Commissioning and Operation Experience with a 400 tph Paste Backfill System at Kidd Creek Mine

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Abstract

A paper was presented at the ACG 2004 Paste and Thickened Tailings conference in South Africa that described the design considerations for a 400 tph paste backfill system at Kidd Creek Mine. Since that time, the system has been constructed and commissioned and has experienced enough run time for observations and conclusions to be made regarding the performance of the system. This paper updates the final design criteria for the system and discusses the key items of interest including commissioning and operation challenges, methods of operation and lessons learned. At the time of writing this paper (December, 2004), the system has been in operation for 4 months and has placed approximately 120,000 tonnes of fill.

1. Introduction

1.1. System Overview

The paste system's primary function is to provide a cemented backfill material to satisfy the mining requirements for Falconbridge Limited's Kidd Creek Mine D. Mine D is the extension to depth of the existing Kidd orebody and includes mining depths from 6,800 ft below surface to 10,200 ft below surface. The current mining operations use cemented rockfill as their primary method of backfill, however, the capital and operating costs required to use rockfill at greater depths was substantially higher than pastefill. Through a number of feasibility studies, paste was identified as being an economical option that could provide the high strength materials and short cycle times demanded by the mining requirements.

The implementation of a paste backfill system at Kidd Creek is unfortunately not easy or typical. This is primarily due to the cost and technical issues associated with the delivery of a suitable fill material to the Kidd Mine site. The Kidd Met-Site (Mill) is located a distance of 32 km from the mine by rail or 50 km by road, which makes delivery of a fine tailings material expensive and technically difficult. A large number of options were evaluated regarding the sourcing, dewatering, transportation and processing of backfill materials. In the end, it was decided that the best option would be to reclaim tailings from an old gold mine to supply the fines required to make a paste and to supply sand for the remaining bulk of the materials. Currently, the tailings used in the paste system are excavated from an old dewatered tailings impoundment and trucked to the mine site where they are stored in a storage dome. Sand is also procured and transported by a contractor to site, where it is stored in a second storage dome.

The tailings and sand are loaded from the storage domes into the batching plant by front end loaders. The batching plant is very similar to a concrete batching plant and discharges a tailings/sand paste to one of two holding hoppers which feed the underground distribution system. The process flowsheet for the system is shown on Figure 1.

1.2. Materials Procurement

1.2.1. Tailings

Tailings are being excavated from an old gold mine tailings area. The tailings were deposited over 30 years from the perimeter of a rectangular dam impoundment and consist of quartz and plagioclase. The mine stopped using the tailings area in 1999 and the tailings have recently been dewatered and are currently being reclaimed and used as paste backfill at another nearby mine.

During these initial years of paste production when the tonnages required are relatively small, the tailings are delivered to the mine site by truck. When the tonnages become more significant, however, tailings will be transported on the back-haul of the ore train which delivers ore from the Kidd Mine site to the Kidd Met-Site.

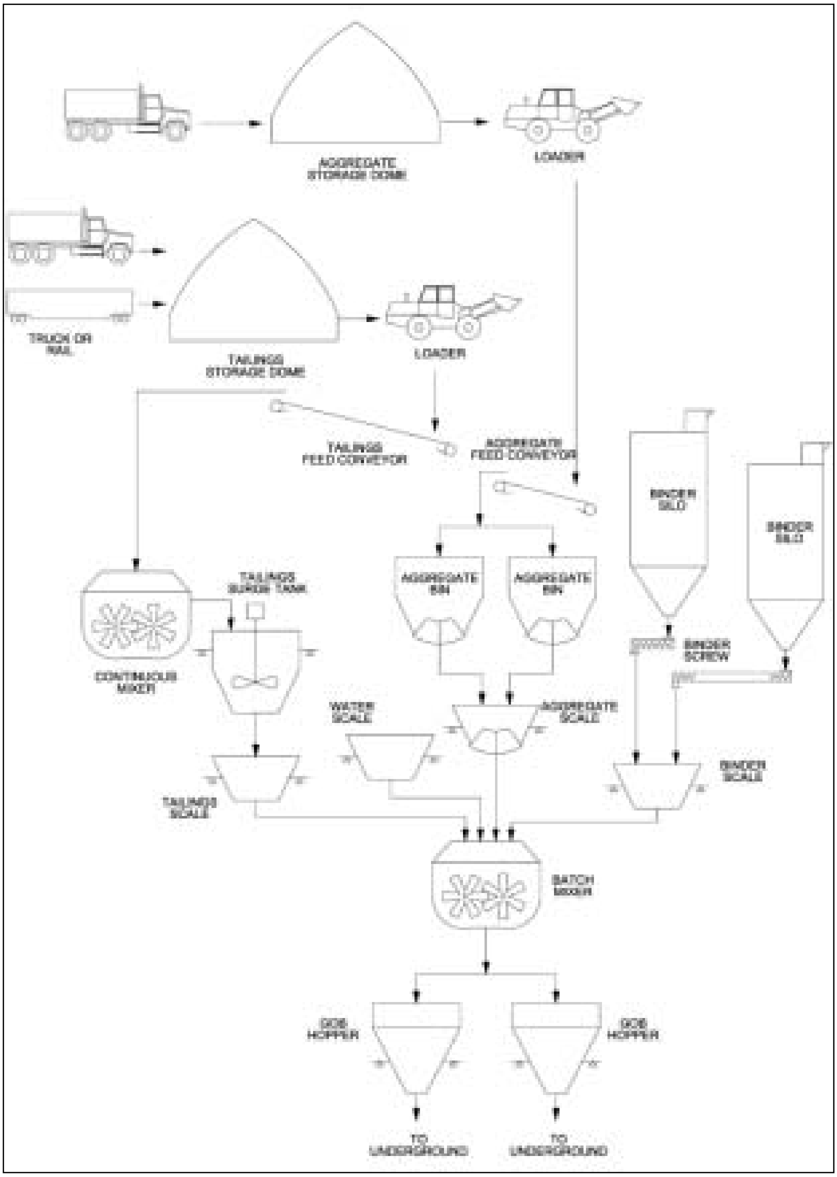

Figure 1: Process Flowsheet.

1.2.2. Sand

Sand is obtained from a nearby esker source. The sand source was selected for its close proximity to the mine site and a particle size distribution that fits nicely with the target tailings particle size distribution. It is desirable for the overall pastefill size distribution to be as well graded as possible since well graded materials tend to exhibit higher densities and higher strengths when cemented.

Sand is screened at the source pit before being loaded into a back dump truck and trucked to the minesite – a distance of approximately 10 km. At the time of writing this paper, the load-in facility to accept sand from the trucks and stack it inside the dome is not yet complete. The load-in facility consists of two bins that can feed the dome stacking belt at variable rates so that two different aggregates can be combined into a single product at whatever ratio is required before being stacked in the dome. The dome feed system is due to be completed in January, 2005. In the meantime, sand is offloaded and stacked by front end loader inside the dome.

1.2.3. Waste Rock

The paste system is capable of incorporating a waste rock product into the mix. Large amounts of crushed waste rock are present at the Kidd Mine site and provide several advantages: 1) use of waste rock results in a minor increase in strength, 2) the procurement cost of waste rock is substantially below the cost of sand and tailings and 3) the cost of closure for the waste rock dumps will be reduced.

Waste rock is not being used at this time because it relies on the dome feed system to be combined in the correct ratio with the sand.

1.2.4. Binder

The reaction of tailings with binder is dependent on tailings chemistry and mineralogy and has a huge impact on the quantities of binder required and, therefore, the cost of the fill. The tailings showed excellent strength properties when combined with a 90/10 mix of blast furnace slag and cement. Although the chemical reaction is complex, it can be simplified by describing it as a reaction between the blast furnace slag and the iron in the tailings which is catalysed by the small proportion of cement. In addition, the iron is present in a non-sulphur bearing mineral which eliminates the post-curing production and growth of gypsum crystals (which can have a detrimental effect on the long-term strength of the backfill). 28 day strengths with a slag binder were approximately 4 to 7 times greater than the strength with Portland cement binder.

1.3. Batching System

The pastefill plant resembles a concrete batch plant with the exception of a tailings handling circuit which allows the moist fine tailings recovered from the tailings area to be handled, weighed and batched into the process. A 3D view of the batching system is given in Figure 2.

The tailings are rehandled by front end loader out of the storage dome and into a live bottom feeder which is essentially a hopper with a bottom that is composed of 12 screw conveyors that convey the material towards the discharge onto a belt conveyor. This type of equipment is required to break up and move the fine sticky tailings material onto a conveyor. The tailings are then conveyed into a continuous mixer where they are diluted with water and mixed to a paste consistency before being discharged into a surge bin. From this surge bin, batches are withdrawn into a weigh hopper as required by the batch process.

The sand is rehandled out of the storage dome and into a hopper before being conveyed through a vibrating screen and then into one of two large surge bins in the plant. From these surge bins, sand is discharged through a clam gate and into a weigh hopper.

Binder is stored in two silos which are an integral part of the paste plant building. Binder is discharged from one or both binder silos through the action of a screw conveyor which fills a weigh hopper. A weigh hopper is also provided for the water that will be required in the batch.

Once all the weigh hoppers are full (tailings, sand, water and binder), they will dump into the batch mixer. Additional water will be added, as required, to bring the paste to the desired consistency before it is discharged through one of two discharge doors on the bottom of the mixer and into one of two paste hoppers.

Each paste hopper is mounted directly over a borehole which extends to the 1600 Level (approximately 1,600 ft below surface).

The underground distribution system is composed of a single borehole and pipeline arrangement down to 75 Level (7,500 ft below surface) at the time of writing this paper. The planned depth of the paste system is 10,200 ft below surface (see figure 2).

2. Design Issues and Commissioning Experience

2.1. Tailings Source

Two main sources for tailings were considered including those freshly produced at the Kidd Met-Site and those that could be excavated from an old gold mine tailings area. The preferred solution was to excavate the tailings from an existing gold mine tailings area rather than obtaining the tailings from the Kidd Met-Site. The pros and cons of this decision include:

- Kidd tailings exhibited only slightly higher strengths than excavated tailings.
- The particle size of Kidd tailings is consistent at 60% passing 20 micron while the particle size deviation in the excavated tailings area is huge (10-80% passing 20 micron). Tailings must be excavated under rigorous QA/QC and frequently require blending to meet the particle size specification.
- The allowable particle size for the excavated tailings for the current paste recipe is between 40 and 60% passing 20 micron. The strength difference between pastes composed of these two different materials is approximately 15%. This requires an increase in the amount of cement to account for the worst case (ie. the finer tailings at 60% passing 20 micron).

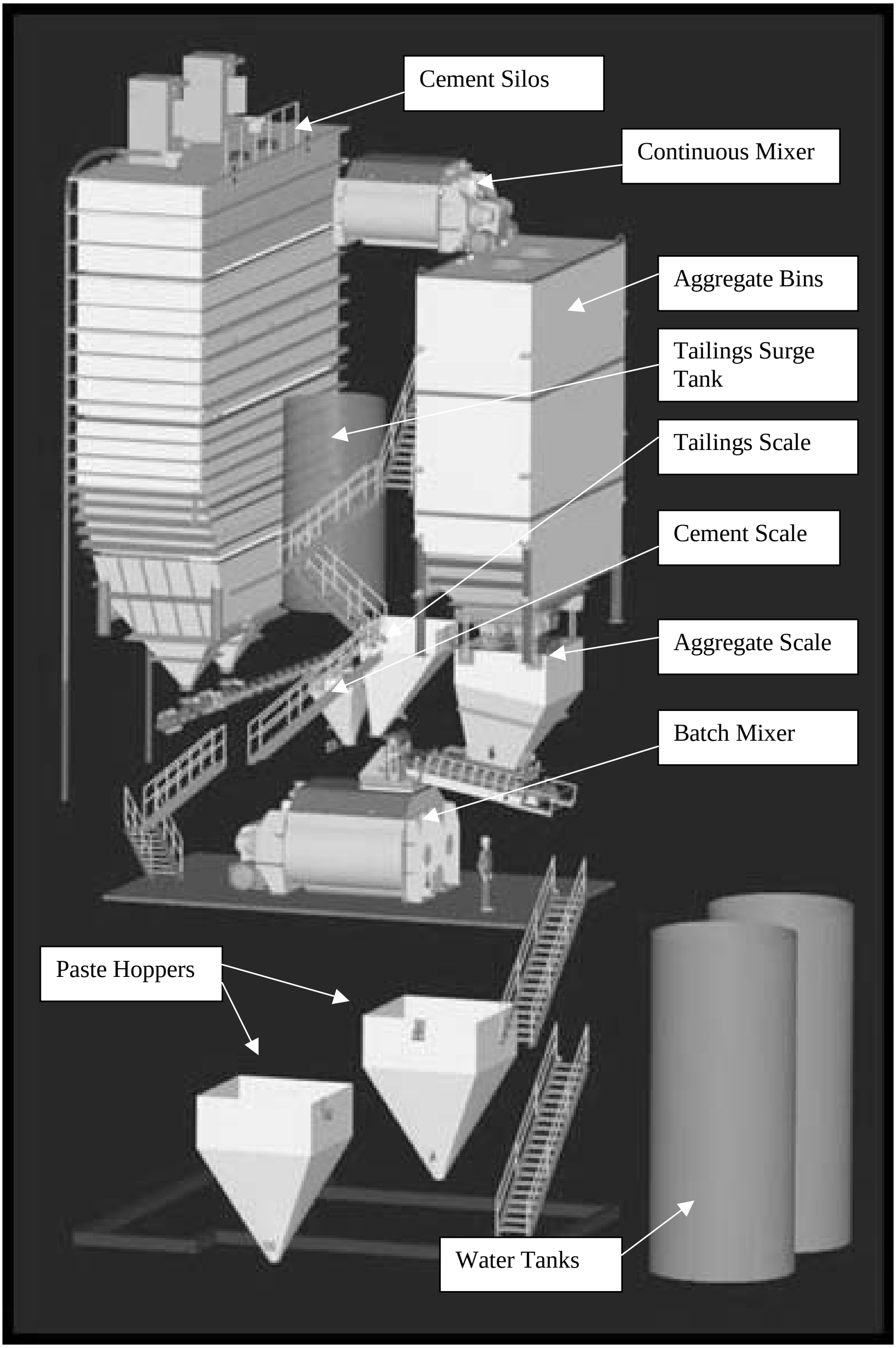

Figure 2: 3D view of paste plant.

Figure 3: Excavated Gold Mine Tailings.

- The excavated tailings can be transported with greater ease than Kidd tailings. The moisture content in the excavated tailings is typically around 17-19% vs. 23% for Kidd tailings that have been dewatered using vacuum filtration. At 17-19% the excavated tailings are manageable and can be discharged from the truck even after haulage vibration. At 23% moisture, the Kidd tailings liquefy and consolidate under truck transport and cannot be discharged easily from the truck.
- In addition, the higher moisture content of the Kidd tailings would result in harder to break up frozen chunks in the winter time. Currently, the tailings excavated from the gold mine tailings area form a crust that can be broken through with only minor difficulty by a front end loader. Higher consolidation levels and higher moisture contents in the Kidd tailings would result in greater difficulty during winter operations.
- Higher moisture contents with the Kidd tailings also results in leakage from the back of the highway dump trucks. The excavated tailings can be hauled in these trucks without any leakage.
- A third option - Older Kidd Met-site tailings (ie. already deposited) was not a serious contender for use in the paste backfill since they are contaminated with Jarosite which has an extremely adverse effect on strength gain.

2.2. Tailings Excavation

Extraction of the tailings focuses on the production of a blended and homogenised tailings that is reasonably dry and within the target particle size range.

As expected, the excavation of the tailings has proven challenging. The discharge of tailings over the years has been from perimeter spigots and generally, the closer to the center of the pond, the finer the particles. No significant mineralogical difference exists between the coarse and fine particles.

The tailings around the perimeter of the tailings area are competent and easily support excavation equipment, however as excavation proceeds towards the center of the pond the tailings become less stable and less able to support equipment. An overhead view of the tailings area is shown in Figure 4.

The target area for extraction of tailings is an approximate annulus midway between the perimeter of the tailings area and the center of the pond. The ground in this area is stable enough for excavation with a backhoe into dump trucks provided that a controlled extraction procedure is followed.

The extraction, blending and load-out is generally as follows:

- The target area is identified according to the results of particle size test pits.

Figure 4: Overhead view of Tailings Area.

- Geotextile is laid down along a ‘finger’.
- The backhoe extracts tailings to a depth of 15 feet from the finger into a dump truck. Water is pumped out of the pits and back into the central pond.
- The backhoe retreats back along the finger.

A QC technician using an on-site laser particle size analyser gives constant feedback to the excavator confirming that the particle size of the material being extracted fits with the mining plan.

Tailings are discharged from the dump truck at the screening area and are rehandled with a loader into a 2” vibrating screen/chopper that discharges onto a stacking belt and into temporary stockpiles. The vibrating screen removes oversize balls of agglomerated fines or chops them into small enough pieces so that the stockpile does not contain significant zones of segregation. Some balling of the fine agglomerated particles occurs and the balls roll down the edges of the stockpile, however this segregation is minor and is made insignificant by rehandling into the highway trucks and rehandling at the plant.

The QC technician determines the particle size of the various stockpiles as they are being produced and, if required, the stockpiles are blended together before being stacked in the load-out area.

Highway trucks are loaded with tailings by a front end loader and truck the material to the Kidd Mine site – a distance of approximately 50 km.

Major challenges associated with the extraction of tailings in this method have been addressed as follows:

- Winter extraction, screening and handling of the tailings was considered too difficult to be done. This issue was addressed by performing the excavation, blending and stockpiling of a years supply of tailings over a period of 6 months.
- Tailings delivered to the paste plant must be largely unfrozen so that they can be handled into the plant easily. This is addressed by removing and discarding the frozen skin of the tailings before loading the unfrozen material into trucks. At the time of writing this paper, the mine is currently experimenting with how much heating is required after the load-out of tailings into the highway trucks. In the worst case scenario, all stages of the tailings journey from the excavation area to the plant will require heating. This will include trucks with heated boxes, heated load-in facility and a heated storage dome.

Figure 5: Excavated Tailings – Note layers of coarse (brown) and fine material (grey).

- Handling of the tailings is difficult since the material is cohesive and tends to pack and bridge under any load. To handle this material, a live bottom feeder is used both to transfer tailings from the highway trucks into the storage dome and to transfer from the front end loader onto the batch plant feed conveyor. To date, the only problem with the live bottom feeder is the periodic jamming of rocks into the feed screws. Most rocks either pass through or ride on top of the screws. On three separate occasions however, a long wedge shaped rock succeeded in jamming the screw and tripping the motor overload. When this occurs it is necessary to run the other two sets of screws for the remainder of the pour and, once the pour is over, draw down the tailings and remove the rock. Figure 6 shows the middle set of screws still covered with tailings before being shovelled off and the rock removed.

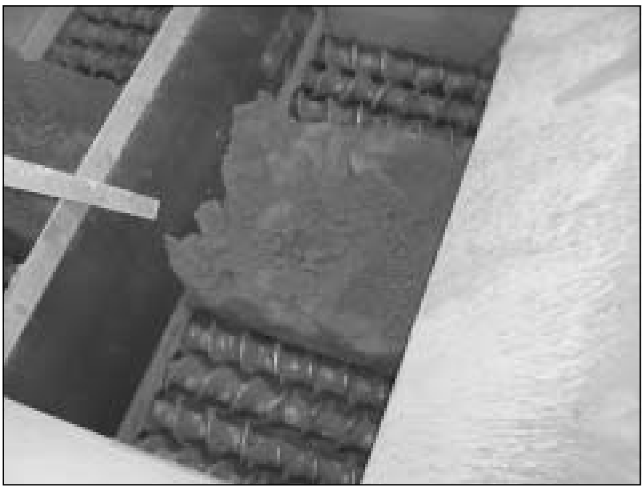

Figure 6: Live bottom feeder with middle set of screws stopped by rock. Screws are reverse flighted so that material is conveyed to the middle of the hopper and discharged out the bottom.

2.3. Paste Recipe

The paste plant was designed with the capability to handle a wide variety of materials as follows:

28%-100% tailings.
0%-72% primary aggregate (sand).
0%-72% secondary aggregate (waste rock).
0%-8% primary binder.
0%-8% secondary binder.

The only real restriction on the ratio of these constituents is that a minimum of 15% passing 20 microns be maintained.

The reason for the wide range of required recipes was that the mine wanted the flexibility to change its source of materials so that they would not be tied to any one material. This was required so that the most economic materials could be used in the paste recipe.

It is currently advantageous, from a cost perspective, to increase the amount of sand and waste rock in the recipe rather than tailings. To use less tailings however, the percentage of fines in the tailings must be higher so that a minimum level of fines in the total mix is maintained (for the mix to exhibit paste properties). Extracting these finer tailings from the tailings area is more difficult than coarser tailings and so there is a balance between the savings due to using less tailings and the extra cost required to extract the finer tailings. Currently, the ratio of tailings to aggregate is 45:55. Ultimately, it is expected that the ratio of tailings to aggregate could drop to 35:65.

The mine is currently investigating the use of some mine waste products such as mine dewatering slimes that could provide partial or full replacement for tailings. While these materials cannot be counted upon, it was desired to construct the system so that these items could be taken advantage of in the future.

2.4. Dome Storage and Plant Feed System

The dome storage and plant feed system was commissioned during the summer months and experienced few problems.

During the winter months however, the effect of subzero temperatures has proven a challenge for both the sand and tailings circuits. Several issues are being addressed at the time of writing of this paper, including:

2.4.1. Discharge from trucks

Currently the highway trucks used to deliver both the tailings and the sand are unheated, teflon lined and are equipped with a vibrator. Both the tailings and sand have been seen to freeze to the walls of the trucks and even with the Teflon liner and vibrator, are not discharged easily. The trucking contractor is currently experimenting with a number of solutions including:

- A change to the vibrator arrangement.
- Heated boxes (accomplished by routing the truck exhaust through a manifold on the truck box and covering the box with insulation.

2.4.2. Sand screening and plant feed

During plant operation, a front end loader picks up sand from the storage dome and loads it into a feed hopper where it is conveyed to a 2” vibrating screen to remove the oversize and then to the plant feed conveyor that fills the two sand surge bins in the plant.

To work properly, all the material and the equipment must (ideally) be either frozen or unfrozen. If the sand is frozen and hits a warm bin, the sand will immediately freeze to the bin and form a layer of buildup. If unfrozen sand is then placed into the bin, it will freeze to the frozen buildup and the layer of buildup will increase. Because of this, it is essential that if the sand is to be handled in a frozen state, that it is all frozen. In practical operation, this is difficult during the initial winter period since the outer skin of the sand stockpile is generally frozen, while the interior of the stockpile is not.

In addition, large frozen chunks of sand have been seen at the plant feed hopper that are jamming at the hopper discharge. This is being addressed by the installation of a grizzly at the sand hopper that will remove the large chunks or allow the loader operator to break large chunks by pushing them through the grizzly aperture.

Figure 7: Sand frozen to hopper.

2.4.3. Tailings freezing

During normal operation, a front end loader picks up tailings from the storage dome and discharges them into a live bottom feeder that, in turn, discharges onto the plant feed conveyor.

To this point in time, tailings freezing has not been a problem at the dome storage and plant feed system. The loader operators have experienced some difficulty breaking through the frozen crust of the tailings during a period of minus 25 deg C weather. However, once the crust was broken through, loading of the tailings into the live bottom feeder and conveying into the batch plant was not a problem. The live bottom feeder broke up frozen chunks of tailings into pieces that were smaller than 5” and conveyed them to the plant.

It should be noted that while there was no problem dealing with frozen material at the storage dome and plant feed system, the introduction of a large amounts of frozen material caused problems further downstream. This will be discussed in a later section.

2.5. Batch Plant and Underground Distribution System

Both the batch plant and the Underground Distribution System (UDS) are lumped together in the same section because they are intimately connected. Every upset, delay or other problem in the plant is reflected in the distribution system to some extent.

The objective of the batch plant is to receive and store the three constituents of the paste recipe and to combine them so that a batch with a precise slump (and viscosity) can be obtained. The paste is discharged to the UDS at a rate that is too great for the UDS to receive it. Essentially the borehole is always in a state of oversupply and the plant is always waiting until the level in the final paste hopper drops down to an acceptable level so that it can dump the next batch.

The slump control accuracy was seen to be quite good with the slump being within ¼" of the target over 90% of the time. Figure 8 shows a plot of the slump vs. mixer power draw for a certain recipe. The high level of slump control is essential to keep the borehole full since a single batch that is 'off-spec' can change the friction factor in hundreds of feet of piping and seriously affect the overall hydraulic balance of the system.

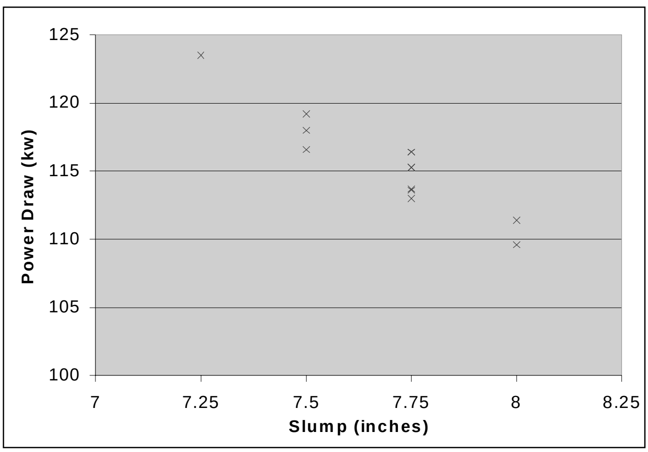

Figure 8: Slump vs. Moisture content for 45:55 Tailings:Sand Mix with 2% Binder.

The design capacity of the plant is 400 tph of dry solids. In reality, the plant can achieve close to 450 tph without sacrificing slump control accuracy.

Overall, the batching system works extremely well and some of the better design features are listed below, however there are also some parts of the design that could be improved upon. These are also listed below:

2.5.1. Tailings conditioner and rocks

During commissioning, a number of rocks were introduced into the tailings mixer by accident since the loader operators were loading tailings in from a temporary stockpile. Because the tailings mixer is an overflow style mixer and the paste level is near the top of the liner plates in the mixer tub, the rocks tended to ride on top of the surface of the paste and were jammed by the mixer paddle into the edge of the liner plates. This problem was addressed by replacing the top row of Ni-Hard liners and installing a row of mild steel liners (with a chamfered edge) at the top of the mixer tub.

2.5.2. Tailings temperature and hot water

The temperature of the paste in the winter time is a concern since only the tailings will be unfrozen and their temperature will be very close to zero. Sand would likely be added at minus 20 degrees C. To bring the total temperature of the batch to above zero hot water must be added to the tailings mixer. The hot water system is due to be commissioned by the first week in January, 2005. Some attempts were made to run the system in minus 25 degree weather which reinforced the requirement to have hot water for the paste mix.

The paste produced during this pour contained ice chunks and had the consistency of a 'slushie'. When the paste was discharged from the mixer, slumps tended to be higher than a warm paste at the same mixer power draw. In addition, as the paste travelled through the UDS it heated up due to friction and went from essentially zero to 20 degrees (Figure 9). If there were any frozen chunks in the line, this resulted in the ice chunks melting and increasing the slump of the paste as it travelled down the system.

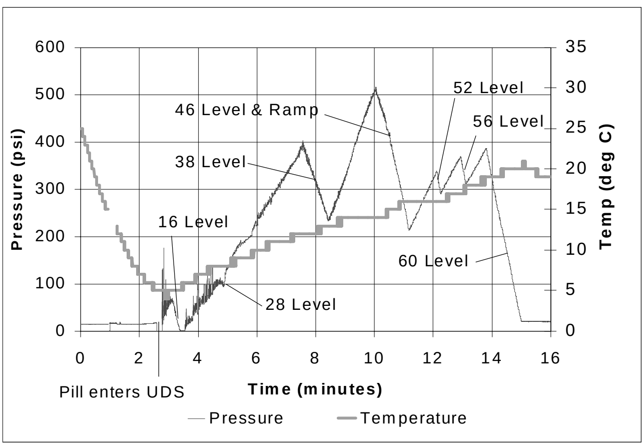

Figure 9: PAR Innovations Pill Data Showing Temperatures and Pressures.

2.5.3. Running the system full

One of the major objectives of the paste system was to run the system full to surface. This was accomplished with relative ease during commissioning to 16 Level (approximately 1,600 feet below surface). It was found that the plant could be operated at 400 dtph and the operators could make small changes to the target power draw every 5 or 6 batches to keep the average level in the paste hopper at the mid hopper level.

Once the pouring location reached a level 5,200 ft below surface however, the operators had to rely on the original design intent of choking the borehole by entering a target power draw that would restrict the flow through the UDS to a rate that was lower than the capacity of the plant. During this phase of the operation, the plant typically ran at between 325 and 400 dtph with a borehole full to surface.

2.5.4. Water hammer

Pipe hammer was observed during initial charging of the system when the borehole was not full to surface. This is a problem that results when the paste hopper valve opens and discharges paste faster than the borehole can receive it (ie. the back pressure due to the advancing flow of paste results in paste flowing in a full column). When this full, moving column of paste hits the existing column of paste in the borehole that is moving much more slowly, the rapid deceleration creates water hammer.

This problem had not turned up in the author's previous experience and, upon further investigation, it appears that the reason is due to the paste hopper placement. In most paste plants, the paste hoppers are located some small distance away from the borehole (not too long or the paste will not flow at all) so that the paste must flow through a pipe at a shallow slope before arriving at the borehole. This piping restricts the flow of paste such that once the paste reaches the borehole it flows down the steep hole (65 to 70 degrees) faster than it can be supplied through the paste hopper discharge piping. This results in the paste being 'strung out' and flowing as if in an open channel down the borehole. When the open channel flow meets the existing paste column, there is room for the paste to expand into and therefore the deceleration of the flow of paste is spread out over time and there is no pressure wave.

To solve this problem, the discharge valve was throttled to see if throttling the flow eliminated pipe hammer. It did and a permanent orifice plate is currently being installed. It should be noted that the throttling of the flow is only sufficient to prevent full column flow but does not restrict the capacity of the plant.

2.5.5. Hydraulic 'balance' of the UDS

Because the UDS extends into every corner of the mine, it is not practical to balance the system for every location. Our objective was to ensure that the system was designed so that the system could be made to run full to surface under virtually all occasions. This requires a smaller horizontal to vertical pipeline ratio on upper levels than lower levels.

Essentially, the system was designed with enough piping on each level so that the paste would be backed up into the borehole and the breakthrough elbow would not be exposed to the impact zone as the paste flowed down the borehole and around the elbow.

During the construction of the UDS, the schedule was tight and a shorter than designed length of piping was installed on 28 Level. During commissioning the elbow on this level wore out after only 25,000 tonnes went through it. The levels before and after were checked using non-destructive testing and were found to have negligible wear. The pipeline was lengthened on 28 Level and visual observations confirm that there is negligible vibration, however not enough paste has been poured since that time to confirm the theory that wear will be reduced.

In addition, the elbow on 16 Level was tested periodically with NDT testing and after 120,000 tonnes was found to have negligible wear. During the most recent pour however, ice chunks were present in the paste and the melting of the ice in the paste caused the paste slump to increase from the target 7” to approximately 10”. After 1,000 tonnes of this high slump paste, the elbow on 16 Level was worn completely through. Although it is not expected to be necessary to pour 10” slump material at any time, the mine plans to increase the horizontal line on 16 Level slightly to remove the possibility of this occurring again.

2.5.6. Casing installation

All paste boreholes at Kidd Creek were cased with 9” O.D., ¾” wall, Microtech W65 casing with threaded connections. Microtech W65 is a material commonly used in the oil and gas industry with excellent strength and abrasion resistance properties. The installation of casing was performed using a dedicated rod handler that was capable of suspending a string of casing for over 1,800 ft.

The rod handler was able to lift casing pipe off of a storage tray and to thread the pipe onto the previous length of pipe already suspended in the borehole. A sealing bead of weld was applied around the threaded connection to prevent infiltration of grout. The rod handler would then lower the casing into the borehole and repeat the process.

Figure 10: Rod Handler.

The rod handler worked well and was capable of installing 150 feet over a 12 hour shift. The only downside of this type of equipment is that the rod handler required welded stubs to be installed on each length of casing pipe. The stubs had to be removed before the casing was installed in the hole. There was considerable cost in the welding and removal of these stubs.

2.5.7. Pipe installation

Pipe was installed using a variety of equipment. For the mainline piping, a zoom boom was used to bring and support the pipe in place while a scissorlift truck was used so that the installation crew could drill holes and install the pipe hangers and bracing.

In addition, a dedicated pipe truck was purchased for installing the underground piping and fittings. It is basically a scissorlift with a zoom boom, pipe positioner and pipe rack attached. The zoom boom allows the pipe truck to load up to 10 pipes into the rack, travel to the installation site and mount them in place while the construction crew installs the supports from the scissorlift platform.

Figure 11: Pipe Truck.

2.5.8. Bulkhead construction

Kidd Creek use a shotcreted bulkhead style that has been used at Brunswick and Matagami mines. It includes an installation skid that is used to transport the bulkhead materials and serves as an erection platform for the installation of the reinforcement steel and substrate upon which the shotcrete is sprayed. Once the reinforcement is in place, the perimeter of the bulkhead is shotcreted with the skid in place. After the shotcrete cures, the skid is detached from the bulkhead and removed. The remaining areas of the bulkhead are then shotcreted, the sides are rock bolted and the bulkhead is ready to receive paste within 24 hours.

Figure 12: Shotcrete Bulkhead Construction.

3. Conclusions

During the initial commissioning period (ie. during the summer months) the plant worked very well. The performance of the plant equalled or exceeded the design standards for slump control, batch accuracy, capacity and consistency of the final paste product.

At the time of writing this paper, the second phase of commissioning – winter commissioning – is ongoing. It was anticipated that there would be materials handling issues associated with getting the sand and tailings into the plant during winter and we have not been disappointed. The solutions to the winter handling issues are currently being implemented.

References

Lee, C., Landriault, D. and Durr, R. (2004) *Design Considerations for a 400 tph Paste Backfill Plant at Kidd Creek Mine.* In *Proceedings for the International Seminar for Paste and Thickened Tailings 2004.*