Paste 2023 – GW Wilson, NA Beier, DC Sego, AB Fourie & D Reid (eds)

doi:10.36487/ACG_repo/2355_28

Selection and operation of Metso Outotec second generation paste thickener at the New Afton Mine

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Abstract

The New Afton Mine has been in commercial operation since 2012 with the New Afton Tailings Storage Facility (NATSF) used as the primary tailings deposition site. In order to process future underground B3 and C-Zone ores and extend the lifespan of the current operation to 2030, new thickened and amended tailings (TAT) facilities were installed.

For the TAT facility, a high yield stress and solids concentration material was required for the mill tailings stream to facilitate amendment with cement and deposition to the Historic Afton open pit (APTSF). A 45 m diameter Metso Outotec second generation paste thickener was selected to achieve the target slurry characteristics and was commissioned in early 2022.

This paper discusses the drivers behind the selection of the TAT process for in-pit tailings deposition as well as the selection of the paste thickener. Early operating results and the process optimisation required to achieve the desired overflow and underflow targets are reviewed. Early operating performance is compared to the original design test work. Furthermore, the paper details the value of Metso Outotec second generation paste thickener technology in achieving operational targets for tailings deposition at the New Afton Mine.

Keywords: *thickener, paste, in-pit tailings disposal*

1 Introduction

The New Afton Mine owned by New Gold Inc. (NGD) is a gold and copper producer, located 10 km west of Kamloops, British Columbia. The mine life was recently extended to 2030.

Prior to 2022, tailings generated from the concentrator were stored mainly in the New Afton Tailings Storage Facility (NATSF). Due to the location of underground mine development, and the proposed volume of tailings associated with the mine life extension exceeding the design capacity of the NATSF, an alternative tailings disposal system has been implemented.

Several tailings disposal options were evaluated to provide capacity for the additional tailings. These included conventional (construction of a new tailings storage facility using cyclone sand + rockfill), filtered and thickened tailings disposal options. New Afton decided to pursue a thickened and amended tailings (TAT) storage option. This option required the construction of the TAT processing facilities, to allow thickening of the tailings and mixing with cement for disposal into the Historic Afton open pit (APTSF). Cement addition increases the strength and stability of tailings in storage facilities. This thickened tailings with cement added is referred to as TAT throughout this paper.

The concentrator has been in operation since mid-2012. Throughput in the process plant has been averaging above the nameplate of 11,000 tonnes per calendar day since early 2013. A mill expansion was completed in 2015 to add a tertiary stage of grinding and additional flotation cleaning capacity. This allowed throughput to increase to a peak average of 16,420 tonnes per calendar day in 2017.

Prior to commissioning of the TAT processing facilities, the cleaner-scavenger flotation and rougher flotation tailings were combined at the final tailings pump-box and then pumped to the sands plant at the NATSF. The coarse and fine fractions were separated by hydrocycloning to meet dam construction requirements. The TAT Processing Facilities replaced this hydrocycloning stage with paste thickening and cement amendment.

The simplified flow sheet prior to the addition of the TAT thickener is shown in Figure 1.

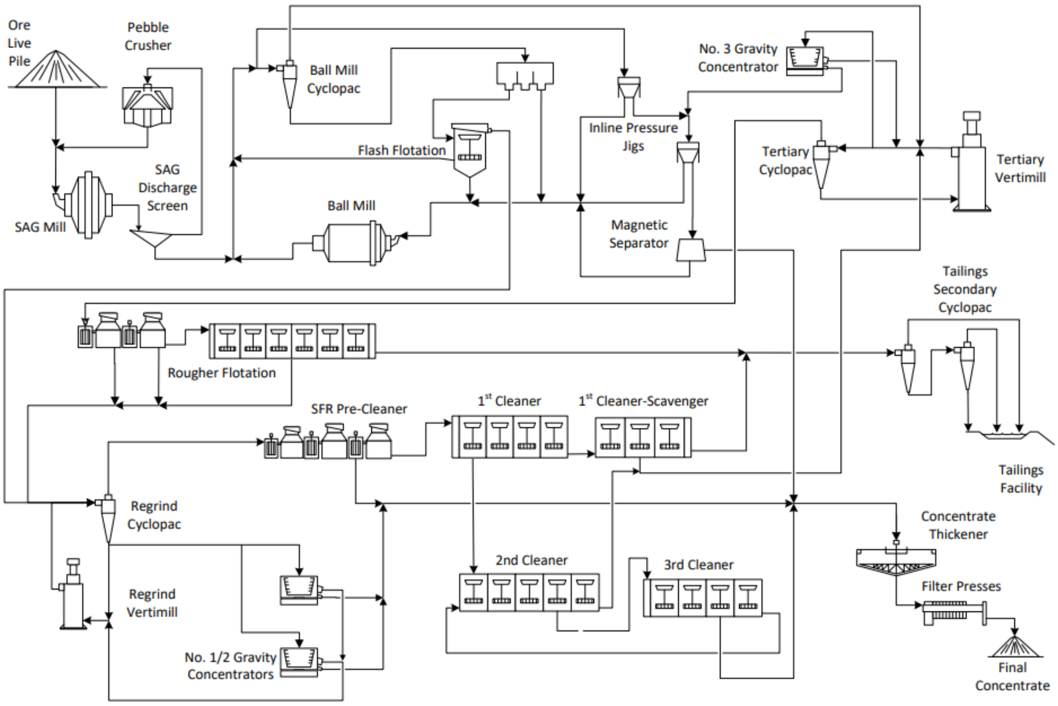


Figure 1 Simplified New Afton flow sheet prior to paste thickener installation

This paper will discuss Metso Outotec paste thickening technology and its application in the New Afton TAT process. Laboratory and pilot test work, commissioning and early operation of the TAT facility will also be covered.

2 Background

2.1 Paste thickener development and features

Paste thickening is best suited to applications requiring a high degree of dewatering, such as minerals tailings, mine backfill, pre-leach and alumina settler and washer circuits. The strategic drivers for each project will differ, whether it be tailings management, water recovery, available land space, environmental, regulatory requirements, or other considerations.

Metso Outotec has a long history of development of paste thickeners. Their successful experiences with large-scale paste thickening have developed a strong understanding of the key aspects of high density thickeners, such as effective feed stream preparation and flocculation, dewatering of flocculated solids, raking capacity, prevention of rotating solids beds, and effective withdrawal of thickened solids.

The Metso Outotec second generation paste thickener optimises thickener performance through a stable solids inventory to achieve a consistent underflow solids concentration. The 45 m diameter paste thickener installed in 2021 at the New Afton Mine in Canada to treat copper-gold tailings is a good example of this modern design. It encompasses the latest technology developments and experience from previous paste thickener installations. A picture of this installation is shown in Figure 2.

Figure 2 New Afton paste thickener

Reliable operation and maximised thickener underflow density were the two key drivers for the TAT project and have been considered in the following ways:

- Reliability of operation considered the latest rake design with SMART Rake lift to maintain rake alignment. The combination of these elements enables more consistent solids raking.
- The drive unit has a high torque capacity of 14.5 MNm to drive the rakes through high yield stress material.
- Static pickets are included as a physical restraint to the formation of a rotating solids bed.
- Maximised thickener underflow solids concentration is assisted through the high sidewall, steep floor slope, and proven feedwell technology.

SMART Rake lift is a key feature of Metso Outotec's second generation paste thickener and relies on feedback from a pressure transducer and position indicator mounted on each hydraulic lift cylinder. Comparing the relative vertical position from a datum and internal pressures of the hydraulic cylinders allows the opportunity to verify the mechanical alignment of the rake mechanism, and importantly to actively adjust any misalignment. Improvement in alignment of the rotating mechanism also has the advantage of reducing wear on the upper and lower guide blocks and maintaining an even clearance between the tank floor and rake blades.

The total vertical load is a useful operational process parameter to monitor in the plant control system, showing changes in the weight of solids acting on the rake mechanism, indicating the presence of a rotating bed of underflow solids. Rotating solids beds can negatively affect thickener performance by disturbing the transport path of solids and increasing rake torque. Early warning of this situation allows for corrective actions to be taken such as raising the rakes to disturb the solids settled on the rakes, and/or adjusting the underflow pump speed.

Part of the overall approach to achieving reliable operation is the inclusion of static pickets, which are patented by Metso Outotec. These are fixed vertical members supported at the top which extend down into the thickened solids bed. They are used with high yield stress and coarse particle beds as a physical restraint to prevent the build-up of rotating solids beds. A picture of the New Afton thickener static pickets is shown in Figure 3.

Figure 3 Static pickets on New Afton paste thickener

The traditional approach to thickener rake arm design has been to use truss members resulting in high overall depth and width of the arm cross-section. Open area ratios of the truss can influence the propensity for solids bridging across these truss members. Evidence shows that settled solids do build across these adjacent structural members over the depth of the arm, hence the recent focus on rake design for paste thickeners is to create a low profile compact arm shape. This is achieved by the use of closed section arms in octagonal or rectangular cross-section shape.

Rake blades are connected to the underside of the rake arm by a post structure known as a 'thixopost', to improve raking efficiency. With four rake arms, the load sharing between arms is done by tie members. The rake arm connection to the drive shaft is stiffened with a short bracing member, rather than a long strut, to allow for the application of static pickets within the raking zone. The rake design on the New Afton paste thickener is shown in Figure 4.

Figure 4 Rakes on New Afton paste thickener

The tank geometry utilised a steep floor slope of 30 degrees to assist the transport of solids to the underflow boot. This assists in achieving a high solids concentration thickener underflow. Figure 5 shows the New Afton paste thickener cone prior to the installation of cladding.

Figure 5 Cone of New Afton paste thickener

2.2 Process selection for New Afton Mine tailings disposal

When evaluating the feasibility of mining upcoming ore sources, it was determined that disposal in the existing tailings storage facilities (NATSF) would not be adequate for the full volume and an alternative tailings disposal method was required. The TAT disposal process was chosen over filtered or conventional tailings after a trade-off study between these options. The former APTSF was selected as the site of tailings deposition.

Initial investigations and test work trials focusing on thickener selection were carried out in 2016 and 2017. Initially, a high-rate thickener was considered; however, discussions and workshops between New Afton, dewatering experts and tailings consultants demonstrated that high density (high compression) thickening technology would be advantageous over high-rate thickener technology in this application.

The paste thickener was selected over a high-rate thickener in order to minimise water reporting to the APTSF, minimise make-up freshwater requirements for the site and to reduce the cement required for achieving the target shear strength of the in situ tailings.

2.2.1 Laboratory testing

Testing of slurry samples is a key step in correctly determining the optimum technical solution for dewatering of a specific slurry. This can be done in various size of test rigs including 99 mm, 190 mm, or 1 m diameter rigs, with the larger test rig producing the more representative results for full-scale application. For paste thickener test work the important aspect is to achieve a representative set of data covering the expected behaviour over a range of densities. Analysing this set of data for variability in solids flux rate, yield stress, flocculant dose and solids concentration across the operating window provides the opportunity to make the best technology selection for performance and flexibility. The following table compares dynamic thickening test results in a 99 mm diameter rig to early operating results. Testing was conducted on a sample of New Afton 100% hypogene ore to best approximate the feed during the second half of 2022. Testing was also conducted on a 50:50 blend of supergene and hypogene New Afton ores; however, the amount of supergene ore in the mill feed had decreased to <5% by the time the thickener was commissioned. As the New Afton concentrator was at relatively low throughput during this period, the comparison is to the lowest flux rate tested (0.4 t/(m^2 × hr)) at laboratory scale. Flocculant was not optimised with respect to overflow clarity at this stage of laboratory testing. Actual yield stress during operation was higher than in the dynamic testing due to the relatively fine grind size. A short-term trial of a higher throughput and coarser grind size resulted in a higher thickener underflow solids concentration and a lower yield stress for a given solids concentration.

Table 1 Metso Outotec dynamic thickening tests and early operating parameters

	Dynamic thickening test results	Typical range during early operation
Feed particle size distribution, P80 (µm)	150	75–90
Feed solids concentration (wt%)	20.3%	16–22%
Flocculant dosage (g/t)	60	35–45
Underflow solids concentration (wt%)	60.6%	58–64%
Yield stress (Pa)	69	90–130 (varies significantly with P80)
Overflow clarity (mg/L)	374	20–150

A picture of the rig used in the New Afton dynamic thickening test is shown in Figure 6.

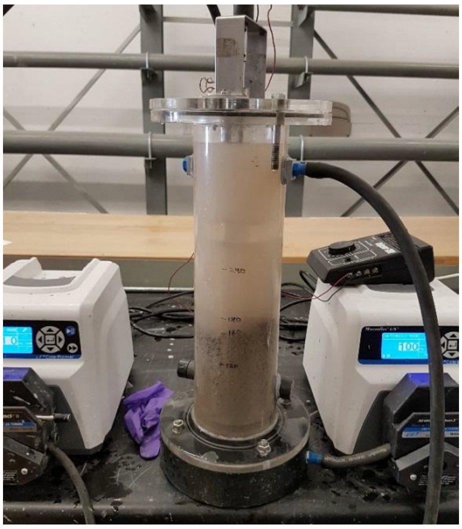


Figure 6 Metso Outotec dynamic thickening tests

2.2.2 Pilot testing

To build on the scoping study and laboratory testing conducted by Knight Piésold Ltd., a pilot-scale version of the TAT process was operated alongside full production at the New Afton mine site in mid-2018. Pilot testing was conducted to improve understanding of the rheological and geotechnical characteristics of the amended tailings. The trial evaluated settling rate, overflow clarity and underflow density at different throughputs and grind sizes, reagent requirements, the water to cement ratio required for control of shear strength in the amended tailings, the amount of bleed water released from the deposited tailings and whether a secondary or alternate binder would improve shear strength over cement alone.

A portion of the mill tailings feeding the primary sands cyclones was diverted to a pilot-scale thickener where different addition rates of flocculant and coagulant were tested. The thickener underflow was transported to a tailings mixing area using a peristaltic pump. Cement and alternate binders were mixed with the tailings before being pumped to the deposition locations for evaluation of the placed tailings characteristics over a longer time period. The trial was also used to predict thickener performance itself by varying ore type and grind size through the mill.

3 Process, commissioning and early operation

3.1 Thickened tailings process description

Depending on the final deposition location, Portland cement is mixed with the thickened tailings to increase the shear strength of the placed tailings. The product is called thickened and amended tailings (TAT). The cement mixing portion of the system is excluded from this process description to better focus on the paste thickener. The rougher and cleaner-scavenger flotation tailings are combined in the mill and pumped to the paste thickener. The slurry discharges to the thickener feed tank where it is mixed with a coagulant (if used). Flocculant can be added at the feed tank and/or the thickener feedwell. The slurry exits the bottom of the feedwell into the thickener and is separated into two streams: supernatant thickener overflow and sedimented thickener underflow.

A minimum of 60 wt% solids concentration is required in the thickener underflow with a higher target solids concentration set based on grind size; typically in the 62–64 wt% solids range. This underflow is pumped out the bottom of the thickener using a centrifugal pump. The pump discharges to a distribution header which splits the flow equally between the operating thickened tailings pump trains. Each pump train consists of a pump-box, a centrifugal charge pump and a high pressure positive displacement pump. The positive displacement pumps discharge into a combined line with the deposition location controlled at a valve yard close to the TAT facility. Thickened tailings can be discharged to the NATSF while TAT can be discharged at one of three spigot points along the APTSF.

The thickener overflow exits at the top of the thickener via a weir into a collection launder. The launder discharges to a pipe which feeds the thickener overflow pump-box. The water is returned to the mill process water system to maintain the mill water balance. Anti-scalant is added to control calcium carbonate build-up from lime addition in the mill and the relatively high temperature of the water.

3.2 Commissioning

The following sections outline the process, challenges and control strategies applied during the commissioning stage of the paste thickener.

3.2.1 Commissioning process and challenges

In preparation for commissioning, a high priority was put on training including on thickening basics, slurry transport and vendor-specific equipment training for both technical and operations personnel. Operational readiness coordinators were designated for both the Maintenance and Mill Operations groups several months before commissioning. Water commissioning of the facility started in the fourth quarter of 2021. Winter commissioning of the thickener was challenging as the interior region of BC saw unusually cold temperatures and the mine was temporarily cut-off from all major distribution centres as historic atmospheric rivers shut down major distribution arteries for the BC interior. Another challenge was dedicating sufficient personnel to thickener start-up while continuing to operate the existing processing facility. The cold temperatures coupled with preliminary winterisation resulted in equipment damage in areas of the TAT building that were not completely drained, although the paste thickener itself was drained and not damaged. Winterisation of the building was improved in 2022 and the system assessed for other potential risk points for freezing. These were remedied to avoid issues during operation. Examples include insulating small diameter water lines in cooler areas and adjusting the position of drain valves to ensure full drainage of water or slurry lines during shutdowns.

Despite the equipment damage and supply chain issues, the setback was minimal and water testing resumed in March 2022. Slurry commissioning followed with the first thickened tailing deposition to the NATSF on April 4, 2022. The percentage of mill operating time with tailings feeding the thickener is shown in Figure 7.

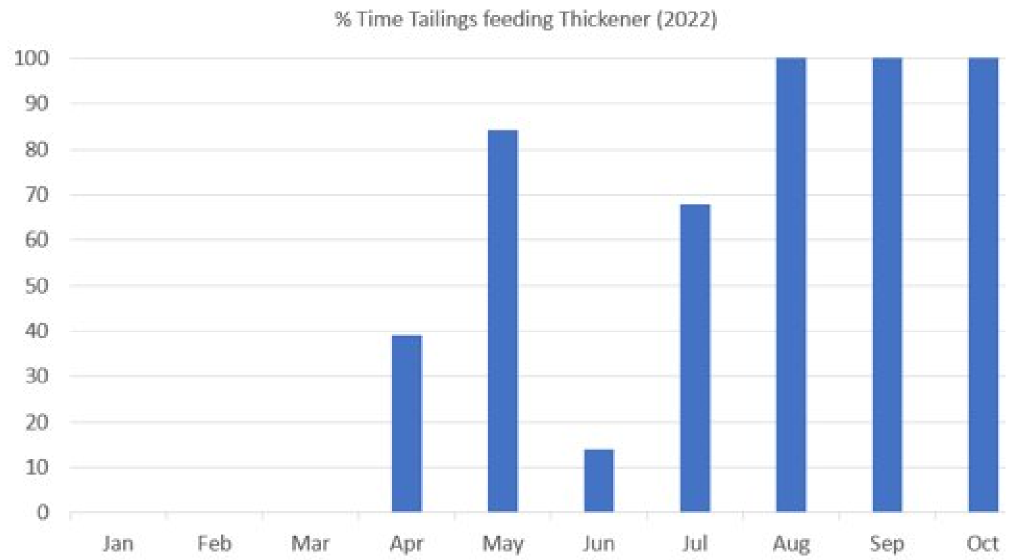


Figure 7 Paste thickener utilisation (January – October 2022)

Downtime in June 2022 was mainly associated with maintenance on the final pump trains which were impacted by oversize particles and foreign objects. Improvements were made to improve reliability of the strainer systems and efforts are ongoing to control oversize reporting from various water sources. The conventional tailings line feeding the cyclone sand plant was decommissioned in August 2022 at which point all tailings were required to pass through the thickener regardless of deposition location. This dependency on the thickener did not result in any unscheduled mill downtime in the August – October 2022 period.

3.2.2 Control strategies

Both yield stress and solids concentration are important parameters for the TAT. Maximising the solids concentration reduces the volume of water available to seep from the tailings over the long-term and thus underground dewatering requirements. It also reduces the amount of cement required to reach the target yield stress. The control strategies surrounding thickener operation centre on product solids concentration. The paste thickener selection allows for high consolidation of tailings. Therefore, the overall control philosophy was to over consolidate and dilute to achieve operational objectives. Three primary control strategies are employed to achieve product solids concentration targets: dilution, reagent, and inventory management control narratives.

There are several key sensors installed within the facility which indicate the operational metrics employed by the control narratives. Early operation of the thickener itself required little scrutiny as it performed well relative to the downstream pump systems. A product solids concentration of 60 wt% was easily achieved early on and with milling rates decreased, the excess capacity of the thickener allowed for flexibility to accommodate operational upset and tuning.

3.2.2.1 Dilution control

With the paste thickener control philosophy focused on maximising underflow solids concentration, the process design included a means to dilute thickener product at the underflow pump suction. The dilution system consisted of both fine and coarse water controls with a high-volume flush feature. The dilution system was identified early on as a useful configuration for controlling downstream distribution and provided a mechanism for effectively flushing equipment for shutdown and emergency situations.

Dilution control was utilised to effectively control both tailings line pressure and underflow solids concentration targets. Due to centrifugal pumping limitations encountered during early operation, the dilution system was adapted to maintain a maximum discharge line pressure. Line pressure had a better correlation to pumpability than solids concentration because underflow rheology can vary independently of solids concentration, hence the decision to include it in the control strategy. A graphical representation of the dilution control strategy is shown in Figure 8.

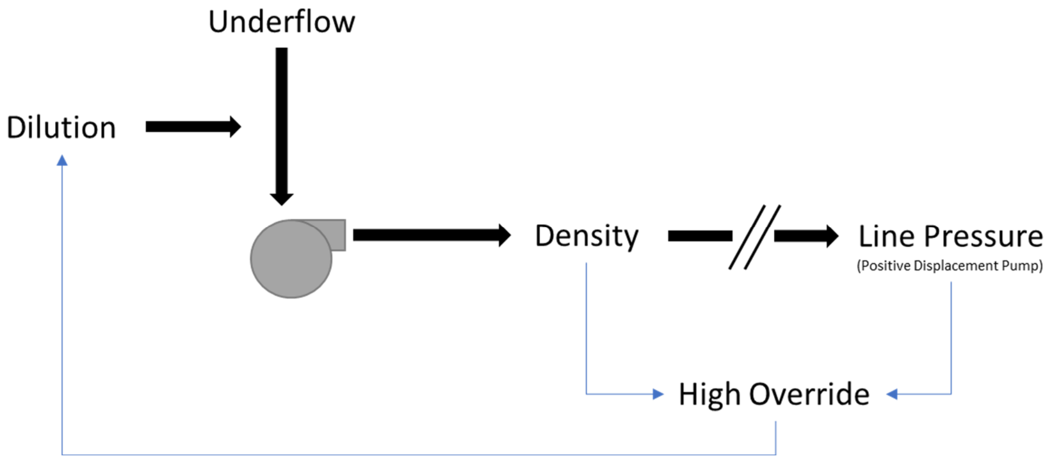


Figure 8 Dilution control strategy

3.2.2.2 Reagent control

The reagent area of the facility consists of both flocculant and coagulant batch mix systems. Each system is capable of utilising either reagent providing added redundancy. Reagent control is simplistic, controlling dosing rates in gram per tonne based on the nuclear density gauge on the thickener feed.

The flocculant process produces a mixture at 0.5% concentration and is diluted 10:1 via a downstream control system. The dilution water provides a carry mechanism for delivery into the thickener where it can be distributed into three dosing locations: thickener feed, auto dilution flocculant addition ports, or thickener feedwell. Auto dilution port locations have typically been utilised to date.

Operational testing along with vendor and consultant support identified a flocculant dose of 40 g/t to be adequate compared to an original estimate of 60 g/t from pre-commissioning test work. The coagulant system has only been used to complete commissioning but may be revisited as mill and thickener throughput increases.

3.2.2.3 Thickener inventory management

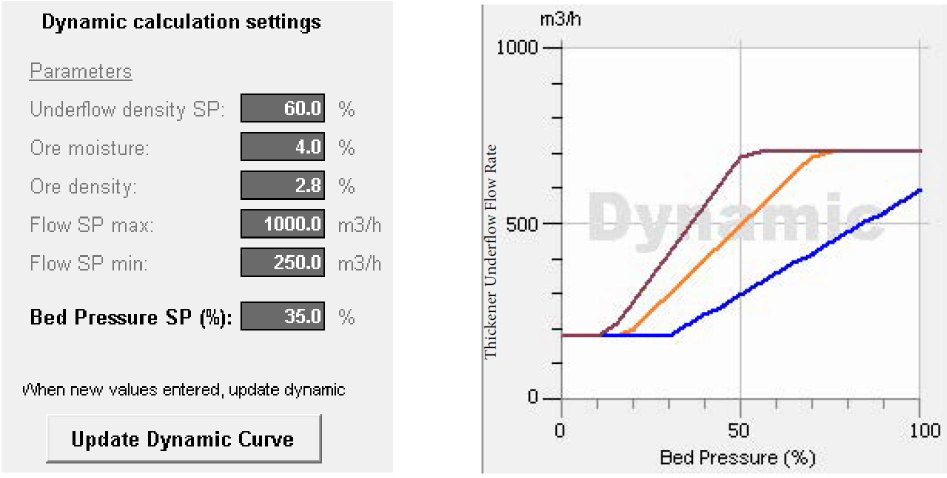
A simple proportional–integral–derivative (PID) loop controlled through the DeltaV Distributed Control System (DCS) pairing bed mass to thickener underflow withdrawal rates can be used to control thickener inventory. A dynamic model controller was also developed and is used as the primary control system.

New Afton paste thickener control continues to revolve around control of product solids concentration. While managing low inventory at the thickener holds value operationally, solids concentration remains the critical control as it drives the foundation for downstream performance related to cement amendment requirements and control of the site water balance. Operational strategy is to run the thickener with the lowest inventory possible that achieves target product solids concentration.

Thickener inventory at the basic control level can be operated via standard PID Loop control system. Bed pressure measurement drives an underflow volumetric pull rate. This is coupled with a low selector governed by discharge line pressure to protect the system from over pressurisation.

PID control in automatic mode allows an operator to select a target bed pressure that will output volumetric flow rates to the thickener underflow pump controlling draw rates from the thickener to manage inventory. This control strategy is reactive and does not consider any upstream changes to the concentrator such as mill throughput.

In the case of the dynamic model controller, a thickener model is generated based on physical design specifications allowing for an inferred volumetric output based on several key input variables. The dynamic model provides a basic framework for predicting thickener performance but assumes 'ideal' conditions. This controller has also been designed to implement a machine learning protocol in the future to better predict thickener performance. Figure 9 is a screen capture from the DCS. The left image depicts the input variables for the model. The right image depicts the graphical representation of the controller output (thickener underflow flow rate versus bed pressure). The different colour trends in the right image signify different mill throughput rates.



(a) (b)

Figure 9 (a) Dynamic model control interface; (b) Controller output

3.3 Early operating performance

During the early stage of thickener operation from April – October 2022, approximately 1.34 M dry metric tonnes of tailings were processed through the paste thickener at a grind size of 80% passing 82 µm.

It was found that the correlation between torque and bed mass provides a reliable method for monitoring thickener filling. Although torque is not used in the inventory control strategies, it provides an indication of tailings distribution and consolidation within the thickener that is evaluated day-to-day. Torque remains coupled solely to rake lift and to date there has been only one event in which high torque has triggered a rake lift to occur. As milling rates are scheduled to increase over the coming years, it is likely that torque will be integrated into the inventory control strategy.

During commissioning, mill operations encountered an event which lead to excess fine particles reporting to the thickener overflow. At the time, torque and bed mass were both considered low (20% torque and 35% bed mass). No downtime was incurred as the issue was quickly remedied. Further investigation concluded that a combination of circumstances including inadequate flocculant coupled with prolonged periods of zero underflow extraction created a scenario in which the thickener 'piled up', plugging the feedwell and eventually short-circuiting feed to the overflow. Aside from this early setback, thickener overflow clarity has been good and has not caused any issues in its use as mill process water. Figure 10 shows the correlation of torque and bed mass measurements using 12 hour shift averages.

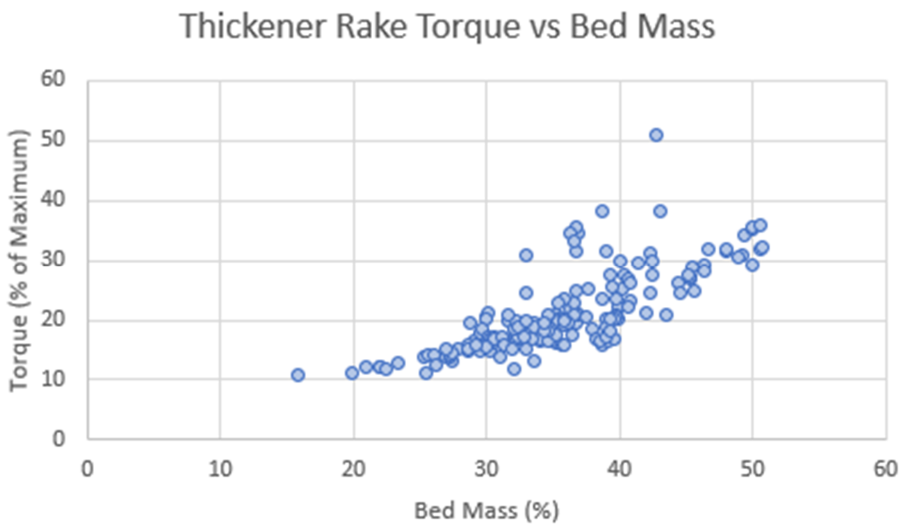


Figure 10 Rake torque and bed mass correlation

Given that the New Afton tailings particle size distribution is usually stable, bed mass and solids concentration are the two critical parameters that drive thickener performance and allow stable operation of downstream equipment through a consistent yield stress. The bed mass calibration is configured to read 100% when inventory reaches the mass/volume equivalent height of the feedwell bottom. Normal operation targets between 40 and 50% bed mass as this satisfies current solids concentration targets and allows ample time to deal with downstream upsets. During early operation, it was quickly identified that the nuclear density gauge was underreporting solids concentration compared to manual samples. This led to implementation of line pressure control that worked in conjunction with underflow solids concentration as described in the dilution control strategy section. This added redundancy was pivotal in increasing the reliability of the centrifugal thickener underflow and charge pumps. Figure 11 plots underflow solids concentration versus bed mass for both the online nuclear gauge readings and oven-dried manual samples. Prior to improvements in calibration, the gauge averaged between 2–4 wt% solids lower than actual. Controlling solids concentration at the higher end requires an increasingly high bed mass and discharge line pressure.

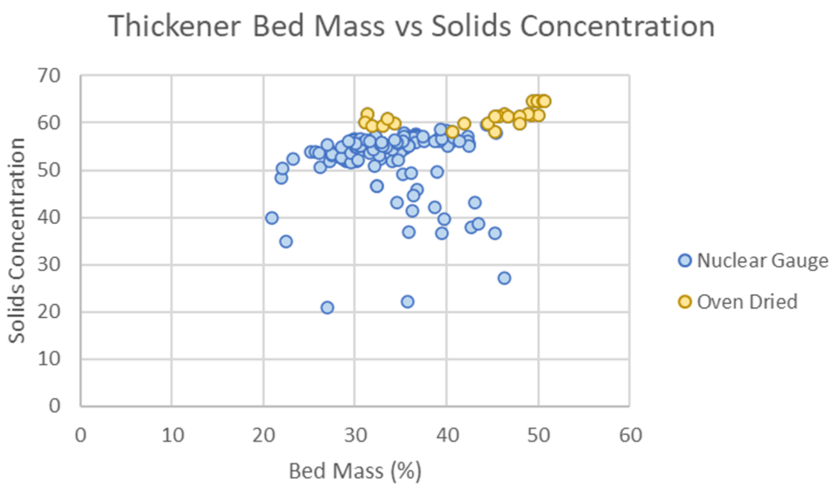


Figure 11 Thickener underflow density versus bed mass (online readings and sampled)

A shear thinning recirculation loop was installed in the TAT system and is usually in operation; however, its effectiveness in aiding thickened tailings transport (via an on-off trial) had not been evaluated as of October 2022.

The flocculant addition rate has been lower than expected at approximately 40 g/t versus 60 g/t. Coagulant was used briefly but was found not to be necessary based on overflow clarity. This matched laboratory testing which showed coagulant was not required for acceptable overflow (process water) clarity due to the low clay content of the current hypogene ore.

In preparation for a change in tailings deposition locations later in 2022, regular manual sampling of the thickened tailings were taken each 12 hour shift and oven-dried. Figure 12 shows the results for September – October 2022. These samples were taken at the charge pump intakes and would include any dilution water being added. Higher densities were periodically obtained in samples taken directly from the cone of the thickener (65–70% solids range); however, the rheological characteristics of tailings at these higher densities required dilution before downstream transportation.

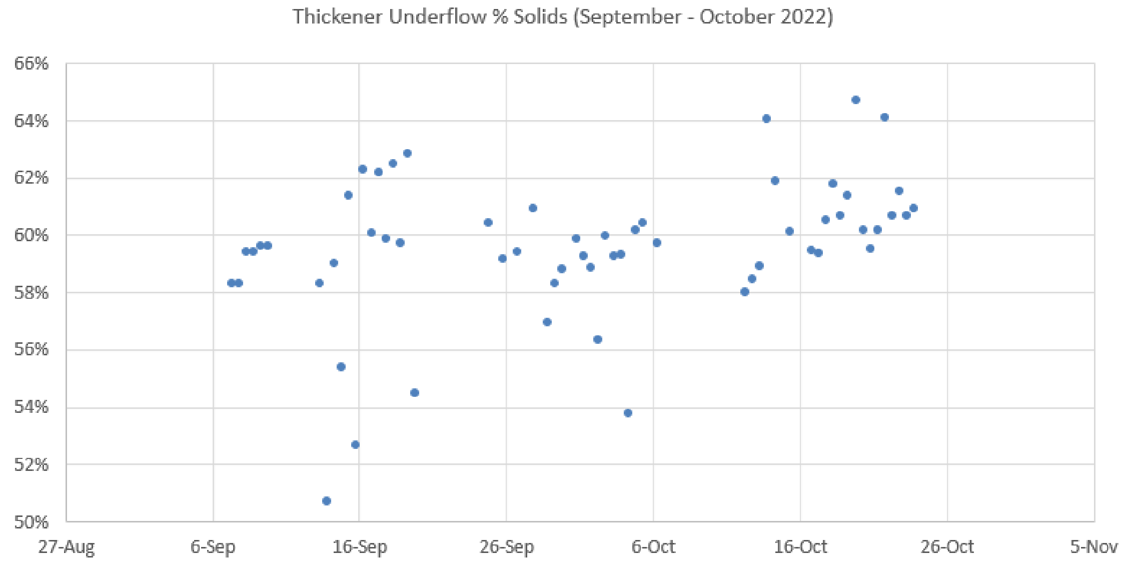


Figure 12 Thickener underflow 12 hour-shift solids concentrations (September – October 2022)

The size and performance of the paste thickener allowed for simplified operation achieving adequate density targets early on and was easy to control with reduced mill rates. The product density ranged about 60% solids during this time. Further increases in density were mainly impeded by the ability of the centrifugal pumps to move the thickened tailings between the thickener and the positive displacement pumps. This affected all centrifugal pumps (shear thinning loop, underflow pumps, and charge pumps). Sampling and rheological testing showed the yield stress of the thickened tailings was above the typical operating range of a centrifugal pump. A variable milling rate trial was conducted to assess the effect of throughput and grind size on the centrifugal pumps as well as to assess the overall performance of the TAT system at the higher milling rate and coarser grind size expected for operation during C-Zone mining. Figure 13 plots yield stress versus thickener underflow solids concentration for three different grind size ranges. Centrifugal pumping performance improved at the coarser grind sizes even at higher solids concentrations. While the chart is based on unamended samples (no cement added), there is a further increase in yield stress with the addition of cement.

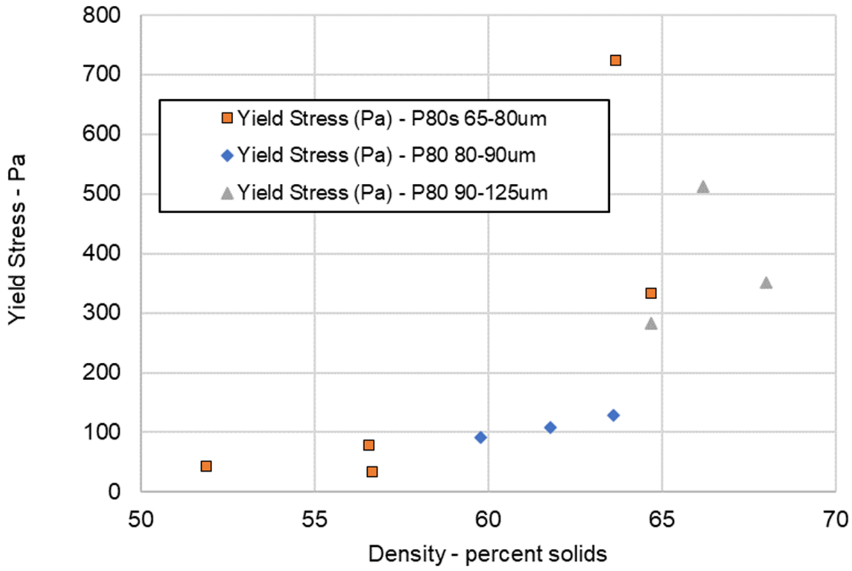


Figure 13 Yield stress of thickened tailings (no cement amendment)

The cement amendment system was commissioned in September 2022 and a trial of TAT was conducted in a specially constructed cell in the existing NATSF. Figure 14 shows the deposited tailings at approximately 61% solids and 1% cement by mass.

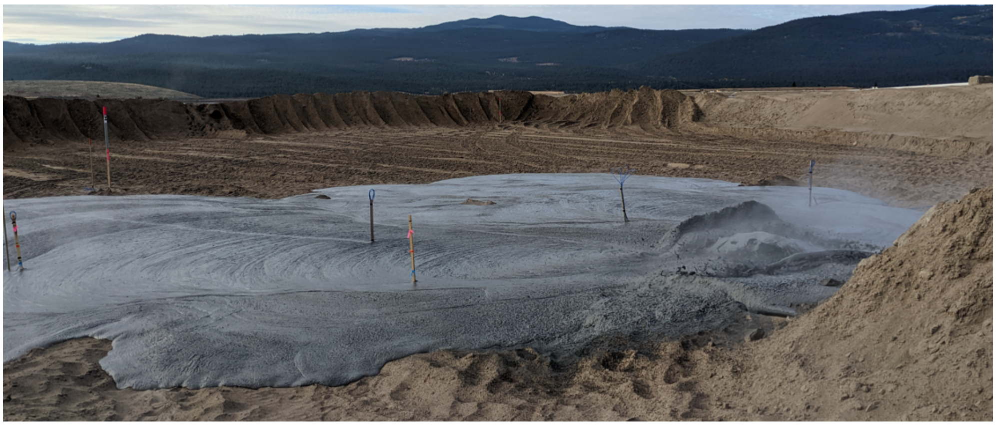


Figure 14 Deposition of thickened and amended tailings to a NATSF test cell

4 Conclusion

Paste thickeners continue to be an important part of a tailings management flow sheet, and improvement in their operational performance can bring benefits to both tailings management and project economics.

This paper has described the selection, commissioning and early operation of the New Afton paste thickener.

The Metso Outotec second generation paste thickener is the latest development of paste thickener with unique design features focused on optimising thickener performance to give the highest underflow solids concentration by maintaining a stable solids inventory and preventing rotating solids beds.

Consistent underflow solids concentration can be achieved through a stable solids bed and can be maximised by the use of multivariable thickener control.

Early operation has achieved target underflow solids concentrations. Initial test work conducted in 2018 indicated a feasible underflow solids concentration for this application was 60%, and during early operation underflow solids concentrations at or above this have typically been achieved. Overflow clarity has been stable and well below the target for total suspended solids. Fulltime utilisation of the paste thickener for tailings deposition was achieved within four months of slurry commissioning.

Acknowledgement

The authors would like to thank the following companies for their support on the paper and TAT project:

- New Gold Inc.
- Metso Outotec.
- Knight Piésold Ltd.
- Paterson & Cooke.
- Pocock Industrial Inc.
- SNF Canada.