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Innovative sampling solutions for the mining industry

Maurice Wicks
IMP Group Pty Ltd, PO Box 1183, Osborne Park, Perth WA 6916, Australia. E-mail: maurice@impgroup.com.au

While online analytical systems are continuously improving, the mine site laboratory remains the benchmark. The laboratory is expected to produce high quality information, so the sampling process is critical. Process managers demand high quality, timely produced results. Mine managers and shareholders are demanding that the process, analytical results and productivity is optimized to maximize return on investment. These demands conflict with traditional sampling and laboratory routines which are frequently slow, labour intensive and commonly involve potentially dangerous, not to mention unscientific methods and work practices. For more than a quarter of a century, IMP has teamed with partners and like-minded customers, to challenge conventional sample collection and processing techniques. In doing so innovative automated sampling and laboratory solutions have been developed for the mining industry. This paper introduces a selection of IMP's automated sampling and laboratory solutions by presenting project examples including a time-based and a mass-based solution for iron ore lump and fines, powder sampling and analysis as well as a slurry sampling and analysis solution.

Introduction

Manual sampling methods and laboratories can involve unsafe working practices, are prone to error and produce historical results rather than timely results. Thus, many modern mines have automated the sampling and laboratory processes, or are in the process of considering automating the laboratory. An automated sampling/laboratory, which usually involves the use of robots and/or utilizes the latest technologies offer the following advantages:

- Improved health and safety as workers are not exposed to dust, repetitive lifting and noise;
- Provides higher quality data as the possibility of human error, such as the switching of sample identification tags and operator bias, is minimized as all samples are handled in exactly the same way improving the overall quality of data produced;
- Increased productivity. Less people are required to operate an automated laboratory than a traditional laboratory. Additionally, automation reduces the need for boring and repetitive tasks to be completed manually – which inevitably leads to mistakes and time wasted due to re-working of samples;
- Laboratory operating costs are more easily managed and automated laboratories usually cost less to operate than traditional laboratories; and
- Sample throughput is considerably quicker. This is because samples are processed sequentially rather than in batches.

However, while laboratory automaton can produce great results in a timely fashion, without a representative sample, that is collected and analysed in a timely way, the laboratory efforts are meaningless. Thus, focus must be on "End to End" solutions – from the point of sampling to final analysis. In doing so IMP has pioneered and/or been involved with the several sampling and associated laboratory innovations, summarized below.

Discussion – Case Studies

Innovative Port Laboratories

IMP's customers include the world's leading Iron Ore exporters. In Australia and South Africa IMP has designed and built several integrated port laboratories where the entire process – from sampling to analysis and cargo certification is fully automated. Thus, all procedures which include sample collection, sample transport, sample drying, sample splitting, particle size determination, moisture determination and chemical analysis are automated. Bulk composite samples can be produced and sampling can be mass or time based.

Each sampling and laboratory solution is tailored to the customer's technical and budgetary requirements while always complying with the relevant ISO standard, usually ISO3082. An Iron Ore port laboratory is illustrative. Frequently when sampling iron ore, primary cuts of up to one ton are taken. This cut is passed through secondary (and often tertiary) cutters to achieve a constant mass division from each primary cut. This constant mass division is typically achieved in one of two ways; this can be performed by collecting the entire cut (which is of a variable mass) in a weigh hopper and using this weight to calculate the size and number of increments that need to be taken from this cut to achieve the constant mass sample output which is sent to the automated laboratory, alternatively, the flow rate of the variable mass cut, onto the sample cutter feeder, is controlled, the sample "slug" length is determined (using belt weightometers together with the belt speed) and using this information the cutter speed and cut frequency is set to achieve the desired constant mass output sample to be sent to the automated laboratory. A portion representing each primary cut is transported automatically to the robotic laboratory via a conveyor system or using IMP's "Monorail Sample Transport System". These aliquots are composited then divided into sub-lots. Particle size analyses and moisture are determined on each sub-lot. Some clients carry out sub-lot chemical analysis while others analyze the final composite.

At the 2014 Sampling Conference in Perth RioTinto presented a paper that discussed the building, design and operation of their new Cape Lambert Iron Ore Port Facility (CLB)[1]. This facility is the world's largest automated iron ore port laboratory (Figures 1–2). The turnkey solution comprises of a fully automated sampling and analysis system that uses time-based sampling methodology. The facility has the ability to sample iron ore products "of medium quality variation as defined in ISO 3082 (ISO, 2009)." [1]. In this instance, there was a need to design a sampling procedure that would collect a representative sample at the required precision and provide full load-port analysis while cargo was being loaded at flow rates of between "6000 t/h to 10 440 t/h. This sampling procedure was

Figure 1. The three components of the Cape Lambert Port B automated sampling and analysis facility [1].

designed in terms of the ISO 3082 specification as a guideline for aspects such as the minimum amount of cuts to be taken from a primary cut and acceptable precision limits for sampling, sample preparation and measurement. Various TOS components were also used in the design of aspects of the sampling solution such as the maximum cutter speed of 0.6m/s, orientation of cutting plane normal to the material flow, minimum cutter aperture of 3x max particle size, distance of cutter park position from material flow to ensure no cross contamination. The sampling approach is to proportionally extend primary increments (of varying mass relative to ship-loading rate) to a standard length using variable speed aero-belt conveyor systems. This enables a fixed number of secondary cuts to be achieved for all primary increment masses and to be delivered to the automated cell. The cell is required to be capable of concurrently processing four individual shipments, each containing multiple cargoes." [1]. To achieve the specified scope, a robotic sample preparation system was designed which incorporates two robots working together on a linear track in effect creating a horizontal sampling tower.

Detailed in this paper [1], during commissioning a bulk sampling campaign was carried out to externally verify all results from the CLB automated laboratory and to check for potential bias in the sample preparation through the automated cell. In addition to this, in order to get an assessment of the sampling, division and measurement precision, the overall precision for this CLB laboratory was compared to a nearby laboratory that processes the same products with similar quality variability. "Precisions are calculated as per ISO 3085 (ISO, 2002), and, in all cases, the precision for each element exceeds the requirements of the standard" [1]. An extract from these results showed the β_{SPM} for Fe % at the CLB sampling system to be 0.102% compared to 0.138% calculated for the other laboratory. Although both systems exceeded the requirements of the ISO 3082 standard and the calculated β_M was only slightly better at the CLB laboratory compared to the other laboratory, the author of this paper discussed that "what is clearly evident at the CLB automated cell are superior precisions for sample preparation and also sampling itself."[1]. Space does not permit to explain the system fully, but the authors conclude that while the challenges of implementing this innovative project were significant, "the success of this system is clearly demonstrated by the improvement in the sampling precision, reliability of the sampling components and quality of the results produced by the system, all of which have been verified externally."[1].

Integrated Automated Mine Site Sampling and laboratory Systems

Increasingly, mine sites require fast timely information that will allow the process to be optimized. While tremendous progress has been made with online analytical systems, sampling stations and onsite laboratories still provide the benchmark for analysis. IMP has risen to the challenge by integrating sampling stations with robotic automated laboratories. In several instances IMP has done so with the aim to determine particle size, and to perform automated chemical analysis along with moisture and density testing. Samples can also be prepared for manual jigging tests and other physical tests (Figure 3). As the entire end to end system is close to the sample collection point and being fully automated, precise results can be transmitted immediately via IMP's "Control Track Lims" software to the

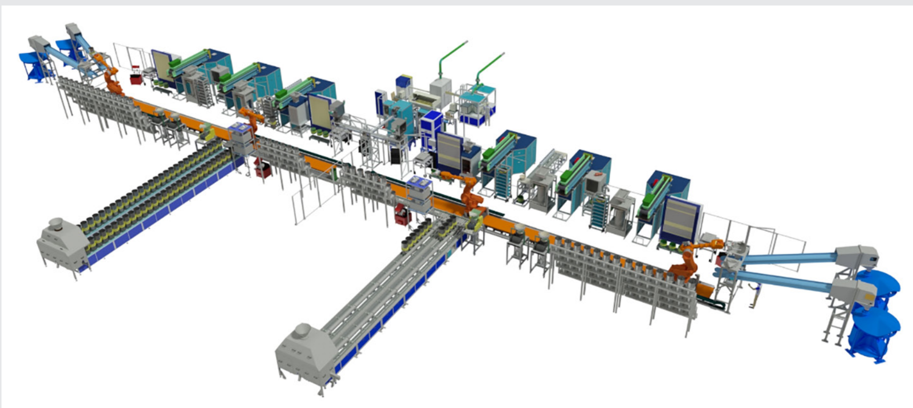

Figure 2. Schematic of dual sample preparation cells, at RioTinto's Cape Lambert Port B (CLB) Laboratory, showing an equipment layout for a "horizontal" sampling, division and measurement system.

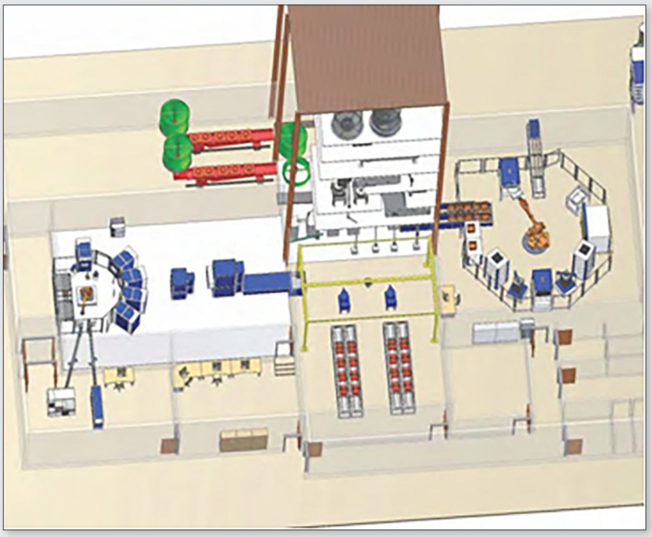

Figure 3. Automated sampling integrated with an automated laboratory.

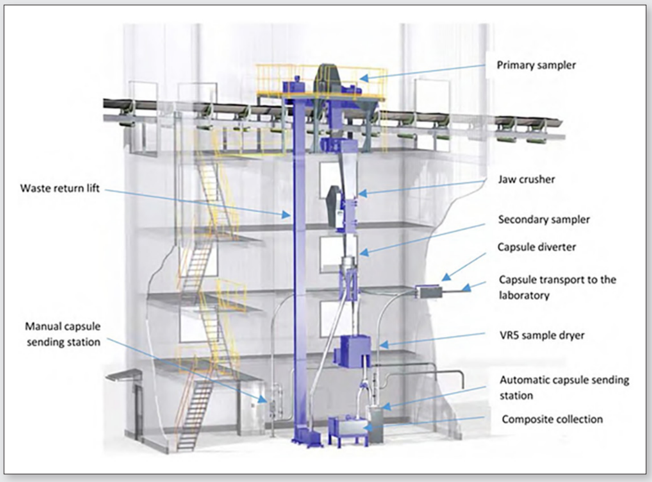

Figure 4. Integrated Sampling Station.

plant control system: allowing the complete "end to end" analytical process to be optimized – transforming the laboratory into a true "Process Optimization Centre".

In another instance, as shown in Figure 4, sample splitting, crushing and drying occurs in the sample station. This allows a dry aliquot to be sent directly to the laboratory using a pneumatic capsule transport system. This is made possible because the entire drying process happens in a few minutes, integrated into the sampling tower. This is achieved using an innovative "IMP vibro dryer", which combines infrared drying with a vibrating oil heated base-plate. As the base-plate vibrates the sample is forced to move in a circular direction. This motion releases trapped moisture while continually exposing fresh surfaces to the infrared lamps – which allows rapid drying to occur. A built-in pyrometer monitors the surface temperature and controls the heat within the predefined limits. This bespoke drying system ensures that samples are dried rapidly without compromising integrity. After drying, the direction of vibration is changed which discharges the sample. The discharged sample is automatically placed into a capsule and sent directly to the laboratory via an air tube system. After the sample is received in the laboratory, it is automatically removed from the capsule for further processing.

Integrated Automated Slurry Sampling and Laboratory Systems

Historically, slurry samples are collected automatically into a bucket and manually transferred to the laboratory. In these instances it is typical for automated slurry stream samplers to direct the sample through one or more Vezin splitters so eventually a correct amount of slurry sample accumulates in a bucket. Normally this occurs once each shift, or a pre-determined number of times during the day but usually two or three samples per 24 hour period are collected in the bucket (Figure 5). Once or twice a day the bucket is transported manually to the laboratory which may be some distance from the sampling point. Therefore it is not uncommon for the first sample to reach the laboratory some hours (often 24 hours) after accumulation of the sample commenced. Because of the manual filter-pressing, drying and sample preparation, typical analysis processing times are 1–2 days for the first composite. These systems may provide high quality data for metal-accounting and good statistics on plant performance but offer no added value to the immediate

Figure 5. Typical bucket sampling system with manual filter presses.

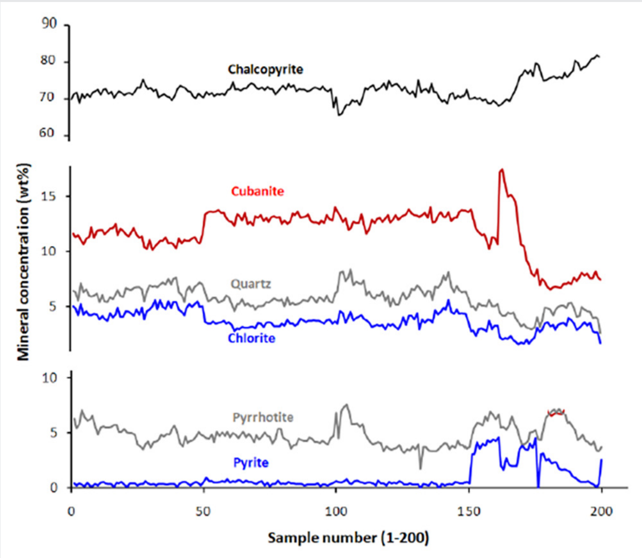

Figure 6. Variation in the concentration of the main mineral phases using XRD.

running of the process. It is because of this that laboratories are frequently seen as an overhead rather than a valued Process Optimization Centre.

IMP has responded to this challenge by developing an automated slurry sampling system and laboratory. By employing a novel solution to transport the slurry aliquots from the various plant sampling points to the laboratory results can be available in minutes rather than hours or days. For example, from time of sampling to getting a finished result, automated X-ray fluorescence and/or mineralogical data can be available in around 20 minutes. Automated fire assay results, using IMP's patented Fast (FIFA) inline fire assay techniques, can be available in under an hour. Thus, many more samples can be processed than in a manual system described above – meaning the plant's processes can be optimized because of the timely data received from the laboratory or the now valued "Process Optimization Centre".

To achieve these analytical times slurry aliquots are automatically filtered and prepared using a robotic sample cell. If required, the liquor can also be captured for analysis. An alternative to this system is to dry the slurry by "trickle feeding" onto a continuous belt infrared drier. When dried the sample is scrapped off the belt and fed into

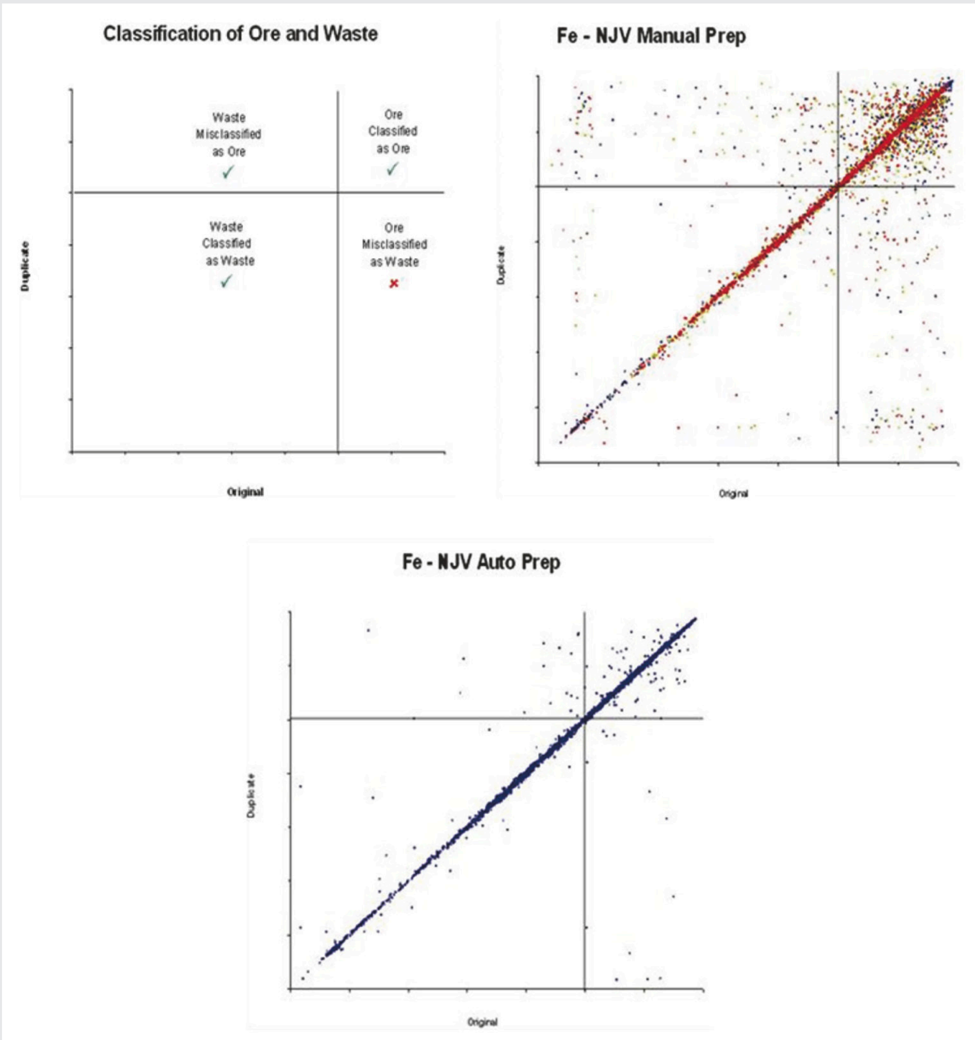

Figure 7. Results from BHPBilliton.

a capsule for transporting to the laboratory. It is essential that the samplers (typically cross-stream) comply with good sampling practice such as cutting the whole stream at 90° and not just part of it. The vezin type cutters should also be radial and cut the full stream at 90° and the slot width of the cutter should be at least three times the nominal particle top size of the solids.

The value of rapid analysis was demonstrated by an experiment undertaken by a copper mine in Australia. During these tests the customer took 200 samples over 32 hours from the concentrator, to replicate an automated rapid "End to End" sampling/analytical system. For the first 150 samples the mineralogy did not change but around the 150 sample mark results showed that the pyrite values had increased (Figure 6). If the operators had known that abnormal proportions of pyrite were floating, a depressant could have been used to benefit the operation. In this case it is predicated that an extra 0.25% of copper could have been extracted, over the 32 hours, which is significant when applied to the life of the mine.

Quality – A Key Benefit of End to End Automation

RioTinto identified significant improvements to precision when using an automatic end to end system that incorporated a time-based sampling methodology with a fully automated analytical facility. This improvement in quality is supported by BHP. At a conference in 2011 BHP Iron Ore gave a presentation [2] that compared the analytical results obtained using an automated system and a manual system. When building the new Mt Whaleback automated laboratory in Newman, Western Australia, duplicates were run through the manual laboratory versus the automated laboratory. Duplicates were used to classify ore into four groups based on a cut-off grade:

- ore classified as ore – a good outcome;
- waste classified as waste – a good outcome;
- waste misclassified as ore – a marginally acceptable outcome as it is a dilution of the ore body and;
- ore misclassified as waste – the worst possible outcome, the equivalent of throwing money away!

Automated preparation of samples clearly demonstrates an improvement in precision and a corresponding reduction in ore being incorrectly misclassified as waste. The difference is dramatic and the questions have to be asked – how much did the manual analytical system really cost in lost revenues? How does one quantify the revenue lost to a company because ore was classified as waste?

In addition to these analytical improvements BHP Billiton were able to quantify a significant reduction in occupational health and safety hazards as workers were not exposed to as many repetitive tasks, heavy lifting and were exposed to less dust and noise level than when working in conventional/manual sampling stations laboratories.

Conclusion

Automating the entire process, from sampling to analysis, results in the fastest possible turnaround times of precise analytical data. This turns the laboratory into a valued process tool, or Process Optimization Centre as data becomes available in minutes rather than hours or days. Quicker results enable production personnel to improve plant control resulting in increased plant efficiencies and improved beneficiation.

Additionally, IMP's customers have published results confirming that with "End to End" automation systems the data obtained improves significantly. This impacts the bottom line, improves decision making, and has the added advantage of improving occupational health and safety.

Finally, automated "End to End" sampling analytical systems are not confined to one particular commodity, laboratory or sample form. Samples can be bulk or large samples, have varying particle sizes, be solid or in the form of a slurry. Across the industries, from aluminum to zinc, IMP has successfully implemented innovative automated "End to End" sampling analytical solutions for ports, at the mine and in mineral processing plants.

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