The evolution of the mechanically agitated hopper in Anglo American Platinum

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For Anglo American Platinum (AAP) to reach their burning ambition goal of doubling the Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) by 2023, sites are required to adopt an alternative approach to improve representativeness of metal accounting samples given the increase in grind and throughput demand. The success of optimization projects will rely heavily on metal accounting data being accurate so that improvements declared are based on sound samples and assay measurements. The 60 litre mechanically agitated hopper (MAH) was initially developed and ratified in order to overcome particle segregation evident in the 20-litre conventional, compressed air-agitated hoppers of vezin type sampling systems. A sustained plant accountability performance within the range of 95-105% was realized due to the correction of the previously overstated feed grade by means of a more representative sample. Pierre Gy's rule of thumb of 30 increments per sampling campaign has not been proven and documented for the Platinum Group Metals (PGM) industry. The MAH however with additional volume capacity allows for flexibility to increase the primary sampling increments per shift from ± 32 to ± 96 to cater for process variability (thereby reducing distributional heterogeneity) without increasing the overall resulting final sample mass. Additional technology and larger 110/220 litre capacity hoppers have been deployed. Enhancements include a wash water and drainage system, an improved trash screen design and high/low hopper level sensors. The MAH principle of operation has also been expanded to cater for a double (3-drive) stage sampling system as well as a triple (5-drive) stage sampling system. It is believed that the latest MAH design will satisfy the Theory of Sampling principles and therefore a motivation for an industrial roll out of the innovation within AAP is underway.

Introduction

A concentrator plant was under-accounting in terms of 4T (Platinum, Palladium, Rhodium and Gold) content in 2015. It was proven that the main reason for the consistent under-accounting was due to the correct sub-sampling of finer, high grade particles and the bias low sub-sampling of the coarser, lower grade particles present in the feed slurry streams into the plant[1].

Test work was conducted, and this involved a series of experimental studies designed to gain an understanding of the presence and extent of particle segregation in the intermediate hopper of a typical UG2 feed vezin sampling system. A total of three stages of test work were conducted, including vezin credibility and chronological sub-sample tests on a re-designed hopper nozzle and a mechanically agitated hopper.

The tests on sub-sampling of the feed material from the intermediate hopper performed on the original sampling arrangement (Stage 1) demonstrated that segregation occurs in the intermediate hopper of the feed sampling system. A consistent bias was observed between the reject and official samples with the official samples being bias low in coarse particles and being higher in 4T grade than the reject samples. By means of a paired t-test, the calculated bias for % mass retained was deemed significant at the 95% confidence level. This outcome together with the assay by size analysis performed confirmed the under-accounting scenario[1].

It is believed that the particle segregation which was so evident in the baseline test was significantly reduced with the incorporation of the alternative nozzle design and mechanical agitation. Compressed air agitation alone does not seem to keep all particles of varying size and density in suspension in the intermediate hopper.

The benefits of the mechanically agitated hopper with alternate nozzle design configuration were realized by the concentrator plant and this provided the ideal business case to replace current intermediate hoppers on metal accounting sampling points within concentrator plants with mechanically agitated hoppers to align with current best sampling practice for Anglo American Platinum.

The added benefits of the mechanically agitated hopper include:

- Accommodating sites experiencing issues with grind. With the mechanically agitated hopper, all particles in the primary sample have the same chance to become part of the overall sample i.e., representativeness is ensured. This can be achieved by increasing the trash screen aperture size on top of the hopper as well as the hopper outlet to cater for larger particle sizes as a result of poor grind. Currently, particle build-up is sometimes evident on the hopper screens and are most likely not incorporated in the final sample;

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- Pierre Gy's rule of thumb of 30 increments[2] per sampling campaign has not been proven and documented for the PGM industry. The MAH however with additional volume capacity allows for flexibility to increase the primary sampling increments per shift from ± 32 to ± 96 to cater for process variability (thereby reducing distributional heterogeneity) without increasing the overall resulting final sample mass. Periodic errors within the process can be factored into the metal accounting to ensure better representability. The process variability can further be assessed via the construction and interpretation of variograms.

In order to reach the burning ambition goal of doubling the EBITDA by 2023, the Anglo American Platinum sites need to adopt an alternative approach to further improve representability of their metal accounting samples. A number of improvement initiatives have thus been facilitated by means of P101 projects. P101 is an Anglo American's asset transformation programme aimed at accomplishing and re-defining industry leading performance in the focus areas to deliver the absolute maximum value from the processing operations. The success of P101 projects will rely heavily on metal accounting data being as accurate so that improvements declared are based on sound samples and assay measurements – the ability to measure better will allow for proactive management. The accountability for a plant is used as a risk management tool to identify issues with mass measurement, plant sampling and analytical tasks. Plant accountabilities being within acceptable ranges will also provide further assurance that other plant performance parameters such as recovery are accurate i.e., it does not make sense to have a recovery of 90% with an accountability of 85% or 140%.

The initial cost or capital outlay for the mechanically agitated hopper is estimated to be in the region of 200 000 ZAR per sampling point. As an illustration, given that two metal accounting points exist, the risk of a parameter such of recovery being inaccurate by ±1% over a 12-month period for five years amounts to a Net Present Value (NPV) of ±244 million ZAR with a payback period of 2 days. It was therefore recommended that the mechanically agitated hoppers be implemented across all metal accounting sampling points to mitigate risk further. Through research, considerable focus has been placed on eliminating particle segregation during primary and secondary stages of sampling by applying rules for Theory of Sampling and sampling correctness[4], and sample preparation through the correct design of automated and mechanical samplers, and the determination of minimum sample size required. Currently though there is still limited knowledge available regarding segregation of particles in the intermediate hopper of the Vezin sampling system configuration. The success of this work and learnings is being strategically extrapolated to all processing plants that treat and sample material with characteristics that involve grade by particle size associations.

Technology modifications and alignment to growing business requirements

The novel idea to collect multiple primary increments over a period of time in a day tank and then sub-sample using a secondary sampler was first established at an Anglo-American Platinum Smelter. It was through this initiative that the proof of concept was trailed and tested to allow for further application to other processing sites. As previously mentioned, in order to resolve 4T accountability issues at a concentrator plant, an extension of this novel idea by means of a MAH design was proposed, fabricated, and implemented. Through planned test work, it was shown that collecting more primary increments over a period of time in a hopper and introducing mechanical agitation significantly reduced particle segregation allowing for a more representative sample to that of the bulk stream being sampled to be realized. Following the first design of the MAH, a number of improvements and enhancements as shown in Figure 1 below have been incorporated as a result of collaboration with site personnel and troubleshooting of operational related scenarios.

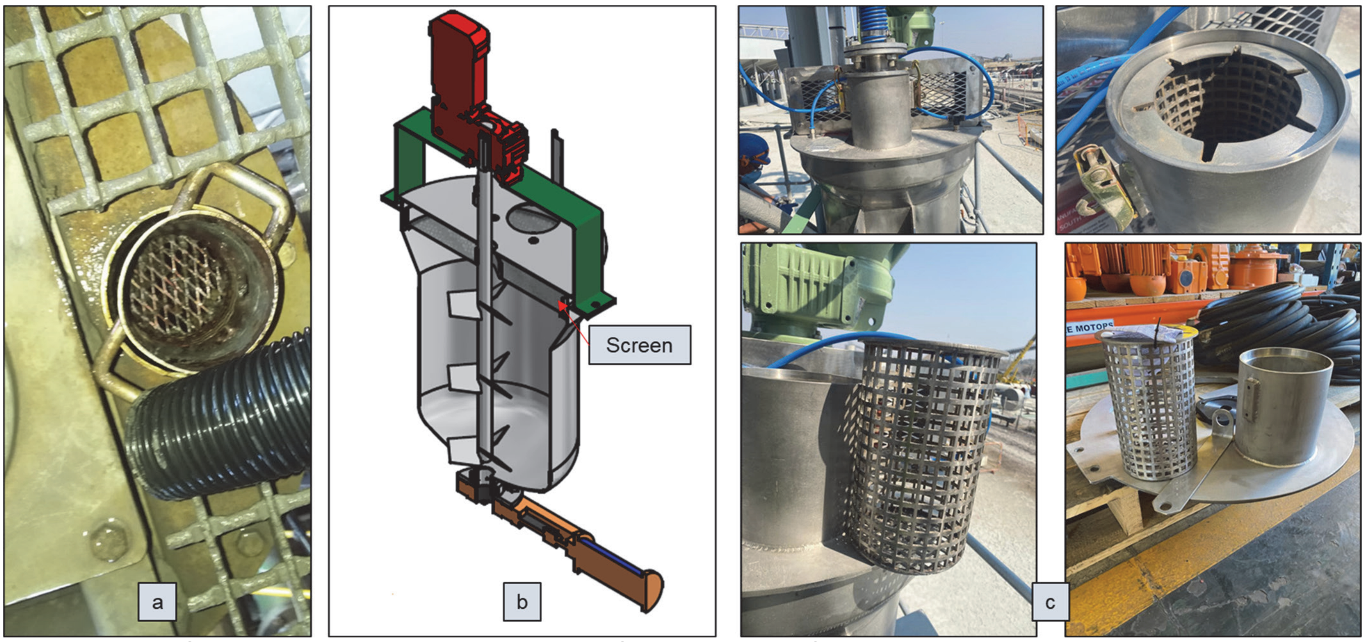

Figure 1. Trash Screen Design – a. Day Tank; b. MAH Original; c. MAH Current.

These include the re-design of the trash screen at the inlet to the MAH for easier removal, inclusion of wash water and a drainage system for housekeeping purposes, larger MAH capacities to cater for increased volumetric flows and hence extension of a double stage sampling system to that of a triple stage sampling system, and engineering controls and interlocks pertaining to level control on the MAH to allow for process variability. The sub-sections below provide further background and detail to the evolution of the MAH design and alignment to the ever-growing business needs in line with the arrival of the fourth industrial revolution.

Proof of concept – Day tank Sampling at a smelter

The original idea of collecting multiple, primary increments over a period of time and then sub-sampling through a secondary sampler stemmed from an existing sampling system design and concerns within the Anglo-American Platinum Smelter environment. This sampler design consisted of a primary Vezin sampler, a conventional, air-agitated, intermediate hopper with a float (to control the hopper level) and a secondary sampler with a rotating tube and two stationary cutters to generate an A and B sample[5]. Material would then be sampled per batch as it is transferred from a homogenising tank to a weigh tank on load cells. The sample % solids was then applied to the weigh tank wet mass to obtain a dry mass for the individual batch. All dry batch samples were then prepared in a weighted composite manner in order to obtain a daily lot sample for Platinum Group Metal (PGM) analysis purposes. The sampling and sample preparation of this material was claimed as being labour intensive and time consuming. It was therefore queried whether it would be possible to collect only one sample per day for this material.

Previous investigations had indicated that collecting only one sample from an individual batch and applying the % solids and grade to all the related batch transfers for the day would cause a small error for dry mass (0.17%) but a more substantial error for grade and thus platinum ounces (-2.12%)[5]. The current sampling system design would therefore have to be modified if the workload around sampling and sample preparation were to be reduced. The use of a day tank was then suggested with caution towards careful design of the tank capacity to prevent overflow and thus loss of material for the sampling period as well as to be mindful of settling of solids of varying size and density. If no flushing or water addition is applied and the number of primary increments per batch is reduced (to the minimum of 30 as per Gy's rule of thumb[2]), then all the primary increments for the various batch transfers of the day can be collected in a day tank. At the end of the metal accounting 24-hour period, the contents of the day tank can be sampled with a secondary sampler to generate an A and B sample. It was necessary to investigate and develop a new sampling system that would conform to the Theory of Sampling principles but also be effective (time, resources, cost) in reducing the quantum of samples collected for further sample preparation and allow for a representative sample for metal accounting purposes[6]. A $1m^3$ day tank design as seen in Figure 2 was then proposed, fabricated, and installed in parallel to the batch sampling system at the smelter.

Figure 2. Day Tank – a. Oval Tank Design; b. Off Centre Agitator inside Day Tank; c. Sampler Inspection/Safety Grid.

The oval shaped tank design was suggested due to the limited footprint available on site and an off centred agitator had to be installed due to this limitation as well. The new design also catered for safe operation and maintenance of the sampling system and included engineering controls like safety inspection screens for separation of people from moving machinery. Gy's theory of sampling of particulate materials is acknowledged and widespread through various applications. On the contrary, however, Gy's theory of distributional heterogeneity of a material, detailing segregation effects is rarely discussed and is usually ignored in sampling calculations[3]. The day tank design thus included a trash screen as well as an agitator to keep the primary increments homogenized and minimize particle segregation. Through test work and ratification of the new design, it was concluded that the new sampling design provided a daily sample which was representative and unbiased. The new design was then implemented on similar streams at the Smelter.

The MAH – The double stage sampling design and principle of operation

Depending on the volumetric flow rates presented to the primary sampler, the actual volume of the primary increment, the need to maximise on the ±96 primary increments in the MAH, having a fixed reduction ratio (2.5%) of the primary increment presented to the secondary sampler and the need to obtain a 15L sample at the end of a given shift, a single 60L or 110L MAH design has proven to be sufficient in holding a number of primary increments without compromising the primary sample itself. In general, a primary linear-cross stream sampler, MAH and secondary vezin sampler combination can adequately provide a representative sample for metal accounting purposes. The 3-stage sampling system consists of a 3-drive panel. The sampling system can be operated in a manual, automatic or remote (via Programmable Logic Calculator (PLC)) mode. The primary and secondary samplers are driven by a direct on-line electric motor with a reduction gearbox whilst the MAH is powered by a variable speed drive. The primary sampler includes two proximity switches to stop the cutter head outside the bulk stream being sampled once a primary increment is taken. The MAH design as per Figure 3 below includes two level sensors for high and low level in order to compensate for volumetric flow surges. Low level is defined as 30% of the hopper full (effective volume including agitator and internal baffles) capacity and high level (high level sensor is adjustable if need be) is defined as 90% of the hopper full (effective volume including agitator and internal baffles) capacity. The formulation of the 30% MAH level is to keep particles in slurry suspension and minimize residual solids build up over time.

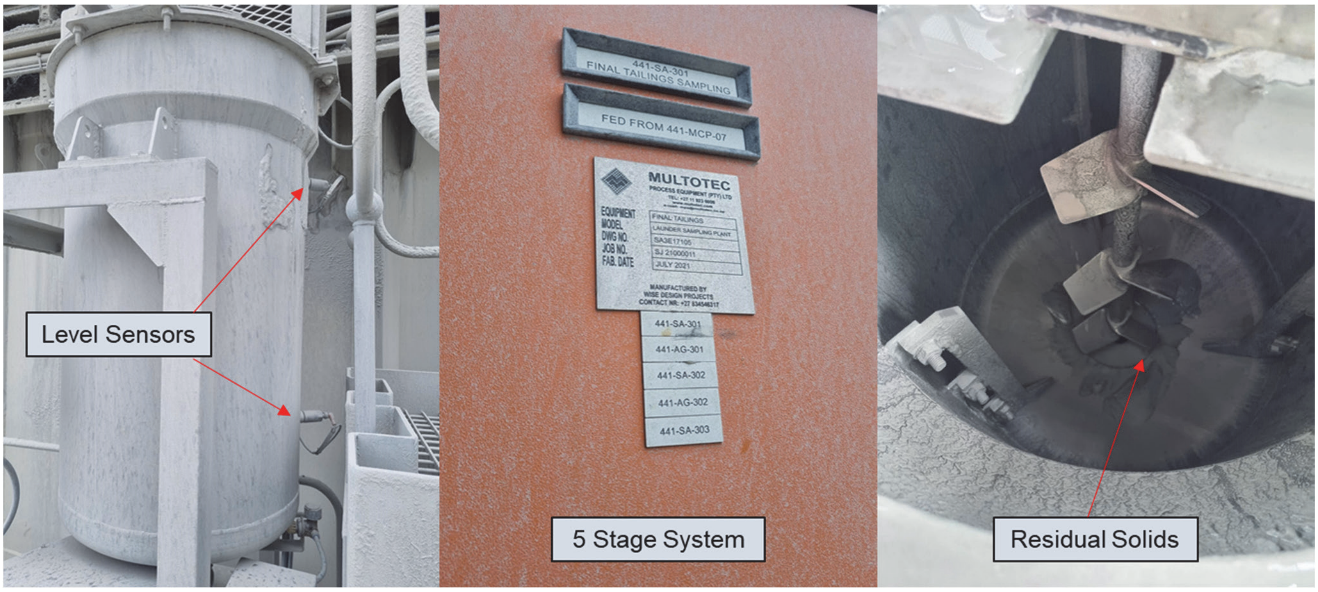

Figure 3. MAH – Internal and External Views.

It is vital during commissioning of the MAH that the impellors on the agitator shaft are adjusted accordingly to always ensure one impellor is positioned in the low-level region of 30% but slightly above the hopper discharge point. The MAH comprises an actuated valve at the base of the hopper which is interlocked with the primary increment counter to open and close accordingly thereby initiating secondary sub-sampling or not. At the base of the hopper, an air blowing nozzle is also incorporated together with an air pressure regulator (should be set to minimum requirement as per valve design or application for the MAH). The agitator with the MAH runs continuously to ensure the material contained within the hopper is homogenized at all times. There are a number of engineering interlocks and control features in place to cater for instrument failure (for example, fail safe position for actuated valve is set to open) as well as the principle of operation of the MAH.

The sampling system is designed to stop and indicate a fault on the control panel if any circuit breaker trips on overload however the sampling system will continue to operate and will only show a VSD fault when the VSD trips. If for any reason there is a loss of power to the sampling system and the primary sampler cutter head is not located in the park position, the motor will start immediately and drive the cutter head to one of the two park positions. This has been factored in to prevent the cutter head from being stuck in the bulk stream after a power failure. A sampling operator in the field may empty the system of material at any time and automate flushing of the sampling system by means of pressing a pushbutton in the vicinity of the sampling system.

In summary, taking into account the latest additions to the design and operation of the MAH, the control philosophy typically adopted is as follows when the system is run in automatic mode:

1. A primary cutting interval will be pre-determined and set on the timer within the control panel.
2. A counter as per Figure 4 will be set according to the number of primary increments one would like to collect in the MAH.

Figure 4. MAH – Primary Increment Counter(s).

3. The primary sampler will be parked outside the bulk stream (determined by proximity switches).
4. The proximity switch is activated by a target plate in the park position.
5. The agitator of the MAH will start and continue to run.
6. The secondary sampler will remain stationery (cutters parked outside the stream to be sampled).
7. The primary sampler will take a single increment at the time intervals indicated as per step 1 above. A “bucket full” timer will then start to run upon the first primary increment being taken.
8. The primary increment from step 7 above will be deposited into the MAH.
9. The air to the hopper will be active and the actuated valve at the base of the MAH will be in a closed position.
10. Steps 7 and 8 will continue until the number of primary increments as per counter setting has been reached. However, if the 90% (high level sensor) is reach before this, the hopper valve will open, the air to the hopper will be deactivated and sub-sampling will occur through the secondary sampler. As soon as the valve starts to open, the secondary sampler will start to operate to ensure no material is missed during the initial sub-sampling activity.
11. Sub-sampling of the collected primary increments will then continue via the secondary sampler until the MAH level reaches 30% (low level sensor). At this point, the hopper valve will close and the air to the hopper will be activated again. The secondary sampler will cease to operate after 5 seconds of the valve closing (delay built into the control philosophy again to avoid missing final sub-sampling of material still exiting the hopper). The counter will then reset to 0 and the counting begins again and so does steps 4-11.
12. Should the hopper valve position be open and the primary sampler cutting interval has elapsed, a provision for an interlock is in place to prevent the primary sampler from taking an increment whilst the hopper is in the process of draining to 30% level. However, if the primary sampler was in the process of taking an increment and the 90% increment has been reached, the control will allow for the primary increment to be taken and then proceed to park the primary sampler in park position outside the bulk stream.
13. This process is repeated for the time set on the “bucket full” timer after which it will then stop. The sampling operator then needs to acknowledge the end of shift/sampling campaign, the flushing of the sampling system (MAH and secondary sampler) with water can be activated by means of a push button in the field. All of the residual solids within the system is then given an equal opportunity to form part of the overall sample.
14. A push button located in the field to manually wash or flush the automated wash water system and reset the “bucket full” timer at the same time will activate the wash water system in the MAH whilst immediately resetting the “bucket full” timer. When this button is activated, the MAH will start to drain. A timer will be activated at the 30% full hopper level whilst the MAH will drain, and the secondary sampler is operating. When this timer has reached its setpoint calculated as the time it will take for the hopper to drain from 30% to empty, the wash water will be activated while the MAH valve stays in the open position. The secondary sampler will run continuously so both the MAH and secondary sampler are washed together. The wash water will then continue with the time set on another timer. When this time has elapsed, the wash water will stop, the MAH valve will close, and the secondary sampler will stop. During this wash time, the primary sampler will not be able to take any primary increments.

The Adaption of the double stage sampling design to a triple stage sampling design

For the more extreme volumetric flow rates, a single 60L or 110L MAH design has proven to be insufficient in holding a number of primary increments without limiting the number of primary increments being collected within the MAH and overflowing the MAH and sample collection buckets. This goes against the original objective of introducing collection of more frequent, multiple increments to cater for distributional heterogeneity. It was thus necessary to design for a 5 stage sampling system viz. primary sampler, primary MAH (250L), secondary sampler, secondary MAH (110L) and tertiary sampler as seen in Figure 5 below.

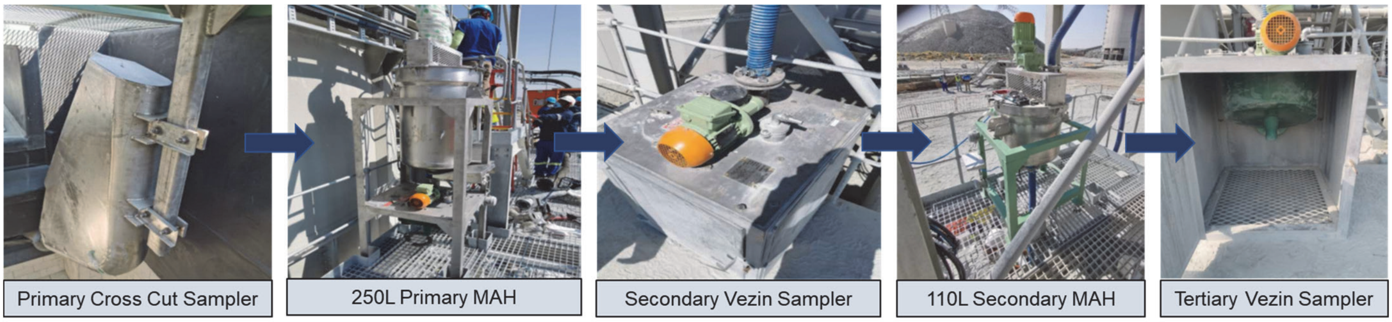

Figure 5. MAH – Triple Stage Sampling Design at a Anglo American Platinum Concentrator Plant.

The principle of operation remains the same as described previously. The washing cycle however will now cater for the primary MAH, secondary sampler, secondary MAH and tertiary sampler configuration.

Conclusion

The hypothesis that particle segregation is present in the intermediate hopper of a typical UG2 feed sampling system was confirmed at a concentrator plant[1,7]. The 4T accountability at this plant step changed to be within the acceptable limits after incorporation of the MAH and this performance has been sustainable. Pierre Gy's rule of thumb of 30 increments per sampling campaign has not been proven and documented for the PGM industry. The MAH with additional capacity allows for flexibility to reduce the sampling interval even further to cater for process variability and increase the number of the primary increments (thereby reducing distributional heterogeneity) being taken without increasing the resulting overall sample mass. Periodic errors within the process can be factored into the metal accounting, to ensure better representability. The process variability can further be assessed via the construction and interpretation of variograms. Currently, there are five Anglo-American Platinum concentrator plants operating with the MAH technology. It is envisaged that further enhancements will be incorporated into the MAH design as the mining industry as a whole embraces the arrival of the fourth industrial revolution.

Acknowledgments

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References

1. N. Naicker and V. Sibanda, "Particle Segregation associated with Sub-Sampling of Flotation Feed at a UG2 Concentrator", **118**, 57-64 (2017). http://dx.doi.org/10.17159/2411-9717/2018/v118n1a7

2. P.M. Gy, Sampling of Particulate Materials: Theory and Practice. 2nd Edition, Elsevier Science Ltd., Amsterdam, Netherlands (1982).

3. G.J. Lyman, "The Influence of Segregation of Particulates on Sampling Variance - The Question of Distributional Heterogeneity", 55, 95-112, International Journal of Mineral Processing (1998).

4. F. F. Pitard, Pierre Gy's Sampling Theory and Sampling Practice. 2nd Edition, CRC Press LLC, USA (1993).

5. E. Le Roux, "Evaluation of Slurry Mass and Volume for Day Tank", (Internal report, no. GEMA-2011-042), Johannesburg, South Africa (2011).

6. P. Qeqe, "Day Tank Sampler Ratification", (Internal report, no. GEMA-2015-016), Johannesburg, South Africa (2015).

7. N. Sukha, C. Kruger and W. Slabbert, "Implementation of an Alternative Sampling Protocol at a Typical UG2 Concentrator in South Africa", Sampling 2018 International Congress for Minerals Sampling, Lima, Peru (2018).