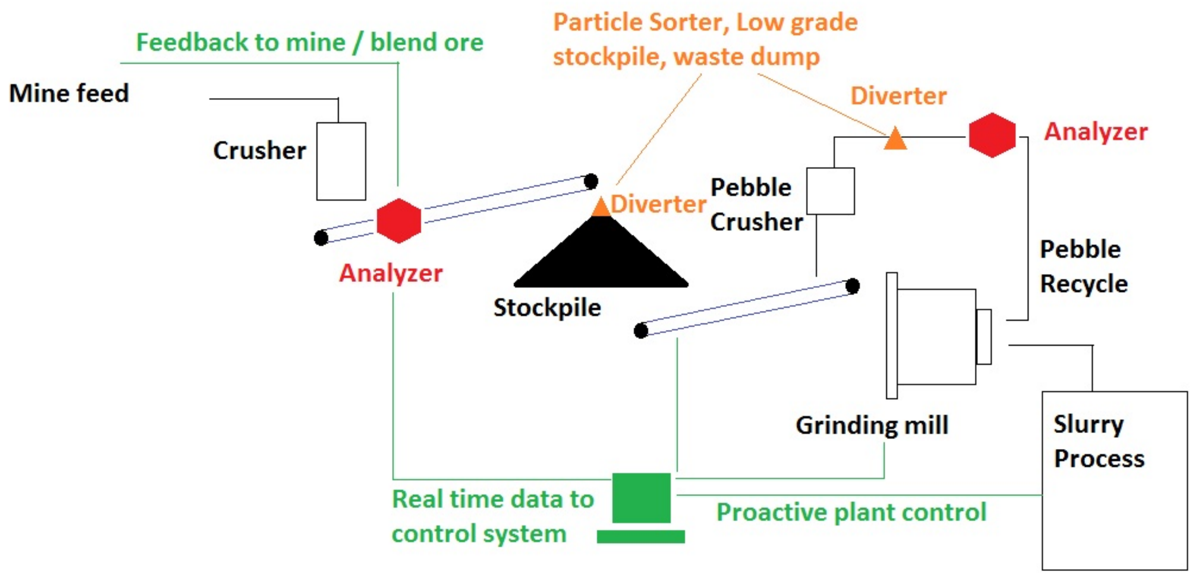

Figure 4 - Plant front end showing analyzer and diverted flows to improve waste removal

Blending and Additive Control

Geoscan can be used to control the blending process to improve quality consistency to a subsequent process stage where there are multiple feed sources for a conveyed flow. Applications can be prior to any process such as blending ore types by grade or other compositional variation, e.g. pyrite content, talc content, etc., to minimize variability and optimize process performance. Products of different quality can be blended to meet specification requirements such as arsenic content in copper concentrates from multiple mines feeding a custom smelter.

Arena and McTiernan, (2011) outlined how the Sepon Copper-Gold operations have benefited from the measurement of Cu, Fe, S, Ca and Mg using a Geoscan. The Sepon plant crushing and grinding flow sheet with the Geoscan location is shown in Figure 5. Ore types are blended by copper and pyrite content. Calcium and magnesium measurement indicates carbonate content in the feed which affects acid consumption in the leach circuit. Acid addition can therefore be controlled pro-actively by knowing what is required for that feed material entering the grinding circuit. The analyzer was justified on the basis of eliminating potential copper metal losses of up to $5million per year caused by exceeding the leach circuit capacity when higher than planned ore grade was processed. The benefits of control of the pyrite and acid dosing were not originally anticipated and have significantly increased the benefits of the analyzer. In other copper applications the ratios of elements, such as Cu:S, are useful as it can be used to indicate copper mineralogy and therefore treatment regime. A good understanding of the mineralogy is required to utilize the analyzer in this way. At least two copper operations in Australia use the Cu:S ratio in the ore body geometallurgical model to predict the process performance based on indicated copper mineralogy. The analyzer can measure Cu and S content sufficiently accurately in real time after the primary crushing stage to provide advance warning of ore changes.

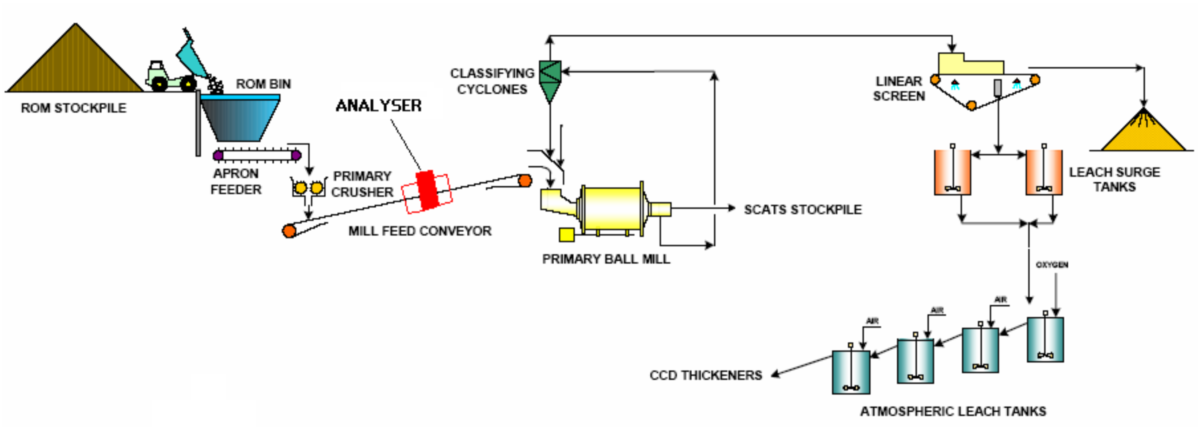

Figure 5 - Geoscan installation at Sepon Cu-Au mine (after Arena and McTiernan 2011)

Additives, such as limestone and siliceous flux materials, can be correctly proportioned to meet a desired product composition range by measuring the product flow and make adjustments to additive flow rates. This application can be used at the mine, mill, smelter (or blast furnace), chemical plant or where any blending of conveyed materials is required.

Feed Forward Control

Measuring the composition of the ore feed to a process plant using a Geoscan after crushing can provide critical advance warning of changes which affect processing of the material. In direct shipping ore applications measurements of ore quality can be used to determine the destination of product to ensure stockpile grade is well managed. Major changes in ore type or geometallurgical domain can be detected through elemental analysis and allow operators to make changes to the treatment process before the ore enters a slurry circuit as there is a significant time delay between the crusher, crushed ore stockpile and grinding mill outflow. Identification of major deleterious components such as talc (through Mg), pyrite (Fe, S), clays and alteration minerals (Na, K, etc.), and other composition components affecting flotation performance on the crushed ore conveyor allows operators to change the reagent dosing strategy to accommodate the composition change. This can reduce contamination of concentrates and improve metal recoveries.

Elemental content can also be used to characterize the grinding performance where silica content, Si:Fe ratio, clays or alteration products indicates grinding amenability. The feed rate to the mill can be adjusted where problematic material is detected in the feed to minimize mill overload, opportunities to increase throughput, or otherwise optimize grinding performance. The most beneficial application of real time elemental analysis is likely to be in combination with other techniques, such as on-belt particle size distribution measurement, to ensure as many relevant parameters are used in decision making for process control. Simkus and Dance, (1998) showed that measuring and monitoring hardness and particle size of run of mine ore related to ore treatment amenability at Highland Valley Copper was very beneficial.

CONCLUSIONS

The applications of the Geoscan elemental analyzer in various minerals industries has been demonstrated through effectiveness of real time measurement in improving process control. The PGNAA technology on which the Geoscan is based is the most appropriate method of measuring conveyed flows continuously and representatively in real time. The Geoscan has proven to be safe, accurate and reliable with over 50 installations in the minerals sector alone.

Decisions can be made on relatively small tonnages in bulk sorting, blending, and feeding the measured results back to upstream mining and grade control operations and forward to downstream process operators to improve performance at multiple stages simultaneously.

This technology does not replace site sampling and laboratory analysis, but enhances process control by providing real time analysis for improved responsiveness to material variability. Utilizing the technology on its own or in conjunction with other measurements, such as particle size, is presenting new opportunities to improve ore quality management and mineral processing, particularly in the mine to mill stage. The benefits provided by the technology include optimizing plant performance through improved utilisation, higher metal recoveries, lower treatment cost per unit of product, and higher revenues. Short paybacks of a few weeks or months are typically achieved in mineral processing operations.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of the sites used in the examples in this paper for permission to use their data. General information discussed with metallurgical research and development organisations, mining companies and process engineering companies has also been included with details not divulged due to confidentiality issues. Thanks are also given to Scantech for permitting publication of the information and for the support and input from reviewers of the paper.

REFERENCES

Arena, T. & McTiernan, J. (2011). On-belt analysis at Sepon Copper operation. *Proceedings: Metallurgical Plant Design and Operating Strategies (MetPlant 2011) 8-9 August 2011 Perth, WA* (pp. 527-535). The Australasian Institute of Mining and Metallurgy, Melbourne.

Balzan, L & Harris, A. (2015). Adaptation and performance of Geoscan on-belt analysers for manganese ore at Assmang Black Rock. *Proceedings: Africa Australia Technical Mining Conference 11-12 June 2015 Adelaide, SA* (pp. 125-130). The Australasian Institute of Mining and Metallurgy, Melbourne.

Beurton, G., Ledru, B., & Letourneur, P. (1995). Perspectives for on-line analysis of bauxite by neutron irradiation. *Internationl Conference on Neutrons and Their Applications, June 12, 1994 - June 18, 1994*. Crete, Greece: Society of Photo-Optical Instrumentation Engineers.

Cottle, I. (2007). Novel online analysis applications in the iron ore industry. *Proceedings: Iron Ore Conference, Perth WA, 20-22 August 2007* (pp. 241-244). The Australasian Institute of Mining and Metallurgy, Melbourne.

Delwig, C., Fettweis, H., Schnitzler, T.,Wienstroer, S., Ferguson, S. and Noble, G. (2011). Use of an online elemental analyser to optimize the sinter process at ThyssenKrupp Steel Europe, Duisburg, Germany. *Proceedings: Iron Ore Conference, Perth WA, 11-13 July 2011* (pp. 381-388). The Australasian Institute of Mining and Metallurgy, Melbourne.

Kurth, H. (2007). Online analyser technologies for conveyed materials - timely, representative and reliable data for improved process control. In M. Hood, P. Knights & P. Lever (Eds.), *Proceedings: 2007 Australian Mining Technology Conference, "Smart Technologies for Overcoming the Skills Shortage"* (pp. 43-52). The Australasian Institute of Mining and Metallurgy, Melbourne.

Kurth, H. (2015). Improving ore quality in mine to mill using real time on-belt elemental analysis. Paper session presented at 2015 CIM Convention, 10-13 May 2015 Montreal, Canada. The Canadian Institute of Mining, Metallurgy and Petroleum, Ottawa.

Kurth, H. & Edwards, M. (2008). Use of on-belt analysers for improved process control of conveyed materials. *Proceedings: Metallurgical Plant Design and Operating Strategies (MetPlant 2008) 18-19 August 2008 Perth, WA* (pp. 493-507). The Australasian Institute of Mining and Metallurgy, Melbourne.

Matthews, D. & du Toit, T. (2011). Validation of material stockpiles and roll out for overall elemental balance as observed in the Khumani iron ore mine, South Africa. *Proceedings: Iron Ore Conference 11-13 July 2011 Perth, WA* (pp. 297-305). The Australasian Institute of Mining and Metallurgy, Melbourne.

Minnett, R.C.A. (2010). The state of sampling practice in the South African minerals industry. *Proceedings: Sampling Conference 11-12 May 2010 Perth, WA* (pp. 31-50). The Australasian Institute of Mining and Metallurgy, Melbourne.

Nelson, M.G. & Riddle, N.K. (2003). Sampling and analysis for optimal ore-grade control. *2003 SME Annual Meeting, February 24-26, Cincinnati, Ohio* (pp. 1-8). Preprint 03-128.

Patel, M. (2014). On-belt elemental analysis of lead-zinc ores using Prompt Gamma Neutron Activation Analysis. *Proceedings: XXVII IMPC 2014, 20-24 October 2014 Santiago, Chile*, Gecamin.

Simkus, R. & Dance, A. (1998). Tracking hardness and size: measuring and monitoring ROM ore properties at Highland Valley Copper. *Proceedings: Mine to Mill – 98, 11-14 October 1998 Brisbane, Australia* (pp. 113-119). The Australasian Institute of Mining and Metallurgy, Melbourne.

Tran, K.C. and Evans, M. (2001). Intelligent instruments (12) for process control of raw materials in the basic industries. *2001: A Mining Odyssey – SME Annual Meeting, February 26-28, Denver, Colorado* (pp. 1-6). Preprint 01-34.