COMMISSIONING OF THE JAMESON CONCENTRATOR AT HUDBAY'S NEW BRITANNIA MILL

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ABSTRACT

Hudbay's New Britannia Mill commenced operation in July 2021, with commercial production declared in November 2021. The New Britannia Mill is a refurbishment project undertaken to maximise the value of the rich copper-gold ore within the Lalor deposit. The refurbishment included the addition of a new flotation module, the first Jameson Cell concentrator in North America and the second-ever constructed to complement the existing fully permitted CIP circuit. The ramp-up to date is tracking the Series 1A McNulty curve with copper and gold recoveries from the flotation circuit at +90% and +65%, respectively.

Copper and gold recoveries have been limited by the achievable concentrate grade, which has ranged from 10% to 20% copper depending on higher than forecasted variations in pyrite and talc content in the mill feed. Achieving this result required completing various rectification actions since commissioning to stabilise slurry feed rates, optimise the preflotation circuit, correct design issues in flotation ancillary systems and improve overall performance. At the time of writing, work within the flotation circuit is primarily directed to actions to stabilise the concentrate grade at 20% copper.

This paper describes the selection of the Jameson Concentrator and the subsequent commissioning journey of this component of the New Britannia Mill.

INTRODUCTION

Discovered in 2007, the Lalor deposit has grown into the largest VMS (Volcanic Massive Sulphide) deposit discovered to date in the Snow Lake camp. With commercial production commencing in 2014, the base metal-rich polymetallic ore lenses in the upper portions of the deposit have progressively been mined and processed through the existing Stall Mill to produce a precious metal-rich copper concentrate and a zinc concentrate. The sulfide mineralisation consists predominately of pyrite, sphalerite, chalcopyrite, and galena. The main gangue minerals are quartz, feldspars, chlorite, calcite, and talc. Gold occurs principally as fine (<55um) gold-silver-mercury alloys with microscopic gold inclusion in pyrite, a minor contributor to the gold balance. Free, sulfide association and non sulfide associated gold is evenly distributed in the flotation concentrate and contribute to flotation recovery averaging 50 to 60% to payable concentrates.

Identified in the initial discovery and expanded through extensive exploration, the Lalor deposit shifts from the pyrite-sphalerite dominant stacked lenses in the upper regions to chalcopyrite-gold dominant lenses with depth. To maximise the future extraction of gold from Lalor, Hudbay purchased the idled New Britannia Mill, complete with a fully permitted cyanide leach CIP circuit, in 2015. From acquisition, Hudbay extensively studied the most appropriate pathway to bring New Britannia Mill back into production to process the gold-rich ore lenses from Lalor. In 2019, the project was fully sanctioned, and construction began on the refurbishment of the New Britannia Mill with the addition of a new flotation module consisting of 100% Glencore Technology Jameson Cells (referred to as the Jameson Concentrator), inside the current building structure, ahead of the existing cyanide leach circuit and after the preflotation stage.

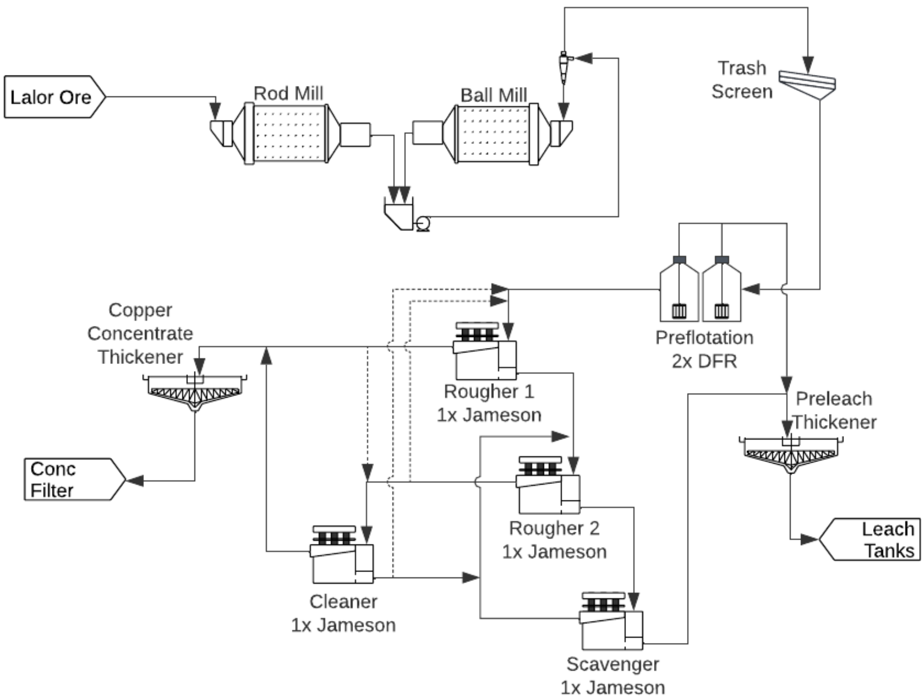

Figure 1: New Britannia Flotation Flowsheet

The Jameson Concentrator was designed to service several purposes within the New Britannia process.

1. Recover copper, gold, and silver into a payable concentrate
2. Stabilise cyanide leach feed grades to <0.10% copper and <2.5gpt gold

First ore was milled on 28th July 2021 on low copper grade (<0.15% copper) and processed directly through the leach circuit, achieving first gold on the 11th August 2021. The Jameson Concentrate received its first slurry on the 15th October 2021, with commercial production for the operation declared on the 20th November 2021.

FLOTATION DESIGN SELECTION PROCESS

When establishing the basis of design, it was identified that the ore composition of the lower region lenses is notably different from each other and that of the base metal lenses in the upper regions of Lalor. The two primary ore lenses designated as the feed source for the New Britannia Mill over the first ten years of operations displayed vastly different characteristics. Lens 25 contains low total sulfides (<10%), low copper (<0.5%) and high hydrophobic gangue (up to 10% Talc) content. Conversely, Lens 27 contains higher total sulfides (>10%), high copper (>1.5%) and low hydrophobic gangue (<2% Talc) content.

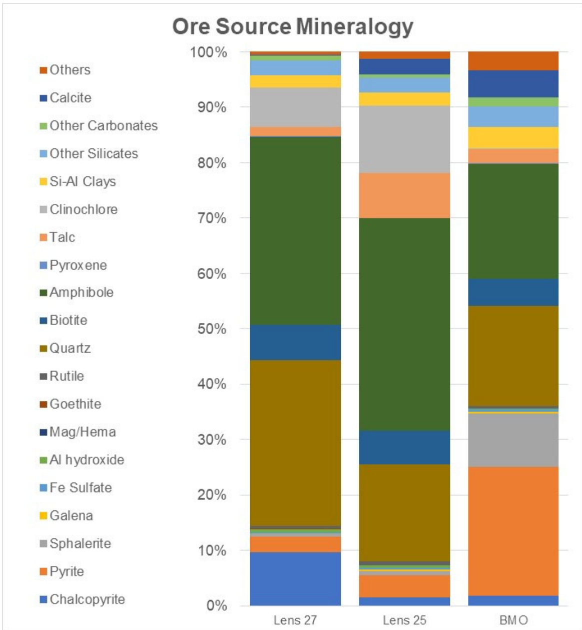

Figure 2: Lalor ore mineralogy of the Gold-Copper lenses (Lens 25 & 27) and the Base Metal Lenses (BMO)

Generally, the basis of design would rely on the mine plan and a nominal/max design feed grade of the principal target metal based on the grade and long term mine plan. For this project, copper was used as the principal metal for the basis of the flotation circuit design. Collaboration with the mining team to determine the basis of the mine plan highlighted two key constraints that would impact the ability of grade smoothing from mine to mill. First, the mining sequence would not always allow the parallel extraction of Lens 25 and Lens 27 ore on a shift-by-shift basis. Instead, the mining would most likely occur as an alternating sequence between extracting from the one lens while the next stope, within the other lens, was being prepared. This would result in the ore feed switching between lenses every four to five days. Secondly, the Snow Lake camp has excess mill capacity between the Stall and New Britannia Mill and is mine limited; this reduces the opportunity to stockpile and blend ahead of processing.

As shown in Figure 3, the average blended copper grade is ~1%, with the average grade varying from 0.20% for lens 25 to 1.80% for lens 27. Based on this grade variation in the long term mine plan, a nominal copper grade of 1.05% and a design copper grade of 2.50% were used for the basis of design. This significant variation in ore feed grade necessitated a flexible flotation module in design and operation.

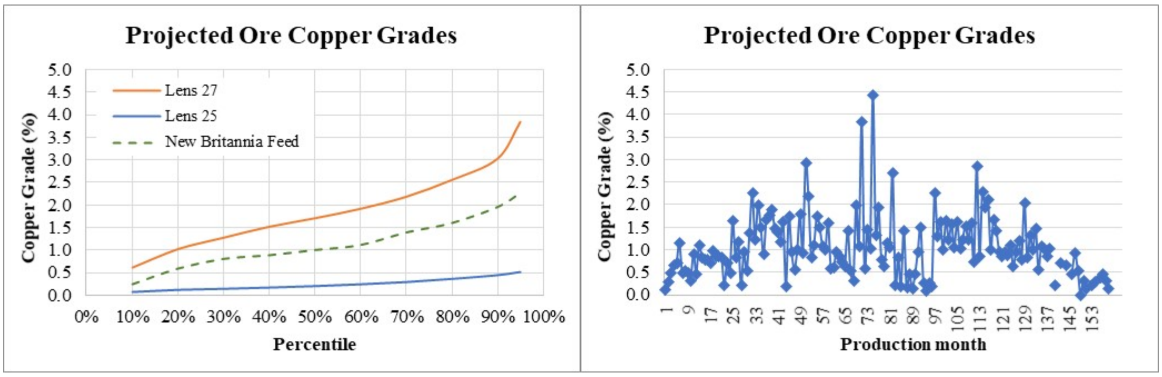

Figure 3: Project New Britannia copper feed grade distribution

The mining industry has a slow rate of new technology adoption, and when a new circuit is being designed, the common practice is to default to conventional mechanical cells. When the mechanical cell design was undertaken, particular attention was placed on adequately designing the cells to accommodate the wide range in feed grades that the circuit was required to handle. The problem that had to be addressed in the design was:

1. Minimised surface area to ensure froth stability when treating low-grade Lens 25 ore and high carrying rate to maximise froth recovery when treating high-grade Lens 27.
2. Eliminate redundant/standby equipment, e.g., no "swing" flotation cells that turn on or off based on the feed grade.

Based on these required design attributes, the Jameson Cell was investigated for integration with mechanical flotation cells due to its large carrying capacity range and tailings recycle mechanism that eliminated particle short-circuiting. Once the Jameson cell was modelled into the flowsheet, it was quickly realised that mechanical cells were not required, and all the required flotation stages could be achieved using Jameson cells. Therefore, the Jameson Concentrator was selected as the go forward technology selection for the new flotation module.

WHAT IS A JAMESON CONCENTRATOR?

The Jameson Concentrator is the concept of replacing all flotation stages with Jameson Cells. A Jameson Cell can perform multiple flotation stages within a single unit while being agnostic to residence time. This is achieved by replacing the mechanical agitator that facilitates the creation of bubbles by mixing all the fresh feed with a standard slurry pump and forcing the slurry through a restricted opening (slurry lens). This process creates a pressure drop that draws a controlled amount of air from the atmosphere to mix with the slurry, ultimately providing ~100% particle to bubble contact. By following this process, the Jameson Cell produces very fine bubbles evenly mixed with the particles to produce a high and consistent recovery rate. The Jameson Cell's high recovery rate through near 100% particle to bubble contact and no short-circuiting reduces the need for multiple cells in a flotation circuit. The natural aspiration removes the need for expensive compressors and blowers. This, in turn, reduces the circuit's overall CAPEX and OPEX and the circuit's footprint.

Applying the Jameson Concentrator methodology to the New Britannia Mill resulted in a change in flowsheet where 12 conventional cells were replaced with 4 Jameson Cells. This replacement resulted in a ~30% reduction of footprint and a height reduction of 3 m while allowing for future capacity expansion with an allocated space for an additional rougher cell. The benefits of the Jameson Cell, when applied to the New Britannia project, can be seen in Figure 4, which compares the mechanical cell circuit initial design for New Britannia with the equivalent Jameson Concentrator.

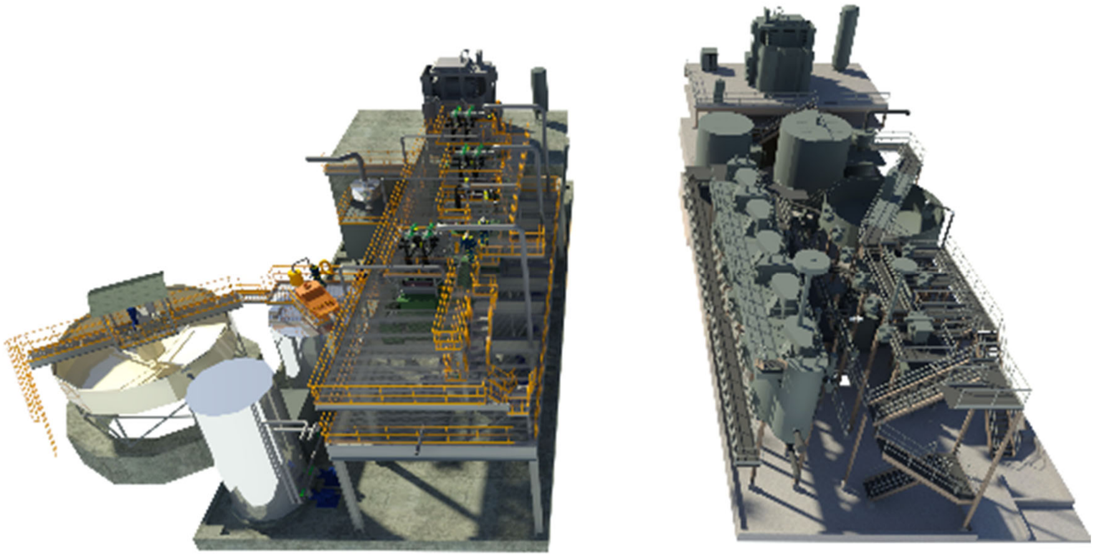

Figure 4: New Britannia Jameson Concentrator vs Mechanical Cell Design

NEW BRITANNIA COMMISSIONING

New Britannia processed the first ore on 28th July 2021, approximately 18 months after construction began. The ramp-up of the mill was remarkable for several notable events that the operational team overcame. This includes but is not limited to:

- Rod Mill shell liner bolt failure (+5 bolts per 24 hours) due to a change in the original liner package from a 3-bolt to a 2-bolt design.
- Inadequate building heating within the refurbed sectors resulting in frequent freeze events.
- Poor quality first fill CIP carbon resulting in high solution losses.
- Slurry short-circuiting within the cyanide destruction tanks limiting mill throughput.
- Delayed availability of the new Jameson Concentrator until October 2021 due to schedule refocus to achieve an "Early Gold" from the existing leach circuit ahead of the flotation module completion.

The performance was compared to the McNulty series to benchmark the ramp-up for the New Britannia Mill. This series describes a commissioning ramp-up utilising mature technology, proven equipment sizes, thorough testing, and good management (McNulty, 2014). As shown in Figure 5, the New Britannia Mill has achieved a best-in-class ramp-up despite the obstacles outlined above. The success of the ramp-up to date can be attributed to the operational team. By adopting a constraint management approach, the team identified the critical constraints, exploited the construction teams still present on-site to rectify the issue, and repeated the process until a manageable operational routine was established.

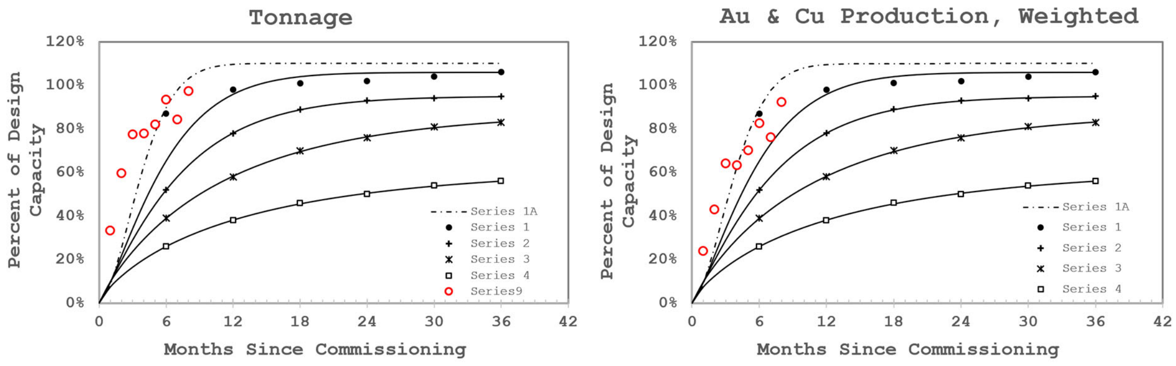

Figure 5: New Britannia ramp-up timeline against the benchmark ramp-up curves (McNulty, 2014)

An excellent example of this practice was the management of the rod mill liner bolt failures. Initially, the mill would not operate for more than a shift before an unplanned downtime was triggered due to broken liner bolts. This stop-start process significantly impacted the stability of the downstream processes. By working closely with the vendor, it was identified that the liner redesign placed an excessive load on the bolts. Additionally, the new bolts would lose tension immediately after mill restart and weaken due to excessive liner movement causing the subsequent breakage failure. By switching the maintenance strategy while waiting for the replacement liner-set to arrive at a fixed downtime period once per week, each bolt was re-torqued to the manufacturer's specific tension. This practice allowed any weakened bolt to be "broken" under controlled conditions and replaced pre-emptively.

All the major commissioning issues were associated with refurbishing and commissioning the existing brownfields infrastructure or flotation support systems. No major issues have been experienced with the Jameson cells themselves.

JAMESON CONCENTRATOR COMMISSIONING

The Jameson Concentrator commissioning began on the 15th October 2021, approximately two weeks ahead of the revised schedule. At the commissioning, several of the basic systems were not fully operational. However, the decision was taken to begin the commissioning process to expose any potential issues as soon as possible and apply the same management approach as taken to manage the commissioning of the brownfield site. Commissioning was determined to be completed, and commercial production was declared at the end of November 2021, five weeks after the first slurry to the Jameson Concentrator.

Outlined below are the obstacles and issues identified during the first six months of operation, including the commissioning period.

Instrumentation and Automation

The delivery timeframe to full operational condition varied from system to system. At start-up, several important systems were only available in either PLS or Field control manual modes or were not available at all. These systems included but were not limited to reagent dosing control, froth level control, flow stability, wash water control and the onstream analyser.

The froth level sensor supplied by Glencore Technology as part of the Jameson Cell standard design is based on two pressure probes placed at separate depths within the slurry zone. The two pressure probe outputs are integrated into the PLC and converted to a physical froth depth measurement. From the onset of programming and commissioning, the field integrators were unfamiliar with this type of level controller and subsequently made an error in the programming. The error was rectified within three days, and no further issues have been experienced with this system.

Prior to the commissioning of the Jameson Concentrator, the primary cyclones were operated based on feed density control. This control philosophy varied the cyclone feed water rate to maintain a constant cyclone feed density and allowed the cyclone pressure to fluctuate within a controlled range. The stability of the cyclone overflow pump flow was not an important control variable as the pre-leach thickener absorbed it. As shown in Figure 6, with the inclusion of the Jameson Concentrate ahead of the leach circuit, maintaining density control was not compatible with a stable operation. This was due to flow variations, and its impact on level control was amplified as it passed from Jameson-to-Jameson cell down the rougher-scavenger line. The cyclone control philosophy was changed to a fixed pressure which significantly improved the flow stability of every cell.

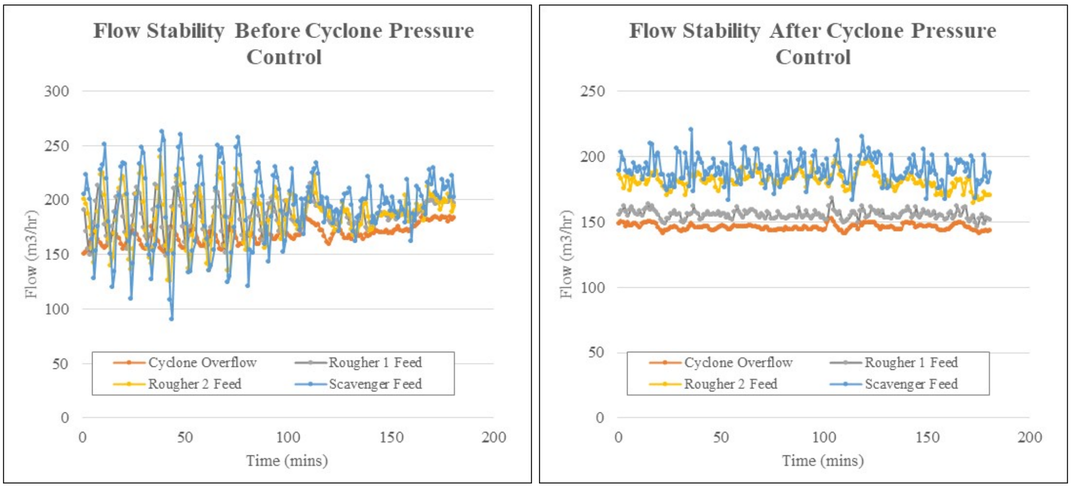

Figure 6: Flotation Circuit flow variation pre and post-cyclone pressure control implementation.

A Metso Outotec Courier 6 was installed to provide onstream elemental analysis for five process streams; flotation feed, rougher one concentrate, cleaner tails, final concentrate, and flotation tail. The installation of the Courier was not completed when commissioning began and only became available for calibration by mid-November. Once the Courier was available to receive samples. It quickly became apparent that there were several deficiencies in the physical installation of the sample delivery system that needed to be addressed; these include:

- No valving was installed on any of the pump feed or discharge lines that allowed for drainage or backflushing of either the sample cutter or pipelines. This was particularly problematic as the plant had been in operation for four weeks prior. The result was the complete blockage of all the sample lines and a delay in commissioning for two weeks while the lines were cleared and modified to include the required valving.
- The feed lines to the sample pumps were poorly laid out, with excessive 90˚ elbows and long horizontal sections. The pumps selected for sample delivery duty are vertical conical tank pumps. The feed lines discharge to atmosphere in the integrated conical tank meaning there is no suction

force back to the sampler that would overcome the poor pipeline installation, leading to constant blockages. The pump feed lines for all sample points had to be reworked to eliminate the installation errors.

These delays pushed the Courier into December before calibration samples could reliability be collected. Calibration was provisionally completed in mid-December, with final calibration completed in February 2022.

Reagent systems

The Jameson Concentrator was designed with four reagents systems: collector (Solvay Aerophine 3418A), frother (Flottec F160-09), depressant (CMC) and pH modification (lime). All the reagent dosage systems experienced issues except for the lime system.

- The dosing pumps selected for the collector and frother did not work as designed. The principal issue was the inability to hold their prime and unexpectedly lose prime without any external indicator to this event while the Courier was unavailable. Additionally, these were installed without any direct feedback to the PLC outside of a basic ON/OFF signal. Several low recovery shifts directly resulted from a loss of collector or frother addition to the flotation circuit. The complete replacement and automation of these pumps was completed in April 2022.
- The flotation testwork demonstrated that a range of 150 to 400 grams per tonne was required to control the talc flotation rate to achieve a suitable concentrate quality. The CMC dosing pumps were undersized for the actual duty required. The correct wet end was installed; however, an incorrect gearbox and motor configuration limited the pump output to 150 grams per tonne at 100% output. At the time of writing, this issue was unresolved, awaiting the necessary parts to rectify.

Flotation Performance

The driving metric for the flotation circuit is to maintain a flotation tailings grade below 0.10% copper and 2.5gpt gold to minimise the operating cost of the downstream leach circuit.

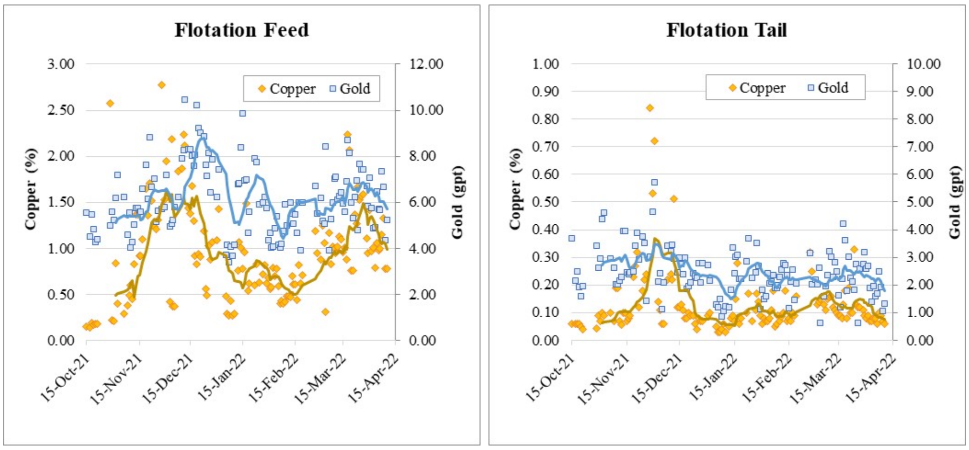

Figure 7: Jameson Concentrator Feed and Tails grade

As shown in Figure 7, the feed grade through the plant to date has displayed the variability identified and accounted for when establishing the basis of design. The first instance of elevated feed grade resulted in a significant exceedance of the design tailings grade. This was when the Courier and reagent control issues were being rectified, as outlined above. The next period of elevated feed grades did not result in the same exceedance. Overall, the flotation tails have been stable after addressing the issues with the Courier, collector/frother pumps and flow stability. Figure 8 shows that the recovery has fluctuated with variation in feed and tails grade over the six months of operation, with recovery from the end of March to the time of writing averaging +90% for copper and +65% for gold, limited primarily by the concentrate grade.

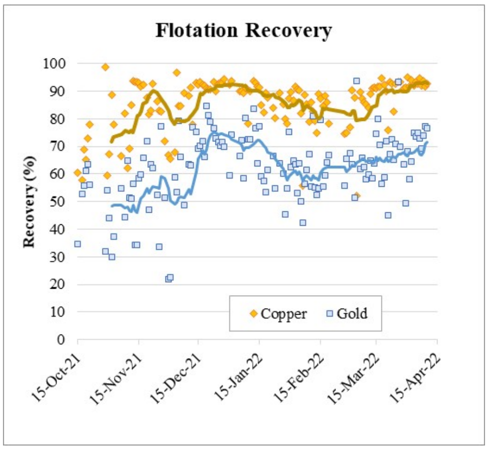

Figure 8: Jameson Concentrator Copper and Gold Recovery

The concentrate grade produced from the Jameson Concentrator is of secondary importance to recovery due to the downstream leach circuit and the blending of regional concentrate from the nearby Stall Mill prior to shipping to Hudbay's customers. The target concentrate grade was +20% copper with a minimum grade of 10% copper owing to the larger gold/silver credits attributed to the concentrate. As shown in Figure 9, the circuit has maintained a concentrate copper grade between 10% and 20%.

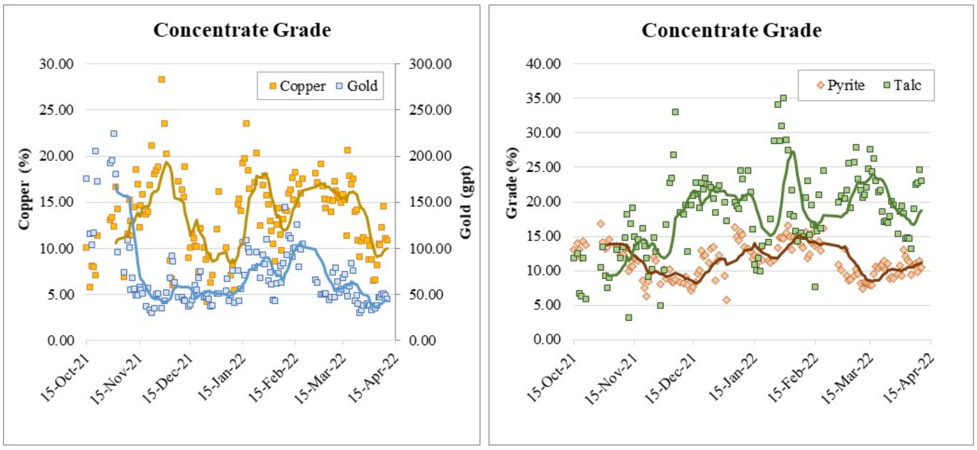

Figure 9: Jameson Concentrator concentrate grade and pyrite & talc content

The ability to achieve the design concentrate grade target has been the most prominent challenge within the circuit due primarily to the increased quantity of talc and pyrite reporting into the concentrate. However, this dilution is a direct consequence of several deviations from the original process design currently being addressed.

- The talc pre-flotation circuit (consisting of DFRs) and talc depressant (CMC) have either been not operational or underperforming design. Modifications to these systems are currently in progress to elevate their ability to meet the plant requirements.

- The content of talc and pyrite in the feed is two to three times higher than the mine plan forecast. The process design forecasted ~10% pyrite and 5% talc in feed, with the levels seen to date at 15% to 25% pyrite and 5% to 15% Talc.
- The operations team has deliberately operated the concentrate grade at times within a 10% to 15% copper range to manage downstream leaching performance. This is a practical approach as the New Britannia Mill concentrate is blended with the Stall concentrate, offsetting the impact of the lower grade on the Treatment Charges/Refinery Charges (TC/RC).

Ongoing work or information that was not available at the time of writing to identify and improve the concentrate grade is:

- Size-by-liberation mineralogy to determine the deportment of chalcopyrite, pyrite, talc, and sphalerite for each process stream - mapping the grade recovery curves for each stage. This will inform the target primary grind size and whether a regrind stage is required.
- Conversion of the grinding media from mild steel to chrome alloy.
- Re-commissioning the pre-flotation stage to remove talc prior to the Jameson Concentrator preferentially.
- Evaluation of alternative IPETC/DTP collector blends against the incumbent Aerophine 3418A to improve selectivity against pyrite.

SUMMARY

The Jameson Concentrator was selected for the new flotation module added to the New Britannia Mill as part of the refurbishment project to treat the copper-gold ore from the Lalor deposit. The Jameson Concentrator was selected due to its ability to treat significant variations in feed grades and a smaller installation footprint. The New Britannia Mill is currently working on optimising the concentrate quality to address the elevated Talc and Pyrite in the feed (from design) through various strategies. However, it is worth noting that the New Britannia Mill site is pleased with the technology selection and ramp-up that was seen with the Jameson Concentrator. At the time of writing, New Britannia Mill was tracking along the Series 1A McNulty ramp-up curves (McNulty, 2014).

References

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[2]McNulty, T., "Plant ramp-up profiles – an update with emphasis on process development." Conference of Metallurgists (COM 2014), CIM, 2014