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Filtered tailings plant design at Krumovgrad Mine

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Abstract

Dundee Precious Metals' Ada Tepe mine is located approximately 3 km south of the town of Krumovgrad in south-eastern Bulgaria. It is an open pit mining operation comprised of a process plant, which employs a conventional crushing, grinding, and flotation process for gold and silver extraction.

Currently, the tailings are being deposited as a thickened tailings in their integrated mine waste facility (IMWF). Cells are created out of waste rock to retain the thickened tailings. These cells are built within two valleys adjacent to the open pit, starting with initial starter platforms at the base of each valley, continuing up the two valleys until the two parts join at a higher elevation to form a single facility.

As the cells are filled and lifts completed, the front berms are progressively rehabilitated. There are two collection sumps at the bottom of each valley from which water is pumped up to the top of the hill into the raw process water reservoir for use within the process. There is limited space on site and filtered tailings was contemplated to reduce construction complexity and placement effort in the IMWF, increase flexibility for future tailings placement, and reduce costs associated with further consolidating the thickened tailings and pumping water to the current reservoirs.

In 2021, a feasibility study for producing filtered tailings within a limited footprint to improve the operability of the IMWF commenced. This consisted of assessing the area required for the filtration plant, overall design efficacy, taking into account the filterability of the tailings, transportation of the filtered tailings, examining the filtered tailings storage requirements and modifying the IMWF deposition strategy to suit filtered tailings instead of thickened tailings.

This paper describes the general benefits of filtered tailings as well as some of the challenges in implementing such a system. In addition to the key design considerations for the filtration plant, outlining the specific operational benefits and identifying recoverable costs for this site are discussed.

Keywords: *filtration, opportunities, design, tailings*

1 Introduction

The concept of using filtered tailings has been growing in popularity in the mining industry in recent years due to the many benefits and/or increasing regulatory requirements with surface tailings facilities. Mining companies have been in search of improved tailings deposition techniques to meet the challenges of today.

This paper looks at the overarching benefits of filtered tailings for surface disposal, as well as the design considerations and the ultimate outcome of filtered tailings application at the Ada Tepe gold mine.

The Ada Tepe gold mine, which was previously known as the Krumovgrad Gold Project, is located at the Ada Tepe prospect in the Khan Krum Deposit in the Kardjali District of Bulgaria, approximately 320 km southeast of the capital city, Sofia. The site location is about 3 km south of the town of Krumovgrad, 15 km north of Bulgaria's border with Greece, and covers an area of about 0.7 km^2, and includes the open pit, process plant

and integrated mine waste facility (IMWF). Ada Tepe is the first greenfield mine to be commissioned in Bulgaria in the last 40 years.

Dundee Precious Metals (DPM) Ada Tepe gold mine contemplated the use of filtered tailings and commissioned a feasibility study to examine whether that would be incrementally more beneficial, compared to the current method of thickened tailings deposition. Since 2019, Ada Tepe has been depositing thickened tailings at the IMWF at about a 56 to 62 wt% solids consistency. Pressure filtration of the tailings would allow for the site to deposit the tailings at about 84 wt% solids.

This IMWF design currently allows for the storage of thickened tailings and waste rock. The IMWF is designed to co-dispose both mine waste rock and thickened tailings within two valleys to the north of the mine process plant. The original design of the IMWF has discreet cells constructed of waste rock, where thickened tailings can be placed within. The cell capacities are sized to match the Life of Mine balance of both waste rock disposal and tailings from ore processing. Figure 1 shows both the north and south valleys of the IMWF, looking from the east. As the IMWF advances to higher elevations, it is progressively rehabilitated.

Figure 1 Aerial view of the integrated mine waste facility at Dundee Precious Metals' Ada Tepe gold mine

2 General benefits of filtered tailings

There are numerous benefits of filtered tailings that may or may not apply to any given situation. This section covers some of the main general benefits of filtered tailings. A mining company may be looking at some or all of these, depending on the specific site conditions and criteria. The three main benefits of filtered tailings are water recovery, stability/safety, and in most cases increased storage capacity for a given tailings enclosure.

The benefit of water recovery is both an operational and capital cost savings. Removing water earlier in the process may allow for simpler design of the tailings enclosure. Possibly removing the requirement for a liner, as well as a definite reduction in the requirement for water recovery and return. For water recovery and return, a reduction in water collection area and/or smaller pumps and piping will be required by comparison to slurry or thickened tailings deposition technologies. In many cases, filtered tailings enclosures will only require a small pond to manage water from the environment. The monitoring and maintenance of water levels in the filtered tailings enclosure and their associated processes (such as return water pumping and piping) are reduced due

to lower levels of water to be managed. This can be a significant cost if the tailings enclosure is distant from the mill, resulting in large quantities of tailings delivery piping and return water piping. Further, for operations in arid regions with accessibility to water issues or in cold climates with added difficulties in handling water during the winter, these factors can drive the decision to a filtered tailings solution.

The benefit of increased storage capacity due to the removal of water comes from the ability to stack at a higher density. This results in the same quantity of tailings solids placed within a smaller footprint. Therefore, a larger mass of tailings can be stored in an equivalent footprint. This is especially beneficial in sites with limited areas for tailings enclosures or if the permitting of new tailings enclosures is not favourable. This increase in storage volume can allow the life of the tailings enclosure to increase substantially. Operations that do not have favourable topography for conventional or thickened tailings enclosures can benefit significantly from this.

When the filtered tailings is compacted at the optimum moisture content to its maximum dry density, the result is a more stable tailings stack. This increases the safety aspects of the operation as the reduced level of water does not apply the same pressure on the dam walls and even if dam walls were not present, the filtered tailings would not flow to the extent compared to a conventional or even thickened tailings. In highly seismic regions where local conditions prove conventional or thickened tailings enclosures unfavourable, the use of filtered tailings could be a solution to decrease any potential downstream impacts of tailings liquefaction.

In evaluating the filtered tailings option, the costs associated with filter cake processing, handling and compaction, must be weighed against the costs of conventional or thickened tailings facilities in a more holistic way that includes the enclosure costs, the permissibility of the tailings enclosure under different tailings disposal options and the true cost of water management. The latter should also include the process water quality.

It is recognised by the authors that filtered tailings is not a solution for every operation. It should remain as an option though with careful consideration to the specific site constraints. One of those constraints could be the dewaterability of the tailings itself. In cases where the tailings is particularly fine or contains mineralogy that makes the filtration of the tailings more demanding, the co-mingling of filtered tailings with waste rock may prove to be the solution. In this case, the filtered tailings may not reach optimum moisture content, but when blended with a much drier waste rock, a stable stack can be produced. This was illustrated by Wisdom et al. (2018) in the GeoWaste^{TM} concept. Some factors that affect whether filtered tailings is a good solution are tailings characteristics such as particle size, shear strength, hydraulic conductivity, and compressibility as illustrated in the paper by Lupo & Hall (2010).

3 Feasibility design of the filtered tailings plant at the Ada Tepe gold mine

The feasibility design of the filtered tailings plant (FTP) at the Ada Tepe gold mine was presented with a few site-specific challenges. One constraint is the available footprint for the FTP and the intermediate storage of filtered tailings or tailings holding cell. Owing to the local topography and constraints from construction boundaries, there are limited areas available for the additional site infrastructure. A haul road traverses between the FTP and the tailings holding cell. The connecting conveying system had to be designed to traverse under the haul road from the basement of the FTP. This also reduced the overall building height as the basement was designed to specifically accommodate the filter cake conveying system.

Another challenge is the particle size distribution of the tailings itself. The tailings D80 is in the range of 30 to 35 microns, with more than 40% of the tailings passing 10 microns. With such fine tailings, pressure filtration cycle times were proportionally high to reach optimal moisture content (84.3 to 83.8 wt% solids) for compaction. This is derived from Proctor testing. Further testing illustrated that the transportable moisture limit of the tailings is 83.8 wt% solids. As a result, the target for filtered tailings solids content was set at 84 wt% solids

Table 1 is a summary of the key design criteria used within this project.

Table 1 Filter plant design criteria

Criteria	Value	Source
Production	0.84 Mtpa	DPMK
Tailings specific gravity	2.80	DPMK
Tailings particle size distribution	D80 = 30 to 35 microns; D50 = 11 to 13 microns	Laboratory testing
Received thickened tailings density	57wt% solids	Laboratory testing
Filtered tailings target solids content	84wt% solids	Laboratory testing
Design codes	Bulgarian/European	DPMK

The design of the Krumovgrad FTP process can be summarised as follows:

- Thickened tailings are pumped from the existing thickened tailings plant (TTP) to the FTP.
- Water is supplied to the FTP via the raw process water reservoir (RPWR) primarily for pressure filter cloth wash.
- Two pressure filters dewater the tailings with the water recycled to either the RPWR or the TTP.
- The filtered tailings are conveyed to either a tailings holding cell in the IMWF or into a loadout bin which in turn fills trucks that bring the filter cake to the respective disposal areas within the IMWF.
- Excess waste water is either brought back to the TTP or to the RPWR.

This next section is a process description of the filter plant. The simplified process flow diagram is shown in Figure 2 illustrating the process concept.

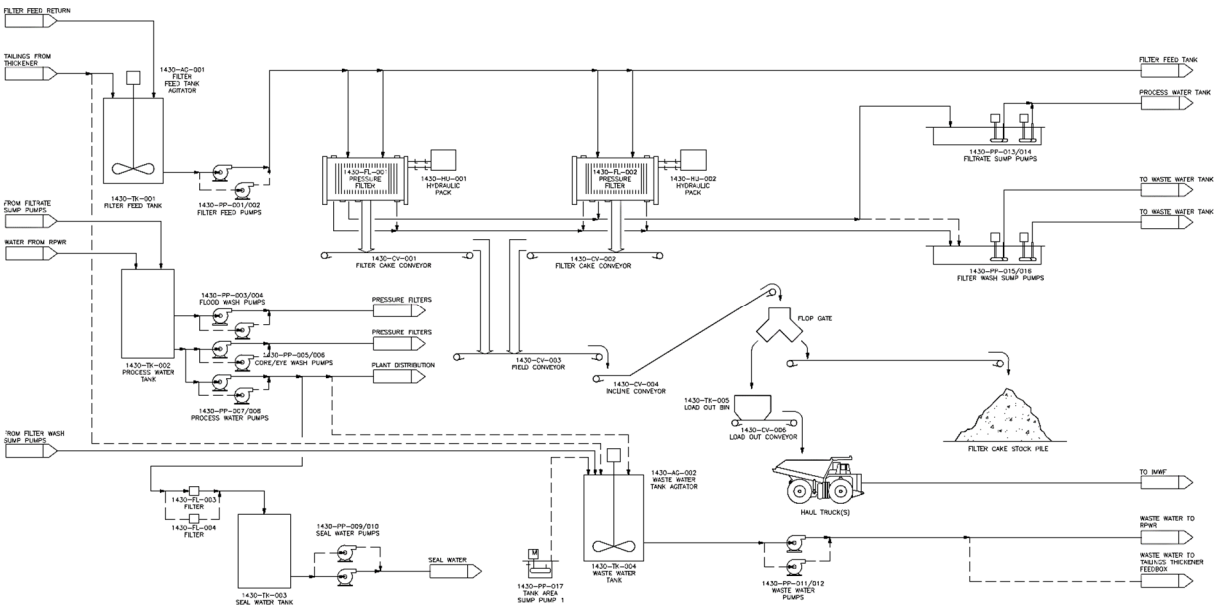

Figure 2 Simplified flowsheet of the feasibility filter plant at DPM's Ada Tepe gold mine

4 Tailings delivery and auxiliary systems to the filtered tailings plant

The tailings are received from the TTP into the agitated filter feed tank. If the FTP has an emergency shutdown, or the solids density of the slurry does not meet the set point, the tailings are diverted to the

waste water tank. The same procedure is adopted for flushing the line from the TTP to the FTP. Contents from the wastewater tank are transported back to the TTP. If it is an extended shutdown, the thickened tailings are diverted to an emergency cell in the IMWF.

The wastewater tank receives water and/or dilute slurry from the filter wash and tank area sump pumps as well as the thickened tailings line, as described. There is also a line from the process water pumps that allow water to be added to the wastewater tank if required for dilution purposes. From the wastewater tank, there is a pump arrangement which discharges to one of two destinations (RPWR or TTP).

Process water for the FTP is received from the RPWR into the process water tank via existing pumps, as well as water from the filtrate pumps, during operation. RPWR water is used at start-up or when the process water tank reaches low level. During operation, the main source of water is the returned filtrate from the filtrate pumps.

The process water tank feeds three sets of pumps. The flood wash pumps which provide high flow/low pressure water to clean the filter chambers after they discharge the filter cake. The cloth wash pumps, which provide low flow/high pressure water to clean the filter cloth of any particles that were not removed by the flood wash. The process water pumps are used for plant distribution (hose stations, etc.), providing seal water to the seal water tank, and providing water to the wastewater tank when required.

Seal water for the FTP is received from the process water tank via the process water pumps into the seal water tank, passing through a self-cleaning filter to ensure that the water meets the required quality. The seal water pumps deliver seal water to the filter feed and/or the wastewater pumps as required when in use.

5 Filtered tailings preparation and transportation

At the FTP, the thickened tailings are agitated within the filter feed tank. The tailings are pumped via a filter feed pump to fill the pressure filters in a sequential manner. Due to the pressure filter cycle time, one pressure filter is filled at a time with the second pressure filter filled only after certain initial steps in the overall pressure filter cycle has occurred to ensure only one pressure filter is being filled at a given time. Under steady state conditions, both pressure filters will operate at full capacity as the minimum lag time is significantly less, compared to the overall filter cycle time.

The process of filling the pressure filter starts with high flow and low pressure pump delivery which gradually transitions to a low flow and high pressure regime (dead head) to fill each chamber with tailings to the maximum possible extent. Once the pressure filter is full, the valve to the filter press is closed and the filter feed pump enters recirculation mode, returning the slurry back to the filter feed tank until the next pressure filter is ready to be filled. This ensures that the filter feed pump is not constantly turning on/off and flushing of the filter feed lines are not required. The filter feed pumps are also on a variable speed drive to accommodate the changes in flow and pressure during the filling cycle as well as during the recirculation time.

During the wash cycles, both the flood wash and cloth wash water is sent to the dirty filter wash sump. During any clean-up of the filters or filter cake conveyors, all clean-up water reports to the dirty filter wash sump located between the two conveyors on the floor below.

The filtrate sump pumps transport the clean filtrate to the process water tank for re-use. The filter wash sump pumps deliver the wash water to the waste water tank.

The filter cake conveyors discharge the filter cake onto a field conveyor which transports the filter cake from the FTP, under the haul road, and discharges the filter cake onto an inclined conveyor. At this transfer point a diverter gate directs the filter cake either onto the tripper conveyor which delivers the material into the filter cake holding cell, or the loadout bin. The loadout bin collects the filter cake and discharges via a loadout conveyor into mine haul trucks. The filter cake holding cell is designed to store filtered tailings during inclement weather, when trucking filtered tailings to the IMWF is not viable. This will allow the mill to continue operations through major storm events while the IMWF operations are on hold.

To provide air to the pressure filters, there are two air compressors that fill two oversized air receivers that hold all the air required in a single pressure filter batch cycle. Any additional air requirements in the plant (i.e. air hoses, etc.) can use either of these air receivers for general plant air. There is also an additional air compressor, air dryer and air receiver that delivers instrument quality air to the FTP.

Figure 3 provides an overview of the FTP and downstream filter cake storage area. The FTP building was designed to house only the key equipment that needed to be protected from the elements. The tanks and respective pumps remain outdoors and hence these pipes are designed with heat trace and insulation in mind. Figure 4 is a focused view of the pressure filters, illustrating the maintenance access needs around and on top of the pressure filters. As well, the conveyor discharge tunnel (perpendicular to the pressure filter) is shown to the left of the figure traversing below the haul road.

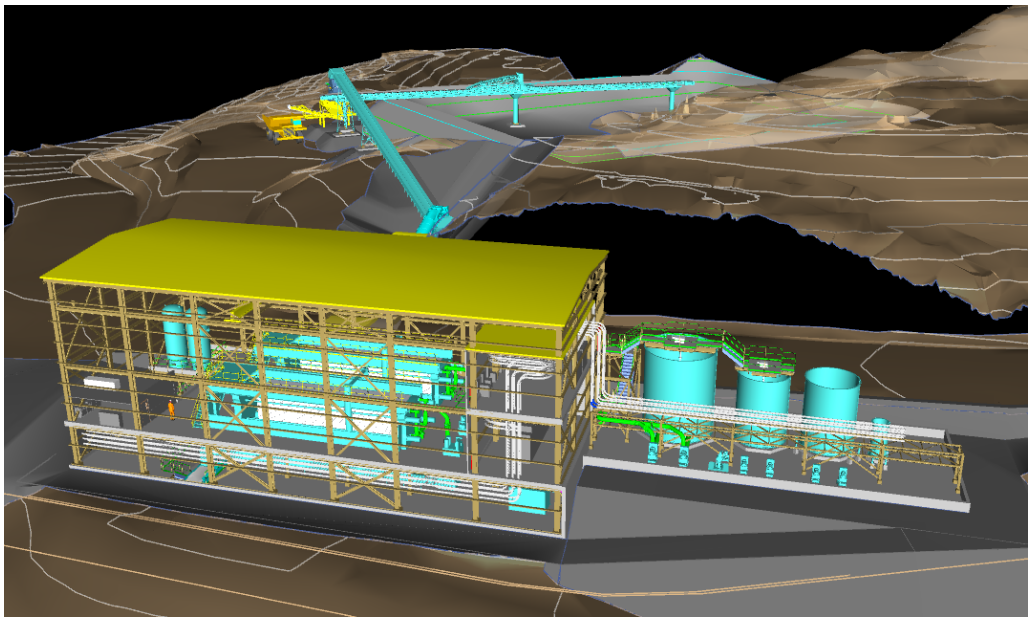

Figure 3 Overview of the filtered tailings plant arrangement with the filtered tailings holding cell in the background

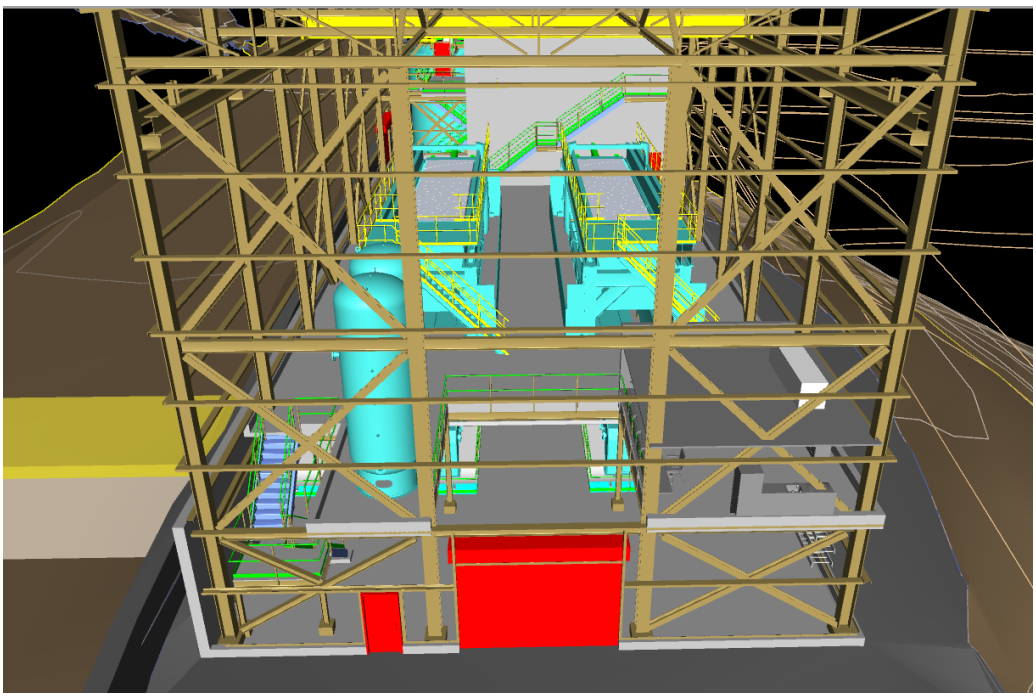

Figure 4 A focused view of the pressure filter and discharge conveyor arrangement

6 Key outcomes of applying filtered tailings at Ade Tepe

The following key outcomes can be summarised as a result of applying filtered tailings deposition at Ade Tepe:

- The remaining life of facility (life of processing facility) could potentially increase from approximately 3 to 10 years, assuming that when the IMWF is filled to capacity, the filtered tailings could potentially be stored in the depleted Ada Tepe open pit. This is significant due to the topography of the area, as well as from an environmental footprint perspective. More efficient storage of tailings would allow Ada Tepe to process additional ore throughout the local area for an extended time should options become available. This would result in socio-economic benefits of employment, local supply chain utilisation and restoration of the open pit to its pre-mining landform profile.
- In terms of the IMWF design, the change to co-mingling (filtered tailings and waste rock blending with mobile equipment) for filtered tailings as opposed to discrete cells for thickened tailings, results in a reduction in the quantities of imported drainage rockfill, geocomposite drainage materials, geotextile, pipework and wick drains required. The potential savings associated with this is estimated at EUR7.27 million for the remaining life of the IMWF. This includes the initial capital expenditures for the FTP.
- The change to filtered tailings reduces the construction complexity of the IMWF compared to the current thickened tailings operations, as described, by a reduction of drainage and piping materials needed. This also provides additional flexibility in available disposal areas for both waste rock and filtered tailings.
- With the implementation of filtered tailings, material at 84%wt solids would be entering the IMWF instead of material at 57%wt solids. This increase in solids result in less water reporting to the north and south sumps at the base of the IMWF. As the pumps already exist, there are no capital savings, but the operation of these pumps would be reduced. On average this translates to a reduction of about 80 m^3/hour (about 150 m of elevation change) of water to be handled by the IMWF return water system, not considering evaporative losses. Eldridge et al. (2013) describes the IMWF concept as well as the north and south sumps at Ada Tepe.

7 Conclusion

The feasibility design of an FTP was completed for the Ada Tepe mine. The objective was to evaluate the efficacy of replacing the current thickened tailings deposition with filtered tailings. The design process and site-specific challenges have been highlighted to illustrate the design considerations for the FTP. The dewatering characteristics of the tailings and the target filter cake moisture content ultimately drives the size of the pressure filters and in turn the overall size of the FTP.

The benefits of using filtered tailings at the Ada Tepe mine is that a co-mingled filter cake/waste rock stack could be produced to maximise the storage of tailings at the IMWF, in a location with limited options for tailings storage. Although there is a significant capital cost to the FTP, the use of filtered tailings does also allow for a different placement methodology which would result in construction cost savings. Further, because a more highly dewatered tailings is reporting to the IMWF, there is significantly less water that is delivered to the sumps at the base of the IMWF and hence less water needs to be transported back up to the reservoirs.

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