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Some Practical Aspects of Downtime and Their Causes in the Paste Plant at Zinkgruvan Mine, South-Central Sweden

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1 INTRODUCTION

In 1857 mining of zinc and lead ore started in Zinkgruvan. The mine is situated in South-Central Sweden and is today owned and operated by Lundin Mining AB. Present ore production is approximately 815,000 tonnes per year from mainly two orebodies, "Nygruvan" and "Burkland". The mineralization outcrops on the surface and mining today is to a depth between 350 and 965 m.

The predominant mining method was cut-and-fill, using sand for backfilling. Eventually hydraulic, deslimed backfill was introduced. Rock stresses and economic reasons have prompted changes, introducing different benching methods and lately open and panel stoping as primary mining methods (Figure 1).

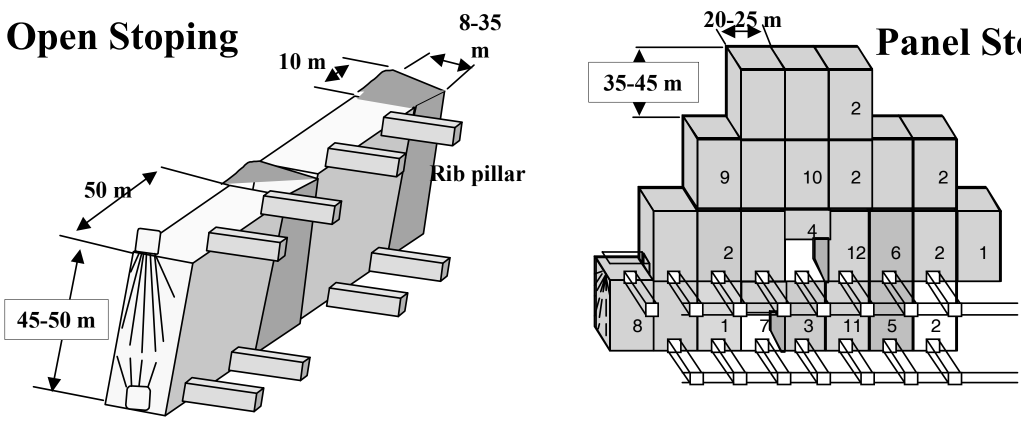

Figure 1 Schematic mining layout / mining sequence

2 REASONS FOR CHANGING TO PASTE

Using hydraulic backfill has one big drawback - no more than 50% of the tailings in Zinkgruvan can be used for backfilling. The rest of the tailings are too fine to allow water to drain through it. The surrounding work for an efficient hydraulic backfilling operation is also substantial, with construction of bulkheads, retaining walls, draining, water pumping etc. In the late 1990´s it was clear that hydraulic fill could not yield enough volume for backfilling voids from the mining operation. At the same time the mine experienced a period of strong seismic activity which demanded more and more ore to be left as rib pillars with increasing depth. This came at a time when pressure on the tailings pond increased and it was obvious that there was a chance that limitations in the tailings dam could possibly affect mining prior to the construction of a new dam. Early studies of the mining operation showed that the most interesting alternative was paste fill. The decision to introduce paste fill and construct a paste plant was taken in May 2000 and the first pour of paste occurred in May 2001 to a stope in the Burkland orebody.

At Zinkgruvan we classify the function of paste into three categories:

- Areas directly depending on paste placement to enable continued ore production. When paste was first introduced some areas were forced to a standstill, waiting for backfill. This situation no longer exists and backfilling is up to date with ore production.

- Areas in need of backfill for stabilizing the surrounding rock, thereby lessening the chance of wall failures and seismic events. Previous mining had created large openings in sensitive areas of the mine where the increasing rock pressure posed a threat to future operations. There are still some voids of this type but the situation is now judged to be under control.

- Other old workings. These may require extensive work with laying out pipes, but the benefits of reducing the pressure on the tailings dam outweighs the additional effort. The more tailings deposed of underground, the longer is the expected dam lifespan. It is also a matter of reducing the impact of the environment on the surface by returning as many tailings as possible underground.

3 PASTE

Figure 2 shows a schematic of the paste production at Zinkgruvan. Tailings from the mill are pumped to a conventional thickener where the relative density of the tailings is raised from 1.3 to 1.65 using flocculant. All tailings are used. From the thickener, the tailings are pumped to a disc filter with a nominal capacity of 105 tonnes per hour. The disc filter reduces the water content to approximately 78% by dry weight. A conveyor belt then moves the continuous stream of filter cake into a mixer, whose purpose is merely to condition it to an even mixture. A small amount of water may be added at this stage.

The next stages shift from a continuous process to batch mixing. A 5 tonne batch of total tailings is portioned into a weigh hopper. The required cement for one batch is measured in a separate bin and together the tailings and cement is dropped into the paste mixer. The batch is mixed for approximately two minutes and thirty seconds while the power draw of the mixer is monitored. Power draw has been correlated with the slump of the finished paste and this is the only chance we have to adjust the slump of the paste. If the mixture is too dry we can add water, if it is too wet it will be introduced into the system and adjustments will be made for the subsequent batches. The paste mixture is fed into a gob hopper that feeds the positive displacement paste pump.

The process now switches back to a continuous process and the pump always has a supply of mixed paste. If the level in the gob hopper drops the pump will slow down and ultimately stop if the level falls below a critical value. Thus we are guaranteed not to introduce air into the distribution system. When the level in the gob hopper rises the speed of the pump increases again.

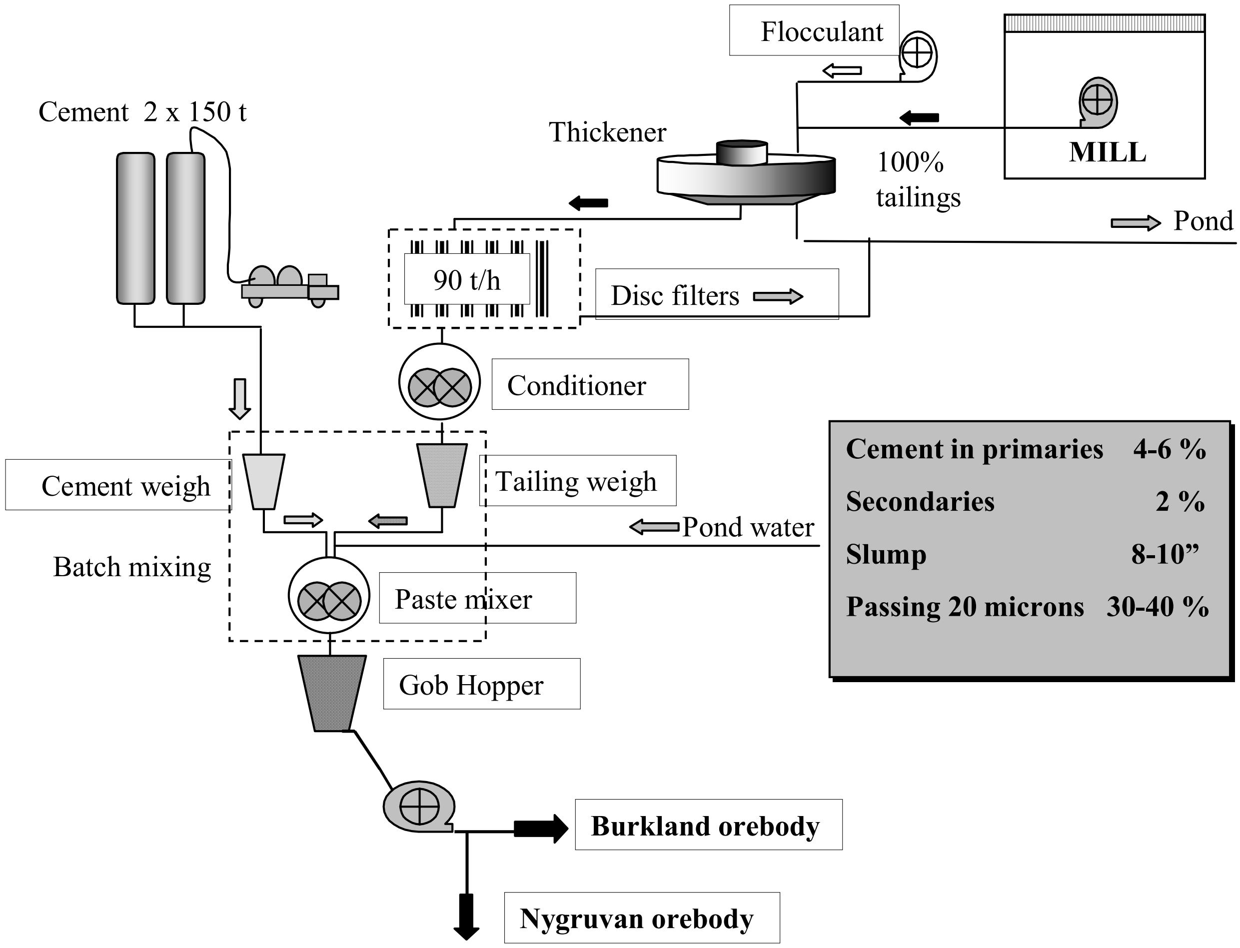

Figure 2 Schematic of paste production at Zinkgruvan

After the paste pump, distribution begins through the boreholes/piping. We use 15 cm (6”) pipes, schedule 80 for high pressure lengths and schedule 40 for lengths closer to the pouring point. One main line is used for the Burkland orebody and another feeds the Nygruvan orebody. The last 100-150 m before the drop point we change to plastic hose, 100 mm in diameter (Figure 3). The plastic hose simplifies pipe hanging considerably.

Bulkheads/retaining walls are constructed by piles of waste rock tightly filled against the back. We have seen only minor amounts of water sifting through these walls during filling with paste. This is a major difference compared to the extensive draining and pumping needed when using hydraulic backfill.

When filling primary stopes we normally add 4% cement by dry weight. Water is approximately 22% by weight at a slump of 22 cm. In secondary stopes the cement content is reduced to 2%.

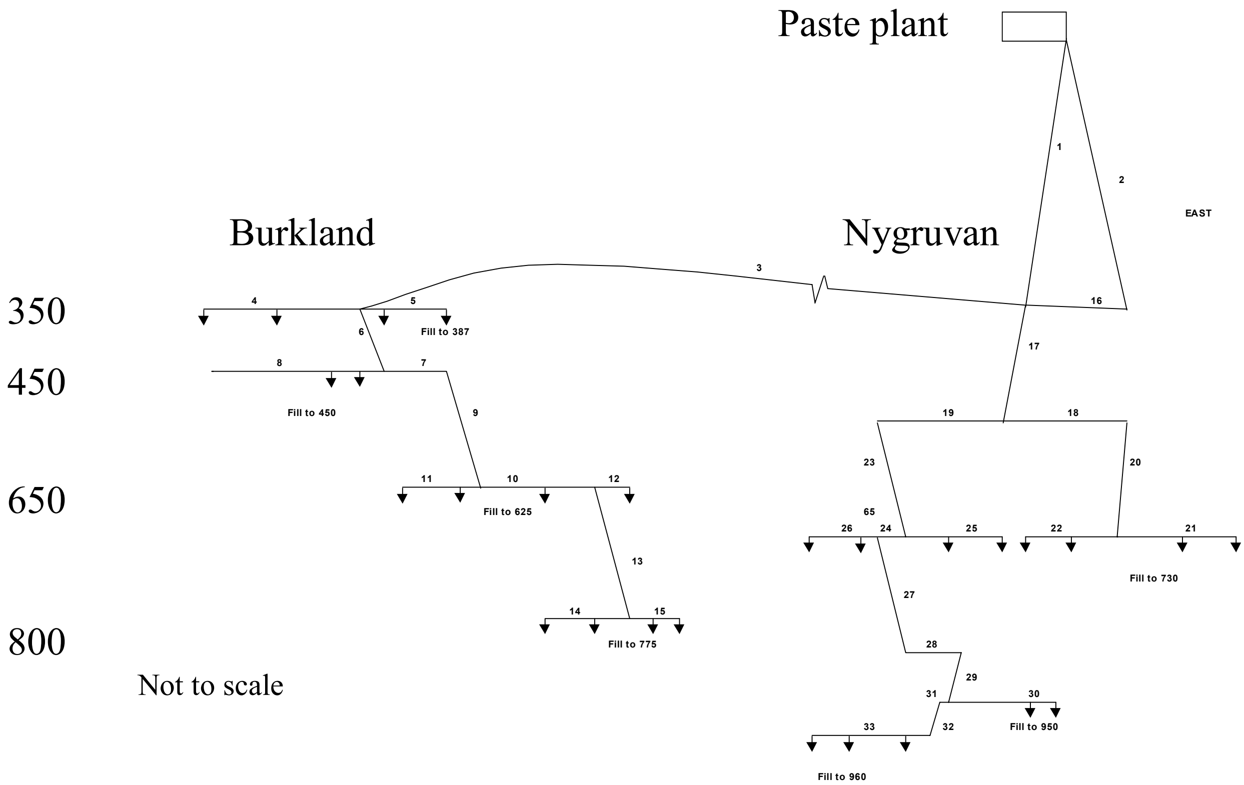

Figure 3 Initial paste piping and borehole layout at Zinkgruvan

The mill processes approximately 2400 tonnes of ore each day. After removing the metal content the tailings are available for paste production. This leaves some 2000 tonnes of tailings per day. In reality some of the fines will disappear in the overflow of the thickener. Also, every time the paste plant is at a standstill but the mill is operating we will lose tailings the tailings pond instead of being used for paste. Overall, we utilize no more than 70% of all available tailings for paste production. Tests have shown that we can increase output from the thickener by changing to another flocculant but this will cause more clogging of the pores at the disc filter thus shortening the effective life span of the filters.

When the paste plant was commissioned in May 2001 the need for fill in the mine was so great that at times the running of the paste plant governed the operation of the mill! If, for some reason, the paste production stopped, the mill also would be shut down until paste production could be continued again. Fortunately enough we no longer have to work under those conditions and today we backfill more volume than mining creates. However, there are still some 400,000 cubic meters of old workings that can be filled so there is still a pressure on the paste plant to operate efficiently.

Manning of the paste plant is kept at one operator per work shift. We have tried to automate the process as much as possible and under normal circumstances the operator is merely monitoring the process. Underground checks of the pour point requires less than a full-time operator but there is always a person assigned to checking and if necessary anyone can be assigned to work with emergencies; i.e. should we encounter a plugged borehole, time is crucial and cleaning work may require several persons to begin flushing pipes at short notice.

4 PROBLEMS

Initially the paste worked like a charm for a couple of months. After that we experienced our first plugged borehole down to the 350 meter level. Someone has said, and we believe it to be true, “It is not a matter of if you will plug your boreholes - it is a matter of when”. Our experiences support this statement fully.

Later in 2001 we encountered several plugged boreholes and pipes. Basically the cause of these disturbances was a heavily fractured rock intersecting the boreholes. Small pieces of rock would fall out into the borehole and plug the piping. In 2002 we cased three boreholes with steel pipes of the same diameter as the rest of the distribution system and since then we have not seen these problems again.

Initially there was also an issue with the filter cloth for the disc filter. Enough detail was not paid to changing filters in time and as a result the filter did not perform well and fines passing through defective filters caused excessive wear on the internals of the filter and vacuum receiver tank

Retaining walls/muck piles underground can easily start leaking if flushing of the pipes is done before the paste level reaches above the old roof. We have not had any extremely large leaks, all have been dealt with fairly easily by adding more waste rock but we feel it is important to try to avoid flushing for a few days if possible.

5 FOLLOW UP

During the second half of 2002 we started to try to detail causes of disturbances and to what extent they influenced paste production. For this purpose we started following the ”components” of the paste production using a simple spreadsheet. The following “components” constitutes our paste plant:

- General.
- Thickener.

- Disc filter.
- Mixers.
- Paste pump.
- Distribution system.

For each main component we also include accessories such as valves, piping, switches, pumps, electrical equipment etc. Each day information is collected and stored regarding production, tonnage, volumes, densities, cement consumption, waste and ore production. By looking at the rate of filling in relation to voids created by the mining we can immediately see if any values deviate and look further into potential causes.

Of particular interest is which type of disturbances to paste production we have. We have therefore, over the years, created a detailed system of recording every disturbance to paste production since these will in the end affect our goal - deposition of paste underground. We register every type of disturbance, which component is affected, type of cause and how long downtime the problem caused. As a side effect we have gained a detailed database of effiency of the paste plant and its different components.

We did not start collecting detailed paste downtime data until the second half of 2002. Therefore this paper only shows data for the full years of 2003 and 2004.

During 2003 and 2004 the mill operated for 13960 hours. During the same period the paste plant operated for 10690 hours, 76.7% of available time since the paste plant can only operate when the mill is operating. The paste plant stood still for 3276 hours of these available hours. The diagram in Figure 4 shows the distribution of these 3276 hours. During these two years, the paste plant poured 511707 cubic meters of paste and used 27565 tonnes of cement. In the same period of time ore production created 506219 cubic meters of voids underground. It is clear that paste can quite easily backfill all voids that the ore production creates. Add the 78385 cubic meters of waste rock that we deposited underground in the same time period and we can see that there is a large overcapacity nowadays, thanks to paste fill.

A closer look at some of the major causes for standstills of paste production during the same time period reveals the following:

- General. The mine needed ordinary deslimed hydraulic backfill to an area which was never scheduled for paste fill.
- Thickener. The thickener has not caused any significant stops in paste production. In 2002, though, we did have a major failure of the main drive gear.

- Disc filter. This includes the vacuum system. Changing filter cloths took some 116 hours. We try to do these changes when the plant is standing still for other reasons so the actual time needed is larger.

- Mixers. This includes weigh hoppers, cement silos and dust scrubber. We encountered major breakdowns of bearings on the main shafts which lead to 544 hours of downtime. Cleaning of the mixers took 216 hours.

- Paste pump. The major cause of standstills was valves and valve seats at the pump outlet that caused a total downtime of 259 hours.

- Distribution system, boreholes and piping. Recoupling work underground and on surface took 277 hours. A plugged borehole required redrilling and pipe cleaning for 508 hours.

Together, these above mentioned major failures, caused paste production downtime for 1906 hours, equivalent of 58% of all downtime for 2003 and 2004.

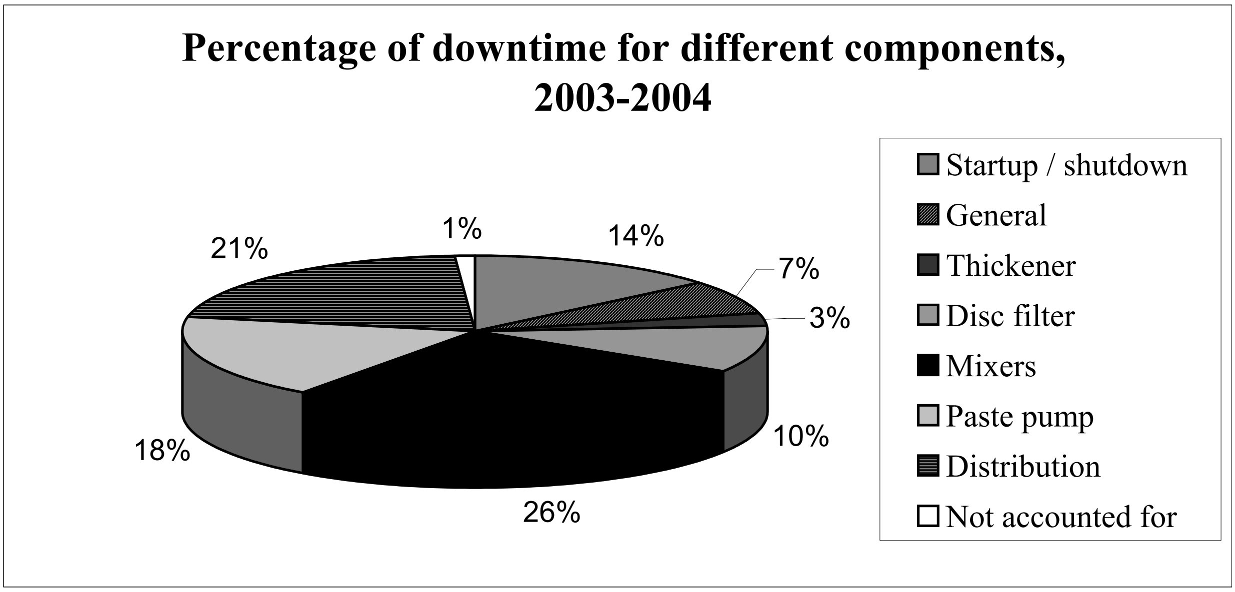

Figure 4 **Percentage of downtime for major paste production components 2003 and 2004, Zinkgruvan**

6 LESSONS LEARNED

It is extremely important to avoid plugging the boreholes. Horizontal piping can be dismantled and flushed one pipe at a time if need be but a long borehole will require redrilling if they are more than 100 m in length. The best results have been achieved with conventional well drilling equipment. Where this has not been possible to use we have had success with diamond drilling from underneath. Our first trials were with high pressure water flushing. This is effective down to a maximum depth of 100 meters but one of the best alternatives for cleaning horizontal piping.

It is also important to keep the speed of moving paste low in the pipes and boreholes. When shifting from one borehole to another there is a big risk of tremendous wear inside the pipe if there is a slight shift in the direction of the paste stream. We experienced a total failure of a schedule 80 steel bend in less than six weeks. After laying out a 100 m long loop before entering borehole two we have not seen any more indications of excessive wear in the bends. Pipe wear on horizontal, straight pipes, is very small and is not an issue.

Tailings can be extremely harsh on valves and valve seats if they gain high speed through pipes and valves, especially in the paste pump. A close watch of the performance of the paste pump is absolutely necessary. Filter bags need to be changed as soon as they exhibit holes in them in order to minimize wear in the vacuum receiving tank and connecting pipes.

Tailings also have a tendency to ”creep” along drive shafts in the mixers we use at Zinkgruvan. The fines would then enter seals and bearings and render them useless in short time. We have rebuilt our bearings and bearing seals and are now protecting the bearings with a pressurized water film.

The wrong flocculant or an excessive dosage of flocculant is detrimental when the tailings reach the disc filter. If there are remnants of flocculant there is a chance of clogging the pores of the filter cloth prematurely, thereby reducing efficiency of the filter. It is better to lose some of the fines early in the thickener than to lose it at the filter because of poor filter cloth performance.

We have changed procedures for filter cloth changes from sporadic, not changing until holes were observed, to changing on a schedule where half of the cloths are changed every two weeks. This gives us a filter cloth life of four weeks and since we change half of them each time we will always have half of the filters no older than two weeks. Overall production of tailings from the filter has improved thanks to this change in procedure.

7 CONCLUSION

Five years ago Zinkgruvan faced a situation where it was obvious that stress issues and rock instabilities more or less forced us to take another approach in mining layout. The decision was to change primary mining methods to open and panel stoping, using paste fill for backfilling since deslimed, hydraulic backfill would not be able to provide us with necessary volumes and/or stability. During the five years we have used paste fill we have managed to keep up with ore production and also filled older workings. This has had a positive effect on regional stability and we have seen a reduction in the number of seismic events. At the same time we have extended the lifespan of the tailings pond by an increase of tailings being processed and deposited underground.

It is not painless to use paste backfill. We have had several plugs in our boreholes. We have also learned the hard way that preventive maintenance is of utmost importance.

The extra cost for paste fill can be recovered by an increase in total ore recovered but only at the end of the mine life. By using paste we estimate prolonging the mine life by one or two years since we have substantially reduced the number of ore pillars in the mine.

Availability of the paste plant has been increased to over 80% of available time at the same time we utilize more than 70% of all tailings for paste production.

We will continue to monitor all disturbances in paste production with the target of further increasing availability and paste production. Further and ongoing trials also include flyash as a substitute for the expensive cement.