High Tonnage Surface Stacking
Impediments to Implementation

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ABSTRACT

Water is a significant issue in the Atacama desert, and at a variety of mining locations worldwide. Maximizing water recovery makes sense both economically and environmentally. Surface stacking of tailings would appear to significantly improve water recovery for a limited additional capital expense. An additional benefit is extending the tailings impoundment life. However, even though surface stacking of tailings would appear to be both feasible and reasonable, the number of mines practicing this method is relatively low. So why hasn't this technology taken off in a dry climate like the Atacama? A number of studies have been done looking at applying these methods to handle very high tonnages, but none of them have gone ahead. This paper will consider some of the reasons why and the barriers to implementing these projects.

1. INTRODUCTION

Thickened tailings disposal (TTD) or surface stacking involving the disposal of tailings without the formation of a tailings pond using either dry stacking or central thickened discharge, is becoming increasingly common. The alumina and sand and gravel industries have numerous plants that have been practicing this for many years. There are a number of base metal mines now using these methods and a significant number of mining operations are investigating this as a means of reducing environmental impact, eliminating tailings ponds or prolonging tailings pond life, simplifying mine closure, increasing water or chemical recovery, and reducing tailings dam construction costs. Potential sites include both operating and grass roots plants.

The plants currently utilizing surface stacking all operate at generally less than 10,000 tpd. The technology however, seems to offer good incentives for larger plants as well. While several large (50,000 tpd or larger) operating or planned plants have studied surface stacking, none of them have started to implement it. There are multiple reasons for this:

- Risk – There is a lack of large scale operating installations, although the technology is becoming well proven in smaller scale plants.
- Capital costs may be higher, particularly for an existing operation to convert to a new methodology.
- Environmental/Permitting issues – Once a permit for a conventional disposal area is issued, reapplying or changing the permit involves significant risk. Applying for an unconventional disposal methodology may also increase the risk of a permit being subject to a higher level of scrutiny and possibly denial.
- Momentum – With an operating plant, the initial capital cost of a large water-retaining dam is already sunk, and the permits are already in place. It takes a significant amount of effort to not only study and engineer a new methodology, but also to obtain the permits. Even at a greenfields plant, once permits are granted, change is difficult. Not only is there a risk that the new permit won't be approved, but the application process also exposes the existing permits to scrutiny.
- Seismicity and liquefaction of the deposit is a concern. There is not a lot of hard evidence or acceptance from regulators that a dry stack deposit necessarily reduces the risk of liquefaction.
- The true value of water is only slowly becoming more apparent in dry regions, as it begins to limit production or expansions, affects the environment, requires longer and longer transport distances, and becomes more expensive.

2. TECHNOLOGY DEVELOPMENT/RISK

There are essentially three technologies necessary for surface stacking: thickening, transportation, and deposition. Each of these areas involves some risk for the operation. The operation can be planned to operate in a certain performance envelope, and for any given envelope there is a risk that at times the performance will be outside the boundaries. Depending on the area of operation and the type of non-performance, the system may or may not be able to continue operation.

2.1. Thickening

Developments in thickening technology over the past 15 years have enabled significantly higher underflow densities to be consistently produced. This technology started as an extension of high rate thickening, utilizing a deeper mud bed to augment the thickening capacity. High density or high compression thickeners usually add depth to a high rate design to aid in increasing the underflow density. Deeper mud beds increase the mud compressive force, reducing the time required for thickening and increasing the underflow density. There are a number of modifications necessary to be able to produce and handle the higher viscosity materials, including significantly higher torque capacity than high rate machines, low drag rake arms, pickets, higher raking capacity, and improved underflow discharge.

Deep cone thickeners (DCT) are a newer alternative which are designed around production of high viscosity muds. They utilize very deep mud beds and steep floors to be able to produce and discharge muds near the limit of pumpability and operate at very high rates in terms of thickener area. Currently these designs are being built up to 24 m diameter although as with many new technologies, larger machines are always on the drawing board. For a 100,000 tpd plant using a maximum size of 24 m, it may be possible to achieve the desired underflow density with as few as 4 thickeners.

Figure 1: Multiple Deep Cone Thickeners.

In some applications, underflow with the consistency of paste can be achieved by high rate, high rate rakeless, or high density machines. However, deep cone thickeners are currently the best technology for achieving maximum underflow densities utilizing sedimentation equipment alone. These units typically utilize very deep mud beds in order to take maximum advantage of mud compressive forces for dewatering and provide sufficient time for the mud to dewater to a paste consistency. The tank height to diameter ratio is frequently 1:1 or higher. Due to the high underflow viscosities, mechanism torques can be 5-10 times higher than high rate machines on similar materials in order to be able to handle performance excursions where very high viscosity material is produced. Installed applications include surface tailings disposal, underground paste backfill, leach feed, and countercurrent decantation (CCD).

2.2. Transportation

Underflow pump and pipeline system design must fulfill three important steps: 1) move the paste out of the thickener, and 2) move the paste from the thickener to the disposal site, and 3) distribute the solids around the deposition site.

Although this is fundamental the importance of designing the capacity of the underflow pump system to accommodate all process conditions cannot be over stressed. Rheological properties of the paste must be defined to select the proper size piping and pumps to remove the paste from the thickener. Pipeline pumping tests must be completed to design the distribution system for aboveground stacking. The location of the discharge spigots will be determined by the deposition plan, and the distribution system must be capable of delivering the material to those points.

Most small and medium size plants require a positive displacement pump, particularly if the deposition site is more than a couple hundred meters from the thickener. Since positive displacement pumps are a significant capital expense and are limited in maximum flow capability, their use is an issue for large plants. However, with large flows, it is more likely that either centrifugal pumps or even gravity flow can be utilized with high viscosity material. Whereas with a small flow, there is a relatively high ratio of wall area and hence drag to the total flow, with a larger flow, the ratio of wall area to the area of the pipe is much lower. As a result, it may be possible to have material with a significant yield stress flow by gravity.

2.3. Deposition

Tailings disposal whether underground or aboveground will require design to define the paste characteristics to be produced at various times for the deposition scheme. Occasionally there are options for the addition of coarse material or in some cases, binders. Examples of binders that have been used include; cement, cement/fly ash, and iron blast furnace slag. Using a binder would not usually be practical for large applications and is not usually a consideration for surface disposal. However, the addition of coarse material is frequently an issue.

Figure 2: Thick discharge to a stack.

The impoundment design will include expected slope angle, rate of consolidation, and soil loading capabilities to be able to move equipment over the tailings over the life of the project. The paste rheological characteristics for a given impoundment may require high slump to flow for distribution or may require low slump to maximize stacking angle. Changes in rheology during operation will affect the material placement characteristics and need to be considered in the engineering phase. An example of thick discharge to an impoundment is shown in Figure 2.

Current dry stacking practices have traditionally utilized relatively high slump, low viscosity material to facilitate flow over a wide area and a relatively thin layer of deposition. Each thin layer is allowed to dry out prior to adding the next layer. Typically, the layers crack during drying, and the next layer fills the cracks. However, as the technology evolves, plants are moving towards producing thicker and thicker materials, taking advantage of the ability to economically produce and transport pastes.

3. CASE STUDIES

3.1. Existing Operations

Alumina operations introduced paste thickening technologies for a number of reasons, mostly particular to the alumina industry. Environmentally acceptable disposal of the red mud residue produced in the Bayer process has become a requirement. In years past, it was normal to use wet impoundment areas or “lakes” to confine the waste solids, while providing the means for recovery of a portion of the caustic soda lost with the final residue. However, the potential impact of disposal on the local environment and the cost of residue disposal provided the impetus to develop alternative approaches for residue storage. These centered on methods to thicken the red mud slurry to a consistency suitable for thickened tailings disposal. This storage method has been utilized by a number of mineral processing industries including several alumina refineries to overcome difficulties associated with the more conventional wet impoundment techniques. Due to the success of this approach it continues to spread rapidly through the alumina industry.

The sand and gravel industry has also found elimination of tailings ponds to be expedient, although they have often used belt press filters in conjunction with thickeners to produce a handleable fines material. The combination of belt press filters and thickeners has been economical for several reasons, including relatively low fines tonnages of generally less than 2,000 tons per day, familiarity with and availability of solids handling equipment, sale of a portion of the fines, the high value of real estate due to location close to building material markets, and the difficulty of permitting ponds in these locations. Typical belt press cake is shown in Figure 3. The use of belt presses requires significant operating costs for both flocculant and belts.

Figure 3: Sand & Gravel belt press cake.

A Peruvian lead/zinc mine recently implemented a stacking system utilizing an Eimco DCT. This plant started up at the beginning of 2004 and has been very successful. The plant was having a problem with their discharge permit, forcing a revamp of their disposal methodology. The options studied were a new tailings pond, thickener/filter combination, and a new paste thickener. The paste thickener was selected and installed. Startup was in early 2004. Discharge solids concentrations are in-line with expectations, operating at roughly 4,400 tpd. The disposal area is achieving an excellent beach slope (see Figure 4).

Figure 4: Cobriza tailings deposit.

The DeBeers' Kimberly operation implemented a tailings disposal system utilizing five 15 m DCTs (see Figure 1) and positive displacement pumps to transport the material to the disposal area. There is no visible pond and the material dries and cracks to form a stable deposit fairly quickly. They are processing about 13,000 tpd.

3.2. Plant Studies

A project for a large Peruvian copper mill currently in the process of engineering considered surface stacking during the feasibility engineering stage. This seemed to be an excellent candidate; a new plant and limited water availability. However, the original engineering firm may not have been well acquainted with surface stacking, and recommended a conventional dam and tailings deposit. By the time the issue was properly examined, a permit had already been procured. Once the permit was in hand, the company was not willing to take the time, effort, and most importantly the risk to reapply. They are currently proceeding with a conventional dam and tailings pond.

A thorough study of thickened tailings disposal was completed for a large Chilean copper plant, comparing it with conventional thickening and tailings impoundment design. The design was based on a tonnage of roughly 70,000 tpd. A single 80 m diameter high tonnage paste thickener would have been used. The TTD option looked very promising financially. Environmental issues with the disposal area being studied prevented this project from proceeding. One significant downside to TTD raised in the study was the uncertainty regarding the stability of the deposit under seismic conditions. Further study is progressing for an alternative tailings deposit area further away.

Other Chilean copper producers are studying thickened tailings disposal as a way to improving water recycle. Some plants aren't reclaiming as much water from their pond as they had planned, resulting in a higher demand for water. At times, the lack of water impacts on plant production. Momentum and risk are major factors preventing rapid conversion.

4. IMPEDIMENTS TO THE TECHNOLOGY

The single largest impediment to implementing this technology at a large scale operation is the lack of other large operations currently using the technology (no one wants to be first). Without a proven operation in the 50,000+ tpd size range, it is difficult for managers to expend considerable resources to examine the benefits.

A majority of the existing operations using surface stacking are operations processing about 2,500 tpd or less. There are several reasons for this, including numerous other existing operations in this size range, the ease of implementation on a smaller scale, amenability to using filtration without the filter plant being huge, and simplification of permitting for a small operation. Operations at large plants are an order of magnitude larger than this. In order to make this jump in scale, the technology needs to have significant proven benefits and be considered low risk. Existing operations are unlikely to implement a scheme that has even a small risk of failure if it will shut down the plant as a consequence, and it is difficult to finance plants if lower risk alternatives are available.

The permitting of a new surface disposal scheme may be required to follow existing regulations requiring the top of the dam to exceed the highest point on the stack. This is only an example, but local regulations can have significant ramifications in Latin America.

The amount of modification required to retrofit to an existing installation, both in installed equipment and operational training and methodology can be daunting. People tend to do what they know, so changing the disposal methodology requires modifications to operating paradigms that have been long established and accepted. It requires extra effort for individuals to take on a project of this magnitude, and the rewards may not match the risk.

There may be significant advantages in a paste type disposal regarding reduction in the mobility of hazardous species like cyanide or sulfides. However, at this point there may not be sufficient data to be able to take advantage of this feature to a point where it offers a financial benefit.

5. Conclusions

Implementation of surface stacking technology is proceeding in smaller scale applications and will eventually be utilized by large, high tonnage operations. As the size of operations increases, the risk decreases and knowledge of the field grows and spreads. There are significant barriers to utilization of the technology that apply particularly to large plants. As the technology grows, these barriers will eventually fall. Recent studies have demonstrated significant financial incentives for using surface stacking. As the technology becomes more widespread the incentives will begin to outweigh the risks.

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