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Design Considerations for the Big Gossan 300 Tonnes per Hour Paste Backfill Plant System

E. Ansah-Sam *Golder Paste Technology Ltd, Canada*

C. Lee *Golder Paste Technology Ltd, Canada*

S. Hewitt *PT Freeport Indonesia, Indonesia*

Abstract

PT Freeport Indonesia (PTFI) is currently developing the Big Gossan mine, a new 7,000 tpd gold and copper underground mining operation located in the mountainous and remote Indonesian province of Papua (formerly Irian Jaya).

Ore production is scheduled to commence in 2009 utilising transverse blast hole stoping methods that rely on the timely and rapid placement of reclaimed tailings paste backfill. A 300 tph paste backfill system has been designed and construction is scheduled to commence in 2008. The paste plant infrastructure is split, with surface facilities located near the mill concentrator and the remaining infrastructure located underground.

The surface facilities include a tailings classification system that allows PTFI to adjust the particle size distribution to optimise the strength, dewatering and rheological characteristics of the paste. The classified tailings are then pumped up by a piston diaphragm pump to the underground paste plant which is located approximately 2 km inside the mountain.

The underground paste plant includes a number of interesting features, such as a cement unloading system designed to handle 25 t bulk pneumatic ISO containers (isotainers), delivered by flatbed truck into the mine, a water recycling system using a Lamella clarifier, and the use of a combination of induction hardened steel and ceramic lined piping to extend the lifetime of the paste distribution pipeline.

This paper primarily discusses these features of the paste system, their benefits and effects on their operation.

1 Introduction

PT Freeport Indonesia's (PTFI) Big Gossan mine is a new 7000 tpd underground mine that will be brought into production in 2009. It is located within the Grasberg minerals district and adjacent to the mill concentrator. The new mine will employ transverse, blasthole stoping and as such, requires a cemented backfill to support all of the primary stopes and most of the secondary stopes. PTFI has elected to use paste backfill to facilitate fast fill cycle times, favourable fill economics and a desire to dispose of some of the tailings produced by the mining and processing operations, back inside the mine.

Most paste plants are located on surface with either pumped or gravity flow paste delivery to the orebody. The Big Gossan mine however, is located several hundred meters above and several kilometers laterally from the mill where tailings can be reclaimed. The mill is located in a valley with steep mountains rising up on either side of the mill, and since the orebody is located significantly higher relative to the mill and over 2 km away from the mill, the best economic location of the paste plant was underground, in the mountain and above the orebody. The obvious benefits of this location are a reduced paste pipeline length and the ability to gravity flow the paste to a large number of stopes. Reclaimed tailings slurry will be pumped to the underground paste plant where it will be dewatered, mixed with cement and either pumped or allowed to flow by gravity to the stopes. The paste plant has a nominal capacity of 260 tph of dry solids.

The Big Gossan paste plant includes several interesting features that are not commonly found on other paste systems. These features include:

- A tailings classification system that will allow the particle size distribution to be modified for various strength and dewatering benefits.
- An inclined plate clarifier that will allow water to be recycled.
- A cement transportation and unloading system that will allow cement to be transported, stored and discharged safely and efficiently from a 25 t bulk pneumatic ISO containers (isotainers).
- An induction hardened steel and ceramic lined piping distribution system.

This paper discusses these interesting features, their benefits to the paste plant system and its effects on the operation of the system.

2 Paste plant system

The Big Gossan mine will be implementing the transverse blasthole stoping method to mine the copper and gold ore. Rapid placement of fill will be required for this mining method so a paste plant has been designed and is to be constructed, in 2008, to provide paste backfill when ore production starts in 2009. The paste plant designed for the Big Gossan mine is split into surface facilities and underground facilities. The surface facilities are located near the mill concentrator while the underground facilities, the paste plant, are located in the mountain, approximately 2 km laterally and 270 m higher than the concentrator. Figure 1 shows the mill concentrator.

Figure 1 Mill concentrator

2.1 Surface facilities

The surface facilities incorporate a tailings reclamation structure, centrifugal pumps, cyclopac, agitated tank and a piston diaphragm pump. The purpose of the surface facilities is to extract a portion of the tailings from an existing 74.67 m thickener underflow, modify the particle size and then pump it to the paste plant located underground for dewatering.

The tailings will be recovered downstream of the 74.67 m diameter thickener as the tailings flow from a drop box through a 1.22 m square opening into an attached drop box. Approximately 6 to 8% of the total flow from the existing thickener underflow will be extracted for the paste plant. To capture the tailings, a new pump box will be constructed and attached to the two existing drop boxes. Tailings slurry from the existing drop box will then overflow into the new pump box from where tailings will be withdrawn for paste application. Flow to the pump box can be stopped by inserting an automated sluice gate when the paste plant is shut down. The pump box will drain into one of the drop boxes when the paste plant is shut down.

The tailings collected in the pump box will be split with part of the flow being pumped to the cyclopac and part of the flow being pumped to an agitated tank that collects the cyclone underflow. By varying the number of cyclones in operation, the percentage solids of the cyclone feed and the flowrates of tailings going either to the cyclones or to the agitated tank, the particle size distribution of the tailings can be adjusted. In addition, the cyclone underflow is discharged at higher percentage solids than is achievable by the thickener. This allows the percentage solids of the tailings mixture being pumped to the paste plant to be increased.

The process flow sheet for the surface facilities is shown in Figure 2 while the layout is shown in Figure 3.

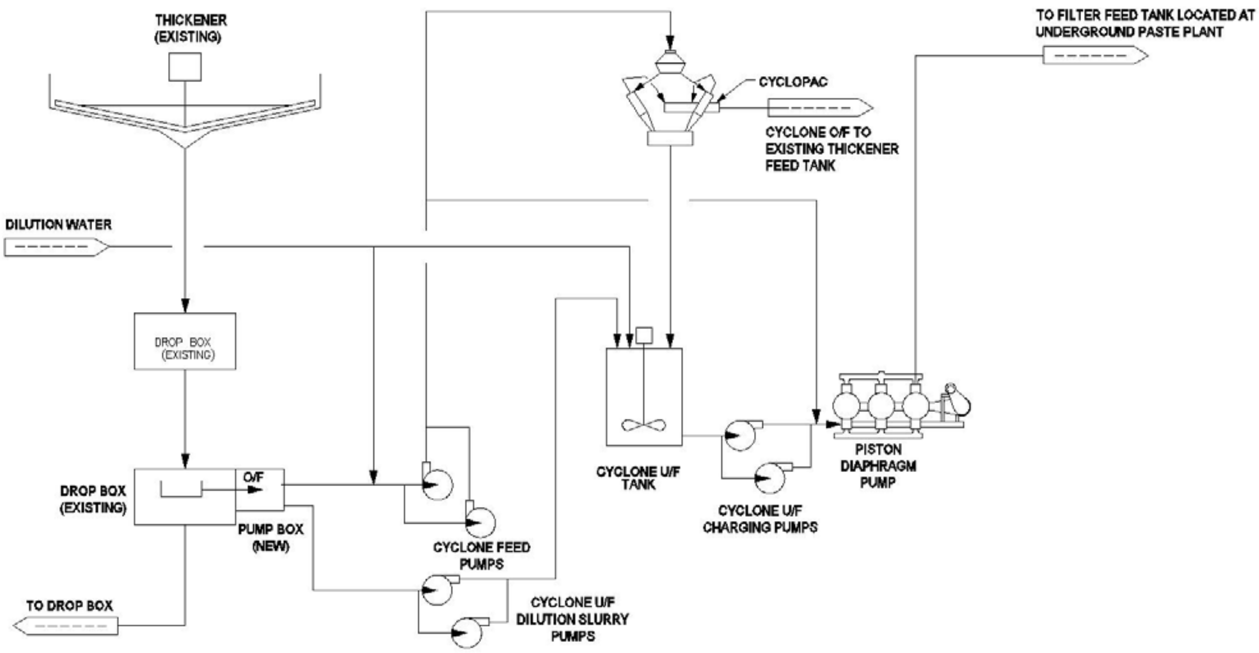

Figure 2 Process flow sheet for surface facilities

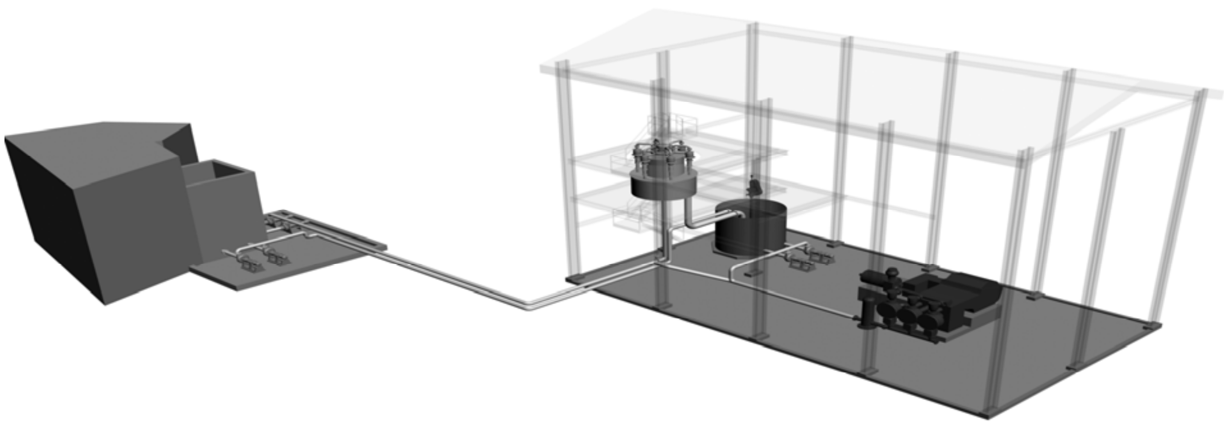

Figure 3 Plant layout for the surface facilities

2.2 Underground facilities

The underground facilities are composed of disc filters, mixers, silos and piston pumps. The underground facilities also feature a piped distribution system that allows the paste to be transported from the paste plant into the stopes. The purpose of the underground facilities is to receive the tailings slurry from the surface facilities and process it into paste.

A 2 km, rubber-lined slurry pipeline will discharge the processed tailings from the surface into an agitated filter feed tank located in the underground paste plant. From the agitated tank the tailings will be pumped to three vacuum disc filters for dewatering. The filters will discharge a cake onto a conveyor which, in turn, will discharge into a continuously overflowing mixer. Processed tailings slurry directly from the filter feed tank will then be added to the continuous mixer such that the overflow achieves the desired paste consistency and slump 212 mm. The paste from the continuous mixer will overflow into a surge hopper from where batches will be withdrawn into a weigh hopper. Cement will be discharged from silos to screw conveyers which will convey the cement to a single weigh hopper. Both the tailings and binder weigh hoppers will discharge into the batch mixer where small amounts of process water will be added in order to bring the paste consistency to the designed slump. When the mixer contents are at the correct slump, the batch mixer will discharge into a hopper and the paste will be pumped by two hydraulic piston pumps or allowed to flow by gravity to the underground stopes.

Water required in the plant will be supplied from a water tank by a pump. Both compressed air and instrument dry air are required in the plant. Compressed air will be required on the vacuum disc filters and will be supplied from the mine compressed air system while instrument air will be supplied by a dedicated instrument air compressor.

The process flow sheet for the underground facilities is shown in Figure 4 while the plant layout is shown in Figure 5.

3 Features of the paste plant system

Several features of the Big Gossan paste plant are discussed here. The features include:

- A classification system.
- A water recycling system.
- A cement unloading system.
- A combination of a ceramic lined and an induction hardened piping system.

3.1 Tailings classification system

The tailings classification system is a featured component of the surface facilities and while not unprecedented is an unusual inclusion in a paste plant. Frequently, most mines are unable to classify their tailings since they need about 60% of the full production rate of tailings to satisfy their backfill requirements. Because the Big Gossan mine is part of a larger complex, tailings availability is not an issue, so the option to customise the particle size to optimise the paste performance is available.

Laboratory test work carried out on the tailings materials during the design phase showed that the fineness and percentage solids of the slurry from the 74.67 m thickener is variable and also contain a high level of submicron particles some of the time. It also showed that the percentage solids of the slurry range from 55 to 65%. The effect of the high percentage of submicron particles on the filtration process is a reduction in filtration capacity and thus a requirement for more filtration units. The submicron particles reduce the filtration capacity by blinding the filter cloth and thus reducing the area available for filtration. To minimise the number of filter units, the cyclone manifold system and the agitated tank was designed into the paste plant system to modify the particle size distribution of the tailings material.

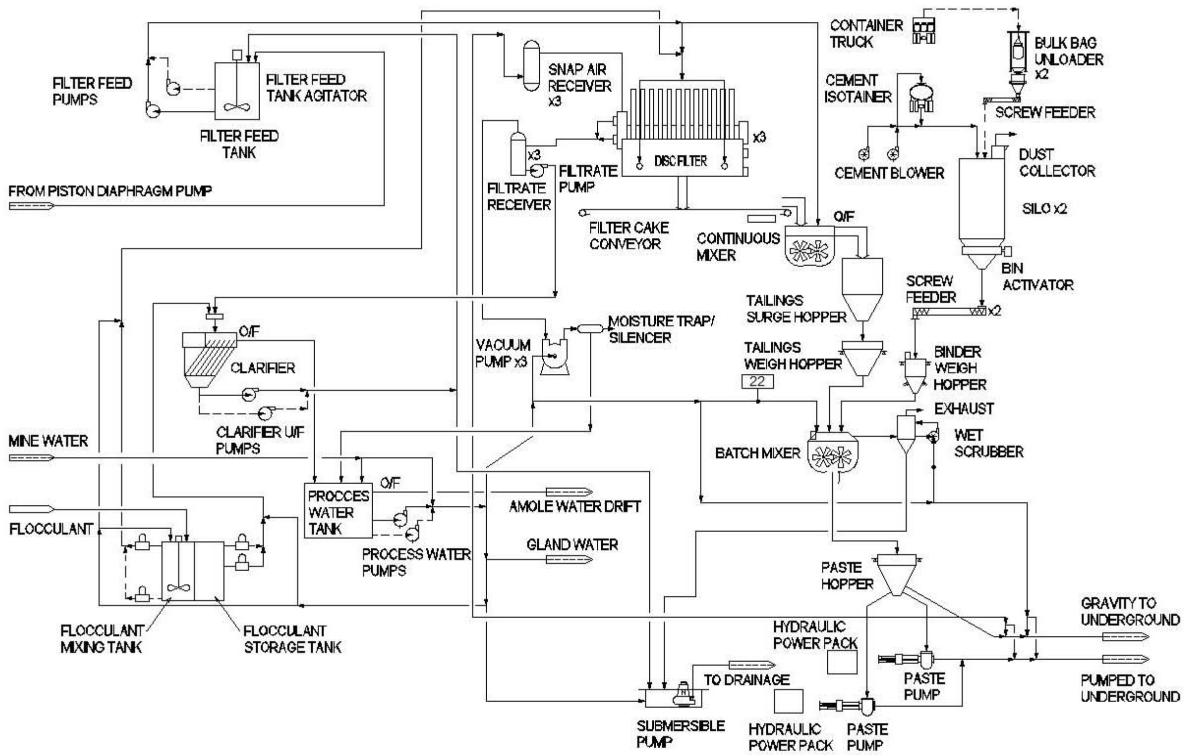

Figure 4 Process flow sheet for underground paste plant

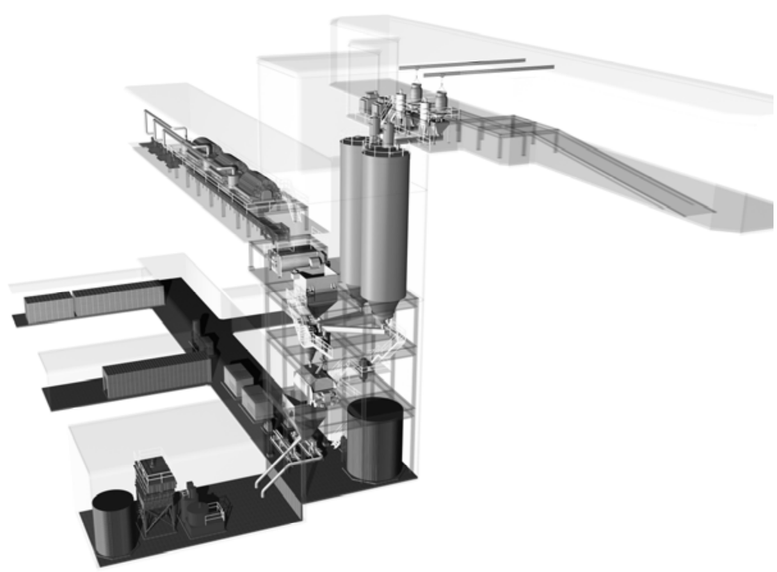

Figure 5 Plant layout for the underground paste plant

To achieve the proper density for operating the cyclone, the system has been designed to allow dilution water to be added to the pump suction to dilute the tailings when the feed is being pumped from the pump box to the cyclones. The fine cyclone overflow will drain by gravity to an existing thickener feed box located approximately 100 m away and close to the mill, while the coarse underflow will discharge into the agitated tank. Primarily, the function of the cyclone manifold system is to reduce the level of fines in the tailings material. However, since the fines are desired in paste production, a second tailings stream will be pumped directly from the pump box into the agitated tank to dilute and modify the particle size distribution. The two streams will be mixed together in the agitated tank. The amount of tailings to be added will be targeted to optimise the strength, dewatering and rheological properties of the paste.

To maintain an acceptable density for pumping and filtration, water will be added to the agitated tank material. A pump will then transfer the modified tailings in the agitated tank to the piston diaphragm pump for pumping the 270 m vertical head into the filter feed tank located in the underground facilities.

The particle size modification system will produce tailings slurry with 20% passing 20 micron versus the unmodified slurry at 38% passing 20 micron. The implications of this flexibility with respect to particle size and % solids are as follows:

- The coarsening of the tailings feeding the paste plant and the removal of a large percentage of the microfines will increase the filter performance (i.e. increase the tonnage of filter cake that can be produced per unit area and increase the % solids of the filter cake). Golder has performed laboratory scale testing with cycloned tailings in order to confirm the filtration capacity that can be expected and these results show an increase from 0.23 $t/m^2/hr$ for unclassified tailings versus 0.33$t/m^2/hr$ for classified tailings. The filtration capacity even increased to 0.60$t/m^2/hr$ when flocculant was added.
- The cycloning step also increases the % solids of the tailings. With an increased % solids, the filter capacity increases since the filter needs to remove less water from a thick slurry than a dilute slurry.
- Although the primary reason for coarsening the tailings is to increase filtration performance, the particle size adjustment will also increase the strength of the paste (or, alternatively, allow the same strength to be achieved with less cement). It is expected that approximately 140 kPa of strength would be achieved through adjustment of the particle size distribution. Target strength for primary stopes is 380 kPa based on the method of Mitchell et al. (1981), and for secondary stopes is 970 kPa based on gamma*H.
- The coarsening of the tailings is not without some drawbacks. The increased particle size typically increases the wear on the system pipeline and, if the particle size is coarsened excessively, the paste matrix will not be stable and the risk of plugging the paste lines will increase.

3.2 Water recycling system

Potable water is required for a number of plant processes including vacuum pump seal water, gland water, slump control water, flocculant water, dust collector flush water, high pressure water and hose station water. Sources of potable water supply are: the mill concentrator, rainwater, and filtrate water from the dewatered tailings.

Water from the mill concentrator (which has an acceptable pH) would have required several high pressure pumps and a 2 km pipeline to get the water up the mountain to the paste plant. The mine water is replenished by frequent rainfall so water is collected within the mine and is used for most of the mines requirements. However, the mine water tends to be acidic due to its filtration through acid producing host rocks. Using acidic water as fresh water in the paste plant will likely accelerate corrosion of the paste plant equipment and pipelines.

The only attractive and economic option was to recycle the reclaimed water from the slurry. To do this, the paste plant has been designed to pump the filtrate water, which typically contains about 0 to 2% fine solids from the vacuum disc filters to a Lamella Clarifier. The Lamella Clarifier is an inclined plate settler and consists of two main components, the upper tank consisting of the plates which are inclined at 55^o and the lower conical tank for the sludge. The Lamella uses the parallel inclined plates to maximise the available settling area and thus requires a smaller footprint compared to other settling equipment. When the filtrate water is fed to the Lamella, the solids settle onto the plates and slide down. Clarification occurs above the feed inlet so there is no mixing of the clarified water with the incoming feed.

Flocculant will be introduced into the feed to enhance settling of the fine particles from the filtrate water. The overflow from the clarifier, which is clear water, is run through a filter to further remove any residual fine particles before it is allowed to flow by gravity into a process water tank. The underflow containing the fine solids will be pumped to the filter feed tank for recycling into the paste backfill. This process allows the water recovered from the tailings to be reused as fresh water in the paste plant. Figure 6 shows the Lamella Clarifier.

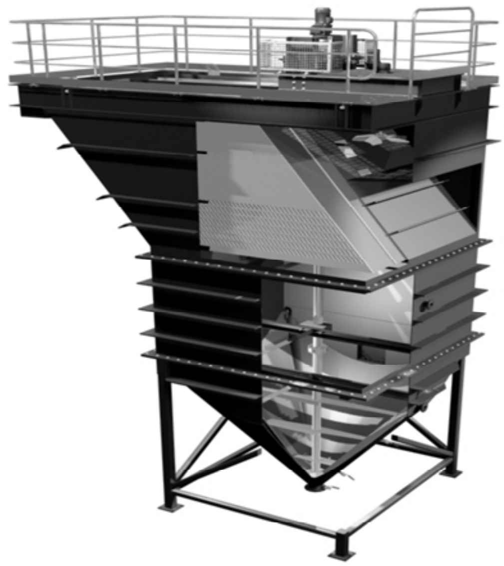

Figure 6 Lamella clarifier

3.3 Cement delivery and unloading system

Cement is typically introduced into paste backfill for structural strength. For the Big Gossan backfill to remain free-standing after exposure, the backfill will need to possess 380 kPa of strength for primary stopes and 970 kPa of strength for secondary stopes. Unconfined compressive strength tests carried out on the unclassified tailings after 28 days of curing time showed 563 kPa at 175 mm slump and 3% cement and 1083 kPa at 250 mm slump and 5% cement. Thus average binder content of 3% and 5% will be required to achieve the strength mentioned above. For a daily ore production rate of 7000 t, the mine will require a daily paste backfill of 3089 t. Thus, approximately 155 t of cement will be required for paste production in a day.

To meet cement requirement for the paste plant, pneumatic transport was considered. Pneumatic transport offers several benefits, including economic short-distance transport of cement, dust-free conveyance, automatic operation and labour savings and flexibility in pipeline routing.

Because the mine site is located on an island, cement is transported to the port by ship where it is offloaded and trucked to the mine site. The mine therefore needs transport, storage and handling solution that optimises the movement of cement from the off-island cement plant, all the way to the paste plant. Currently, the mine uses 1 t bulk bags which are shipped in standard containers. The containers are stored until needed, at which time the bags are extracted from the container by forklift and discharged into a bag handling system. The empty bags are disposed of through the plant-wide waste disposal system.

For the paste plant, cement will be delivered in specially designed 25 t pneumatic bulk ISO containers (isotainers) on a flat bed truck. The isotainer is a high quality tank container protected by an ISO frame (i.e. a frame that fits within a standard container shipping specification). The design enables ease of cleaning, maintenance and reuse throughout its long life. It is safe to use, easy to clean and economical to transfer between road, rail or sea. It has a working pressure of 175 kPa and is typically hydrostatically tested to 1.5 times this working pressure when manufactured.

The vessel has an air supply inlet and product discharge outlet and functions much the same as a typical bulk cement tanker truck. The discharge outlet has four discharge cones, fitted with aerators which aid a complete clean out of the isotainers. The cement-filled isotainer will be transported by flatbed trucks through the mine to the cement unloading level. From the cement unloading level, the isotainer will discharge via a blower into either one of the two silos. The isotainer can discharge 25 t of cement within 20 to 25 minutes. Figure 7 below shows a trialled isotainer on a flatbed truck.

Figure 7 Isotainer on a flatbed truck

As a back up to the pneumatic system, a bulk bag unloading system is also designed into the cement delivery system. Cement will be transported to the cement unloading level in 1 tonne bulk bags. A forklift will withdraw the bulk bags from a container and will place the bags underneath a monorail hoist. The hoist will lift the bag onto the bulk bag unloader where the bottom of the bag will be punctured to allow the cement to discharge into the unloader. The unloader has an integral dust collection system and screw discharge into the cement silo.

3.4 Paste distribution pipeline material

Ore production will rely heavily on paste backfill which suggests that paste filling will be very critical in the Big Gossan mine operation; hence, any downtime in the filling operation will be detrimental to ore production. Paste fill utilises distribution lines, including boreholes and pipes, to transport the paste to its desired location. At the Big Gossan mine, the boreholes will require casing to prevent underground water from diluting the paste.

Generally, paste distribution lines experience wear with time and especially with free fall in long boreholes. The wear is mostly due to the impact of abrasive particles on the surface of the distribution piping material (as opposed to corrosion). The impact causes plastic deformation which eventually causes loss of casing material. Wear is even more severe when particles are coarse and velocity is high.

Drilling of new boreholes or rehabilitation of long boreholes and replacement of high-pressure piping is not only costly but also requires a lot of time. For these reasons, correct casing and piping material must be selected for paste distribution lines.

Particles of the Big Gossan paste material are expected to be fairly coarse and will thus have the tendency to accelerate wear on the paste distribution lines. Consequently, a carbon steel material lined with a ceramic composite material has been selected as the casing material for the long boreholes. The composite material comprises beads of alumina oxide, silicon carbide and silicon dioxide in an epoxy resin matrix as shown in Figure 8. It combines the wear resistance of ceramics with the flexibility and shock resistant benefits of a composite technology.

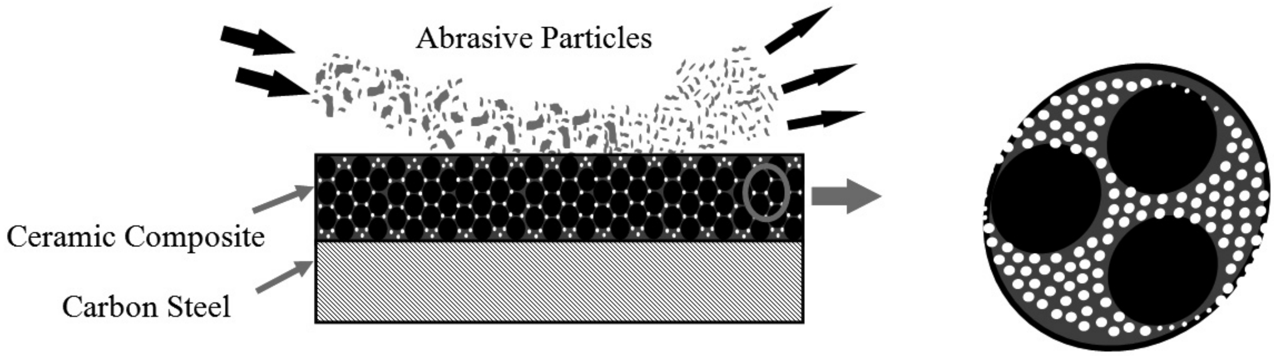

Figure 8 Ceramic composite material showing beads of silicon carbide and dioxide

Properties possessed by the ceramic composites include high-energy absorption and high Rockwell hardness, both of which are desirable for the long boreholes.

Abrasion resistant piping has also been selected for the lateral low and high pressure lines.

The abrasion resistant piping material selected for this application is a high-yield steel. The pipe will be a single wall pipe material which has been hardened on the inside by induction heating followed by quenching. A hardness profile of 600 BHN (58 HRc) is achieved on the inside and 250 BHN (25 HRc) on the outside after quenching. This hardness profile provides an abrasion resistant inner wall to resist service wear and outer wall properties that provide strength for resisting pressure and ductility for absorbing shock and vibration typical in paste fill applications. Figure 9 shows the hardness profile of the selected pipe.

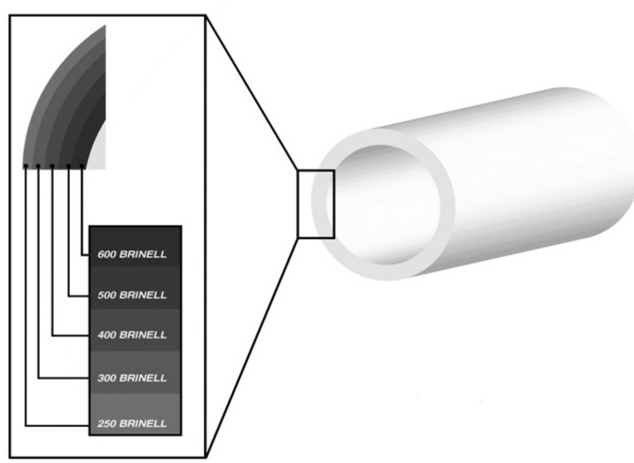

Figure 9 Hardness profile of the selected high and low pressure lateral lines

The pipe thickness for the high and low pressure applications are 12.7 and 9.5 mm, respectively. They are designed for a maximum pressure of 70 and 120 Bar respectively. The pipes have an available thickness of wear of 6.0 mm for the low pressure pipe and 6.5 mm for the high pressure pipe.

The combination of induction hardened steel and ceramic lined piping system selected for the Big Gossan underground paste distribution system will no doubt allow a high tonnage of paste fill to be placed before failure and will form an integral part of the filling operation and ore production.

4 Conclusion

Several challenges were faced in locating the paste plant given the landscape of the mine site and the elevation difference of approximately 270 m between the mill and the orebody. Locating the paste plant on surface and close to the mill where the land is relatively flat would have incurred an extremely high pumping cost. Although locating the paste plant underground presents some challenges as well, the economic benefits are higher and include the ability to gravity flow the paste into stopes which means a lower pumping cost and a reduced paste pipeline length. Essentially, the option of pumping slurry over 2 km and to an elevation 270 m higher is preferred over pumping paste the same distance.

The paste plant designed for the Big Gossan mine will be a critical component and an integral part of ore production. The paste plant system can boast of certain interesting and critical features that will allow the operating cost per tonne of backfill to be minimised. These features include a classification system that will allow the particle size distribution of the tailings to be adjusted to optimise cement requirement for the desired strength. The water recycling system will also allow the water dewatered from the tailings to be reused as process water and thus avoid fresh water requirement. Even more critical is the cement delivery and unloading system which allows a cost-effective means of handling the cement.

The superior ceramic composite and induction hardened piping material selected for the borehole casing and the lateral lines for the underground distribution system will allow a high tonnage of solids to be transported before failure/replacement and thus minimise the cost per unit of fill placed.

References

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