57th Annual Canadian Mineral Processors Operators Conference
Ottawa, Ontario, January 21-23, 2025

Engineering, Commissioning and Operation of a Stirred Mill in the Arctic Circle

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ABSTRACT

The Meliadine mine, strategically located near the western shore of Hudson Bay in the Kivalliq region of Nunavut, stands approximately 25 kilometers north of the hamlet of Rankin Inlet and 290 kilometers southeast of the Meadowbank mine. The mine marked a significant milestone by pouring its first gold bar in February 2019 and achieving commercial production in May 2019. Originally designed with a throughput capacity of 3,000 tonnes per day (t/d), the mill underwent several upgrades to reach 5,500 t/d by 2022, and is now undergoing a major expansion project aimed at increasing its throughput to 6,250 t/d.

Meliadine's original single-stage SAG grinding circuit had already been upgraded in 2022 with new hydrocyclones and a new SAG shell lifter design in 2023 that collectively helped increase the throughput to 5,500 t/d. In order to achieve the targeted 6,250 t/d, the addition of a secondary grinding circuit was deemed necessary. A trade-off study was completed and determined that the best choice was to go with a 4500HP Metso Vertimill due to lower specific energy consumption and reduced generation of ultra-fine particles compared to a traditional ball mill when top fed.

This presentation describes the construction, commissioning, and initial results from Phase II of the secondary grinding expansion.

KEYWORDS
Stirred Mill, Commissioning, Comminution, Trade-off, Operational Readiness, Ramp-up

INTRODUCTION

The Meliadine mine, solely owned by Agnico Eagle Mines Limited (AEM), is located near the western shore of Hudson Bay in the Kivalliq District of Nunavut, Canada, about 25 kilometers (km) north of Rankin Inlet and 290 km southeast of AEM's Meadowbank mine. Initial ore processing commenced in early February 2019, using low-grade stockpiles; commercial production began in May 2019.

The concentrator was originally designed as a two-phase operation with the initial phase processing 3,000 t/d through a conventional gold plant flowsheet comprising crushing, single-stage SAG mill grinding, gravity concentration, cyanide leaching with a carbon-in-leach circuit, followed by cyanide destruction and filtration of the tailings for dry stacking.

The second phase aimed to achieve a throughput of 5,500 t/d by adding a secondary grinding circuit (Phase II).

From 2019 to 2023, continuous improvement programs increased the overall throughput of the mill from 3,000 to 5,000 t/d with minimal impact to recovery. A detailed description of the Meliadine deposit, the Phase I design and different mill improvements is presented in Robichaud et al. (2023). Following the commissioning and ramp-up over the first three years of operation, the detailed engineering of the Meliadine plant expansion was subjected to an initial review of the bottlenecks. The main study takeaways showed that the plant could sustain an increased throughput of 6,250 t/d with the addition of major equipment to the grinding, leaching, and filtration circuits. Figure 1 presents the Meliadine process plant flowsheet with the Phase II expansion shown within the red outlines.

This paper discusses the steps taken to commission and operate the secondary grinding circuit in the Arctic circle. More specifically it will highlight:

- the preparation (technology selection and the engineering phase)
- the implementation (construction of the circuit, the operational readiness program and the commissioning steps) and
- the current results as preliminary metallurgical findings.

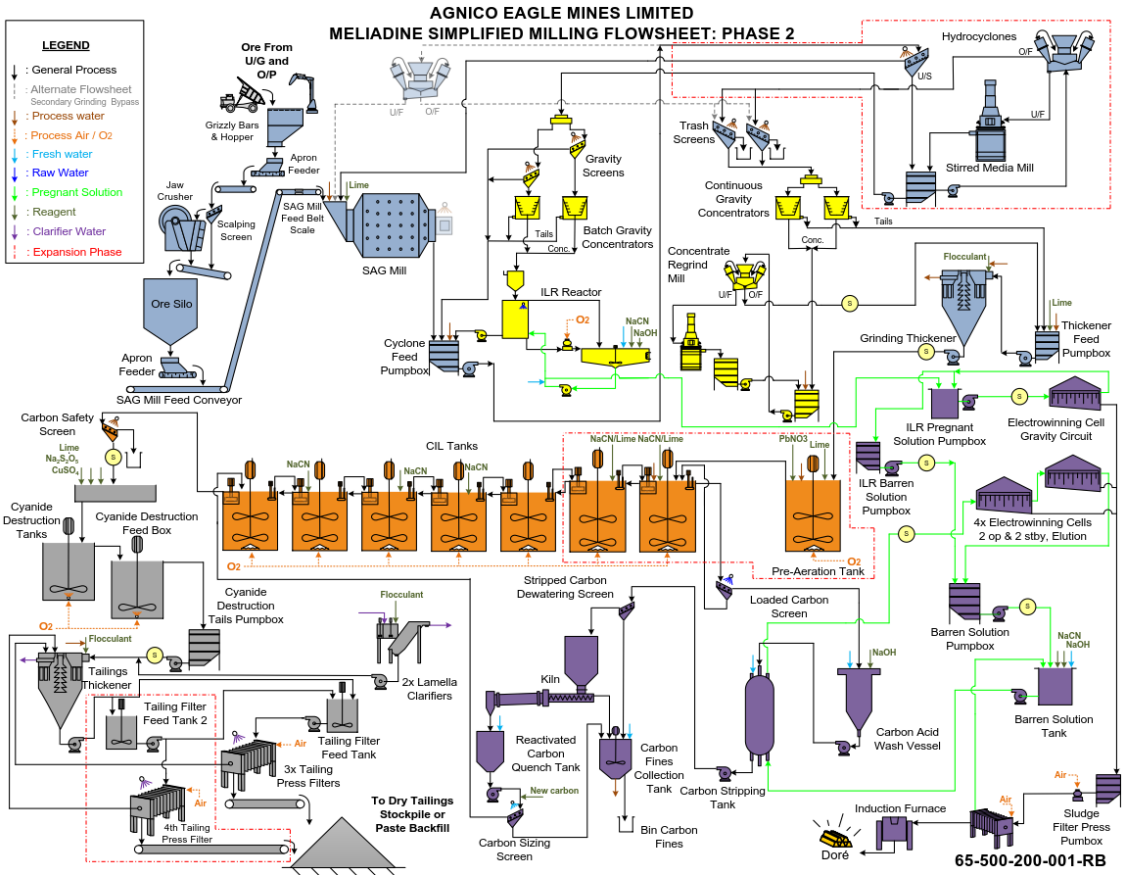

Figure 1 - Meliadine Simplified Milling Flowsheet: Phase II

SECONDARY GRINDING TRADE-OFF, ENGINEERING AND CONSTRUCTION

Stirred mill vs ball mill trade-off

The initial work on the application of tower mill grinding technologies for the Meliadine project dates back to 2012. At that time, a desktop-level trade-off study (Leetmaa, 2012) was carried out to compare the benefits of replacing the ball mill with a tower mill, as the secondary grinding circuit needed to expand from 3,500 to 5,500 t/d three years after commissioning the single-stage mill. In 2021, the trade-off (Robichaud et al., 2021) was reviewed using audited data from the largest tower mills commissioned and operated during the previous decade. Initial estimations of the direct costs to install a stirred mill compared to a ball mill for this application in Nunavut predicted a 20% increase. The main drivers for this direct cost increase were:

1. Increased mechanical equipment supply requirements (including additional capital spares)
2. Increased building volume to accommodate indoor grinding media storage
3. Higher costs for auxiliary lifting equipment needed for liner changes

However, the increased capital expenditure required to commission a stirred mill in Nunavut is offset by significant operational cost savings. Supplying the remote Meliadine area necessitates sealifting all consumables via barge during a short summer period when the Hudson Bay is ice-free. The study identified the following main drivers for operational expenditure (OPEX) savings: 1. A reduction in energy consumption of 10% to 30%; 2. A reduction in grinding media consumption of 35% to 50%; and 3. A 0.3 to 0.6% reduction in cement addition to the paste backfill. This last point is particularly noteworthy, as the reduction in cement usage is attributed to the relationship between the cement ratio in paste backfill and the proportion of sub-20 µm particles (Robichaud et al., 2021). Additional advantages when reducing the ultrafines are also expected in the cyanidation and filtration circuits, such as reductions in reagent consumption, filter press cycle time, and filtration plant compressor energy consumption. These elements were not included in the trade-off study.

Overall, by varying the design criteria to simulate base-case, pessimistic, and optimistic scenarios, the calculated payback period for the stirred mill ranged from 1.5 to 4.5 years.

Additional information pertaining to the selection of Metso's Vertimill technology is provided in Robichaud et al.(2023).

Engineering and Construction

The building design for the new circuit (Figure 2) was developed to ensure sufficient space for Vertimill maintenance. Although top fed, the new building's height was determined by the secondary cyclone cluster, to allow the underflow stream to bottom feed the stirred mill via gravity if required. Benchmarking the maintenance strategies of multiple Vertimill operators led the design to include a fixed liner handler and an open area in front of the mill for mobile equipment to handle bulk grinding media. Due to the arctic winter conditions and for site security with regards to gold inventory, it was decided that the used media should be stored inside the building during shutdowns, and an indoor ball sump was added to this end.

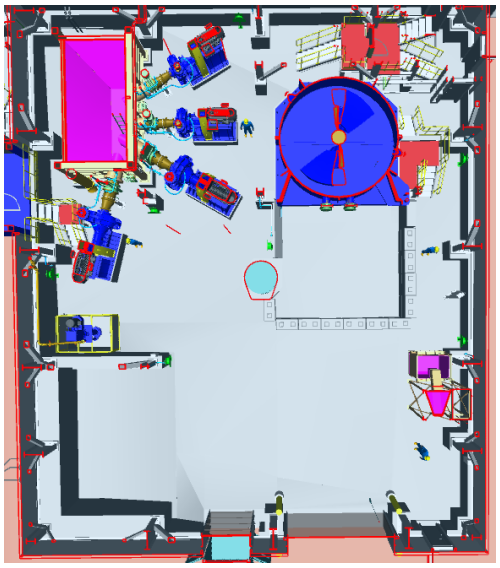

Figure 2 - Plan view of the Meliadine secondary grinding area with the Vertimill base (blue), liner handler base (cyan), and cyclone feed pump box (pink); (North at top)

At the beginning of the Engineering, Procurement and Construction Management (EPCM) project, the circuit commissioning was scheduled for December 2024, with the critical path requiring basic engineering to commence in October 2021. This early initiation facilitated the procurement of long-lead items, including the stirred mill and liner handler, ensuring their arrival at the port for the Q2-2023 sealift.

Moreover, advancing the engineering phase allowed critical design elements to be finalized, and minimized scope changes during the subsequent awarding of contracts for building supply and installation. Construction activities began in Q1-2023 with earthworks and concrete placement, creating the necessary foundation for building erection once the 2023 summer barge delivered the primary steel. In the Arctic region, outdoor construction productivity factors are severely impacted by frequent blizzards and extreme cold during the winter months. Consequently, achieving building enclosure prior to winter was identified as a critical milestone, as it would enable structural, mechanical, and electrical installations to proceed under controlled indoor conditions. The building structure and architectural panels were erected on time, thus construction of the mechanical equipment started in Q1-2024 (Mata, 2024).

The planned 2024 milestones for the stirred mill equipment erection were:

1. January 15th – Mobilization
2. March 19th – Motor installation
3. April 8th – Screw & door installation
4. April 29th - Final installation

The primary factor contributing to the on-schedule installation of the machine was the installation team's familiarity with the Vertimill, gained from their previous experience at IAMGOLD's Côté Gold project in 2023.

OPERATIONAL READINESS PROGRAM, COMMISSIONNING AND RAMP-UP

Operational Readiness Plan

At AEM, the specific goal of an Operational Readiness Plan (ORP) is to ensure efficient start-up and facilitate handover from Construction teams to Operation teams. This aspect has an important impact on the ramp-up period. The ORP at Meliadine, owned by the Process Plant Operation team, started in October 2023, and ensured collaboration between all teams throughout the construction, cold and hot commissioning, and start-up of the secondary grinding circuit. During this process, roles and responsibilities were assigned, and relevant information was transferred from the Construction department to the Process Plant Operation and Maintenance teams.

In the past decade, AEM's Technical Services visited multiple sites, namely New Afton, Raglan, Kaunisvaara and Côté Gold, which have operating Vertimills ranging from 1250 to 4500HP. The collaboration with other companies having experience with the Vertimill 4500HP was useful through exchanges with Metso during the trade-off process. Closer to commissioning, training sessions from Metso Subject Matter Experts were presented to the teams three months before the start-up. Operation and maintenance procedures, and all operation material were available before the Vertimill start-up.

Commissioning

As construction was officially completed earlier that originally planned, by the end of April, the commissioning team started the Pre-Operational Verifications (POV) and IO tests on all the equipment in the secondary grinding circuit. Cold commissioning took place all through the month of May (Mata, 2024) and then all teams were ready to start the Vertimill at the beginning of June. At that time, the external consultants (Metso, BBA, Soutex) were mobilized on site for the hot commissioning. From that perspective, the design decision regarding the option of reverting back to a single stage was a significant risk mitigation measure for the new grinding circuit commissioning. Challenges faced during the start-up could be addressed by stopping the secondary grinding circuit while allowing the existing circuits of the mill to remain in operation.

On June 17th, the team water tested all the secondary grinding piping that could not be tested in the single-stage circuit. After the first hour of operation, water balance issues arose due to the scaling of major process water lines, and caused the shutdown of the Vertimill. Switching from single stage to two stages by starting the secondary grinding circuit requires an important amount of water at the discharge of the SAG mill. The process water volume was not sufficient as the overflow of the grinding thickener pipe was 90% scaled. (Figure 3). Following this first trial, Construction and Operation collaborated to resolve the issues before July 5th. On the Operation side, an unplanned 4-day shutdown was initiated at the end of June, allowing the critical process water lines to be cleaned and replaced. Construction also seized the opportunity to complete key items on their deficiency list, having increased the efficiency of the secondary grinding circuit ramp-up.

Figure 3 – Grinding Thickener Overflow pipe during the first trial of Vertimill Commissioning – June 17th

On July 7th, with the readiness objectives reached and the water balance operational issues resolved, the Meliadine teams carried out hot commissioning of the secondary circuit with slurry. For three consecutive days, the Vertimill was operated only on dayshift. During this key period, the teams solved the remaining technical issues such as adjusting the operational parameters to reach a P80 between 90 and 100 µm at the overflow of the secondary grinding cyclones clusters, tuning the control loops, and setting the alarms limits. With this work done and with the consensus of the various Process Plant teams, the secondary grinding circuit was operated on both day and night shifts. The circuit has been fully operational since July 10th.

Ramp-up Period

The ramp-up period was initially planned for Q4-2024 (Meliadine Process Plant Management, 2023). With the results from the commissioning and start-up process, the tonnage target of 6,250 t/d was reached at the end of July 2024. Figure 4 presents the start-up tonnage ramp-up and the effect on the P80 resulting from the secondary grinding circuit operation.

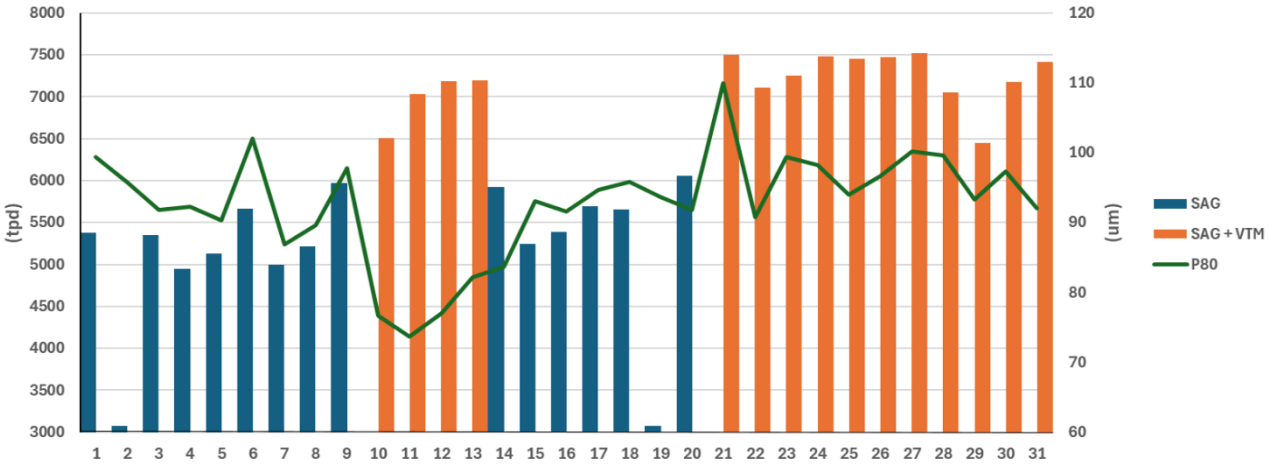

Figure 4 – Vertimill 4500HP Commissioning and Ramp-up Period – July 2024

Tonnage increased significantly, from 6,000 to 7,250 t/d, between July 10th and July 14th. As the parameters were not adjusted, the P80 was below target at approximately 80 µm. From July 14th to 21st, the secondary grinding circuit was shut down due to a shortage of fuel at the mine site. The amount of fuel remaining was not sufficient to sustain the Meliadine site energy consumption. This shutdown period provided the opportunity for the teams to optimize grinding circuit parameters. Since the Vertimill restarted on July 21st, the grind target P80 of 90-100 µm has been reached at the sustainable throughput of 7,000 t/d.

In August, the CIL expansion circuit was delivered. Maximal tonnage with the new secondary grinding circuit could be tested without any loss in recovery. On August 4th, a new daily tonnage record of 7,579 t/d was achieved while maintaining a P80 of 98.6 µm (Meliadine Process Plant, 2024). Despite the high tonnages reached by the end of the summer, the mill throughput was subsequently reduced to address a necessary maintenance overhaul of the filtration plant, which was planned in Q3-Q4-2024 (Keogh and Pickup, 2024). In summary, thanks to the collaboration of all the teams involved and the proper planning of the ORP process, the Vertimill ramp-up period beat the target and was reached in Q3-2024. The results obtained created many opportunities in terms of mill throughput for the future.

PRELIMINARY METALLURGICAL FINDINGS

Reduction in energy consumption

The technical study on the Vertimill indicated that energy consumption would be reduced while maintaining a P80 between 90 and 100 µm at the secondary grinding cyclone overflow. As electricity in Nunavut is generated by “Genset” and hence extremely expensive, this reduction in energy consumption would significantly and positively affect the OPEX. Figure 5 presents an overview of the energy consumption since the start-up of the Vertimill.

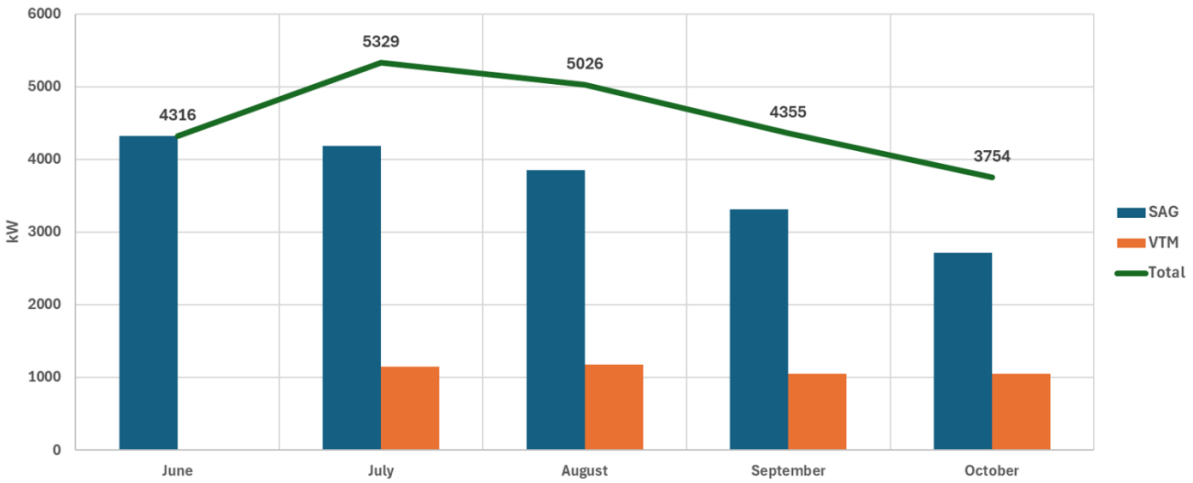

Figure 5 – Energy consumed by the SAG Mill and the Vertimill since the start-up of the Secondary Grinding Circuit

The early results presented in Figure 5 demonstrate a progressive reduction of energy consumption month-by-month since the start-up in July 2024. With the optimization projects in progress, an additional decrease in energy consumption at the grinding circuit is expected in 2025. The results for specific energy as a function of grind size are presented in Figure 6. The daily data from the single-stage circuit (blue) are from September 2023 to June 2024, and those from the two-stage circuit are from July to November 2024 (dark and pale orange) (Meliadine Process Plant, 2024).

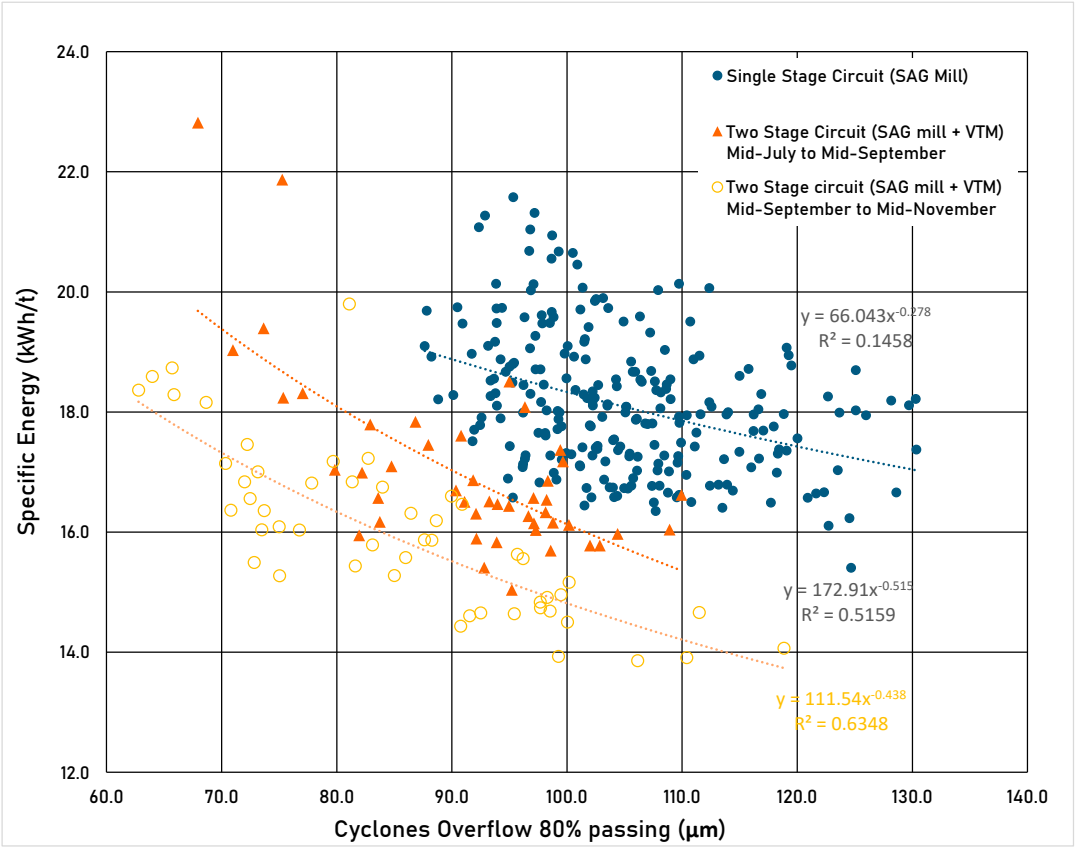

Figure 6 - Specific Energy before and after the Vertimill start-up as a function of the Cyclone Overflow P80

The results demonstrate a notable reduction in specific energy by operating in a two-stage circuit. The single-stage circuit data (blue dots) show a specific energy between 16.2 kWh/t and 21.8 kWh/t to maintain a P80 of 90-100 µm. Operation of the Vertimill provides not only the opportunity to produce a finer grind than 90 µm, but also a meaningful reduction in the specific energy consumption for a P80 within the

range of 90 to 100 µm. The specific energy since the start-up in mid-July to mid-September (orange triangles) is 15 to 18.5 kWh/t which is lower compared to the operation of the single-stage circuit. The results since mid-September (yellow circles) demonstrate an improvement of the operation of the secondary grinding circuit, with a specific energy consumption of 13.9 to 16.6 kWh/t. After only four months of operation of the two-stage circuit, early results illustrate a month-by-month decrease in the energy consumption associated with the current optimization initiatives.

CONCLUSIONS

The engineering, construction and commissioning of the Meliadine secondary stirred mill are complete. The Operational Readiness Plan and the efficient collaboration between the Construction and Operations teams positively influenced the start-up and the ramp-up of the Vertimill 4500HP at Meliadine. Despite the water balance issues during cold commissioning, the operational targets (6,250 t/d and P80 90-100 µm) were reached within a ramp-up period of one month at the end of July.

Initiatives are currently underway to optimize the two-stage grinding circuit. The Meliadine comminution circuit will become more efficient following a planned review of the operation philosophy regarding the ball charge balance between the SAG mill and the Vertimill. New liners, a lifter and the discharge grate design are also in the project pipeline. Moreover, a sampling campaign was conducted with COREM in August 2024, and another is planned in February 2025, to verify the effects of grind size on filtration efficiency and cement consumption at the paste plant. In the upcoming years, these initiatives and all additional valuable data will contribute to an evaluation and feedback on the business case that justified the selection of the Vertimill 4500HP for secondary grinding in Phase II of the Meliadine Expansion.

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