Commissioning and Operational Experience of a Thickened Tailing Facility with Two Thickeners

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ABSTRACT

Luossavaara-Kiirunavaara AB (LKAB), an iron ore company with mines in northern Sweden is continuously considering new technologies for handling, transportation and disposal of waste rock and tailings. The mines and concentration facilities are located north of the Arctic Circle which in Scandinavia means an average temperature of about 0° C. Snow from mid-October to mid-May. In winter the temperature may reach -35 to -40° C during weeklong cold spells.

At the Svappavaara mine early technical-economical feasibility considerations together with expected space limitations in the concentrator area favored location of two thickened tailings thickeners on a hill close to the disposal area about 1600 m away from the concentrating plant. In this way only short distance pumping of thickened slurry is required and warm process water is recovered directly by gravity from the thickener to the concentrating plant.

A thickener of a high-density type with 18 m diameter was first installed. Four years later an additional thickener of paste type with diameter 24 m was put into operation. The design (maximum) capacities were 115 and 275 tph (tons per hour) for the 18 m and 24 m thickeners, respectively, with solids flux rates of 0.45 and 0.6 ton/m^2h. Both are planned for common use for 390 tph within a few years.

The tailings product is characterized by an average particle size of about 30 μm with a maximum of about 500 μm and about 40 % passing 20 μm. Solids density about 3000 kg/m^3. A solids concentration by mass of 70 % was considered sufficient for deposition at a slope of up to 3 %.

The objective is to present and discuss the performance of the thickening, transportation and deposition systems during the commission stages and first years of operation. The aim is also to describe how initial conditions related to changes in the tailings production rate together with climatic conditions called for robust by-pass arrangements. Furthermore, complicating factors related to the choice of auxiliary equipment and instrumentation for central functions are discussed.

INTRODUCTION

At the Svappavaara mining, beneficiation (15 000 tpd) and pelletizing operations thickened tailings deposition was considered already in 2003-2005 when thickening and pumping bench and pilot tests were carried out. However, it was then decided to use an adjacent clarification pond for tailings storage and go on with conventional deposition at a solids concentration by mass of about 5 % for some more years. Töyrä et al. (2018) discussed the difficulties with adopting an old tailing storing facility (TSF) to become suitable for thickened tailings placement.

Evaluations related to the deposition and use of centrifugal pumps for transporting highly concentrated slurries were gathered in a thesis by Wennberg (2010). Geotechnical stability considerations for the thickened tailings deposition at Svappavaara due to freezing and thawing were brought up by Knutsson et al. (2016).

OBJECTIVE

The objective is to present and discuss the performance of the thickening, transportation and deposition systems during the commission stages and first years of operation. Unforeseen changes in production plans for the ore beneficiation meant that the smaller thickener was commissioned and initially operated at a throughput considerably larger than the design capacity and later the 24 m unit was in turn operated at a throughput mainly below the nominal design capacity.

THICKENED TAILINGS FACILITIES

The thickeners were designed to produce a solids concentration by mass of about 70 %. The location at the TSF of the 18 m and 24 m diameter thickeners is shown in Figure 1. The 18 m unit was initially equipped with centrifugal pumps for underflow pumping while peristaltic (hose) pumps were chosen for the 24 m thickener and later also used to replace the centrifugal pumps for the smaller thickener. The three slurry delivery lines from each of the thickeners consist of welded plastic pipelines with an inner diameter of 127 mm and a total length of from 160 to a maximum of about 600 m.

A typical profile of the pumping system from the 24 m thickener is shown in Figure 2 where the pumps initially pump against a 4 m static head at the highest point on the pipeline route. Both the centrifugal and present peristaltic pump systems were with few exceptions initially exposed to low working pressures of 150- 200 kPa mainly related to the static head and the dynamic head up to the first vacuum breaker, Figure 2. The total elevation difference has been sufficient for delivery to the discharge end by gravity.

18 m thickener

The underflow was initially pumped with two centrifugal pumps in series at a maximum working pressure of 1000 kPa. The first pump with an inducer impeller design and the second with a standard unit. The impeller diameters were about 0.25 m. In connection with the start-up it was

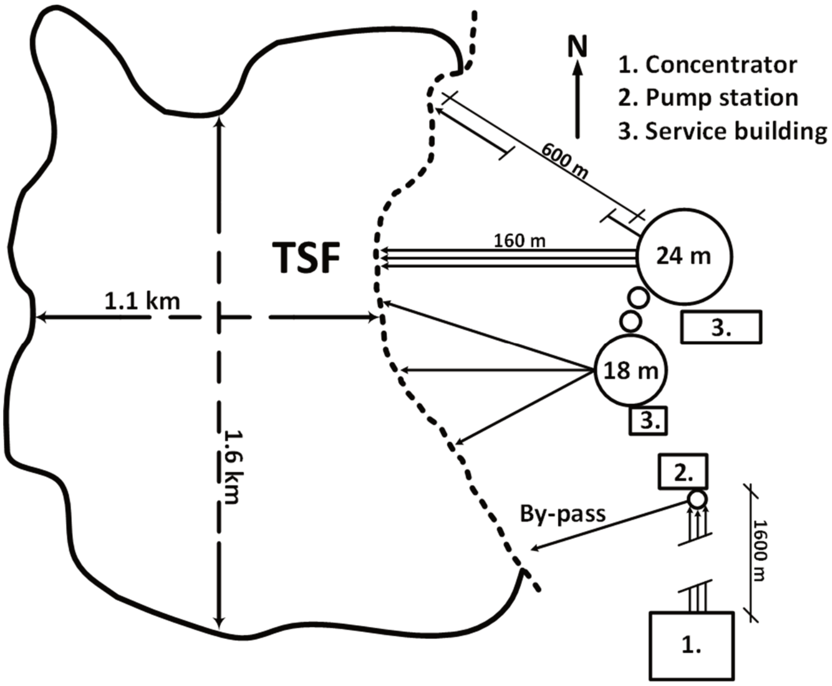

Figure 1 Schematic sketch of the two thickeners located about 1600 m from the concentrator on the eastern side of the TSF. Note that distances are not to scale

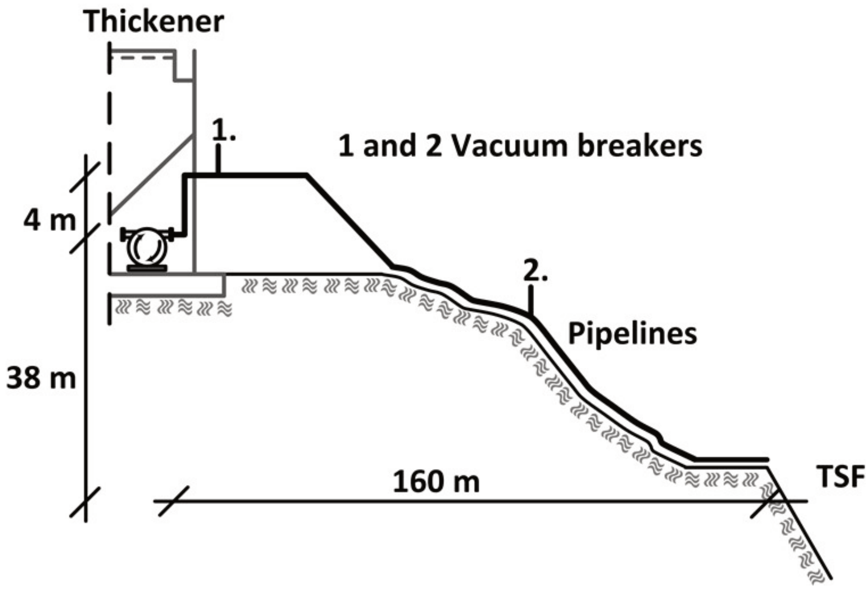

Figure 2 Schematic sketch of the tailing pipelines from the two thickeners to deposition

found that coarse particles of up to about 25 mm in size occasionally were transported with the tailing slurry to the thickener. These particles got caught in narrow passages in the pump impellers which caused reduced flow areas and imbalances that led to vibrations that led to breakdown stoppages. A coarse particle trap was later installed ahead of the delivery to the thickener. The trap was emptied in sequences through a valve arrangement. Efforts were also made at the beneficiation plants to eliminate the large particles at the source. The pumps were equipped with pressurized gland water seals which initially were not fully instrumented. Seal water was received from a nearby borehole which at times did not have sufficient capacity.

The unforeseen increase in tailings production also led to variations in the tonnage to the thickener. At times the feed flow had to be by-passed directly to the TSF from the adjacent pump station, Figure 1. The thickened tailings pumps were exposed to gland seal with interruptions in water supply which together with harsh winter conditions lead to an arrangement with gravity flow controlled by a valve from the evacuation discharge at the bottom of the thickener. The slurry density could not be regulated, and the system operated at an underflow solids concentration by mass of 50-55 %. During nearly six months the average feed often exceeded 170 tph with peak values of over 200 tph (solids flux of 0.78 t/m^{2}h). The design capacity was only 115 tph for the thickener.

The thickener control system was instrumented for the 18 m unit as illustrated in, Figure 3.

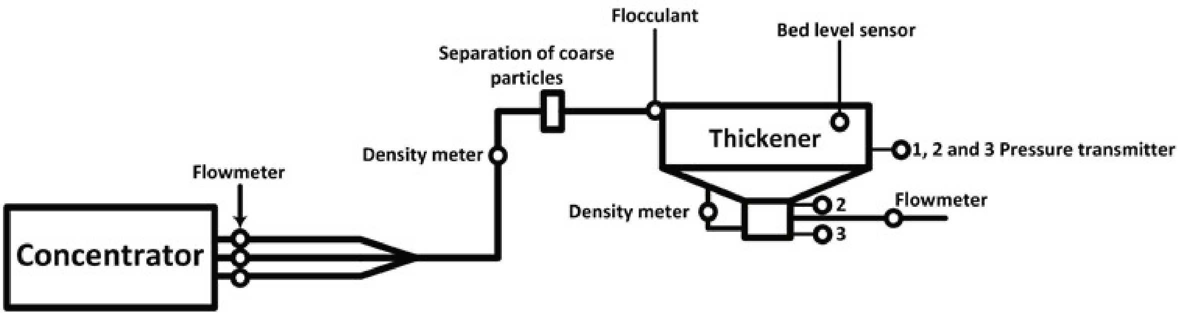

Figure 3 Schematic representation of control arrangements

The slurry density from the thickener was measured in a separate loop before the pumps. For the outgoing slurry, a sonar-based flow meter was found to be unreliable. The bed level was estimated with an acoustic pulse-based sensor and overflow water recovered was generally of very good quality with a suspended solids content well below 0.1 kg/m^3.

The mechanical seals for the centrifugal pumping system installed for the 18 m worked well. However, after the experiences with peristaltic pumps with the 24 m thickener this type of pump was also installed for the 18 m thickener. With the new pump and some other modifications of the instrumentation and controls the 18 m unit was operated at up to 65 % solids concentration for a throughput of about 90 tph during a month-long maintenance stop for the 24 m thickener.

24 m thickener

The 24m thickener system was fully instrumented from the beginning. However, the planned increase in beneficiation capacity was delayed which meant that the design feed rate of 275 tph could not be reached. Most of the thickener operation took place at throughputs rarely exceeding the design capacity, 200 tph (solids flux rate of 0.44 ton/m^{2}h). The acoustic meter for bed level detection worked at times but after a while the standard method was to use a slurry filled bottle fastened to a rope to determine the bed level.

A separate centrifugal slurry pump is often used for recirculating the thickened slurry in this type of thickener or to feed the underflow positive displacement pump. In this application with hose pumps for slurry delivery a centrifugal pump served the double duty of charging the peristaltic pumps as well recirculation into the thickener. A schematic sketch showing the feeding, circulation and delivery arrangement is given in Figure 4.

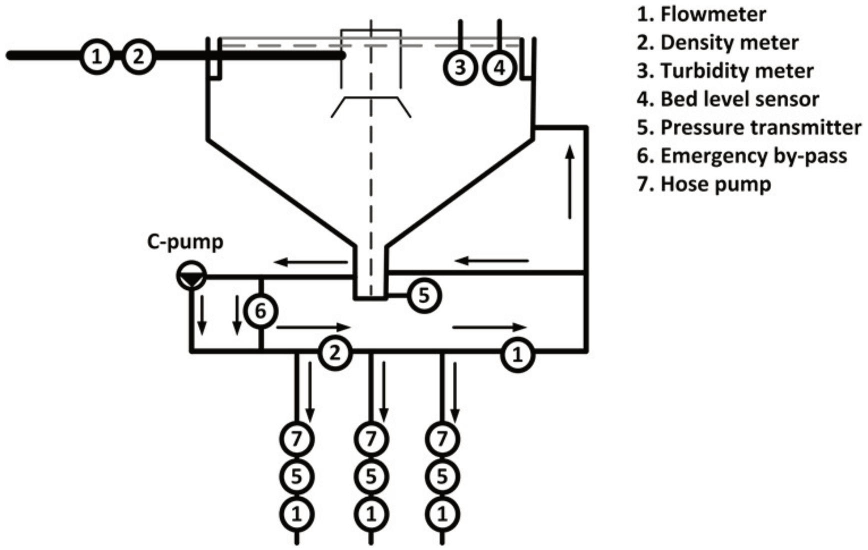

Figure 4 Schematic sketch of the recirculation arrangement with a centrifugal pump and the feeding of the hose pumps that deliver the thickened slurry to the TSF

Steady state operation is based on slurry passage through the centrifugal pump to feed the hose pumps with recirculation to the thickener lower part in order to reduce the resistance to flow. Recirculation via the thickener cone/cylinder intersection can be used to reduce the resistance further and to fill the thickener. If the centrifugal pump is not in operation the hose pumps can draw the slurry directly from the thickener. However, this should not be considered for normal operation. During a month-long maintenance stop for the centrifugal pump the discharge system was however operated without any problems with the three hose pump drawing the thickened tailings slurry directly from the cone through the emergency by-pass at the centrifugal pump, Figure 4.

The underflow flocculated undisturbed tailings slurry has a high yield stress which is reduced considerably by shear thinning during passages through the centrifugal pump. On the other hand, slurry passage through a hose pump does not induce as much shear and the yield stress degradation is generally negligible. Changes in slurry consistency were not observed when the recirculation pump was off, however the solids concentration during this period was held slightly below the maximum as a precaution.

Even with the recirculation pump in operation and adjusting the bed level it was not possible to reach 70 % and hence to achieve the desired deposition slope. The average feed slurry solids concentration was from 5 to 7 %. Minimum, nominal and maximum throughput rates were 180, 200 and 275 tph, respectively. Unfortunately, only a maximum feed solids concentration of 13 % had been specified by LKAB for the feed rate. The difficulty to reach the target figure of 70 % was related to the specified 13 % feed value. The supplier considered this to be the sole reason for not reaching the target after testing various control philosophies.

LKAB repeated flocculant dosage testing and attributed poor performance to unstable operation of the flocculant fluid preparation system which had frequent but relatively short downtimes. Possibly this downtime resulted in less effective use of the flocculant. For the preparation of flocculant fluid, the powdered dosing was fed with a screw to be wetted in a funnel where formation of polymer stalactites and local fouling occurred in this application. The 18 m thickener has different type of flocculent fluid preparation system based on blowing air to facilitate dry flocculant feed to mixing in water jets which works without any problems. This type of flocculant preparation unit was later installed in the 24 m thickener where-after the feeding system worked satisfactorily.

TRANSPORTATION AND DEPOSITION

The hose pumps with pressure class 1000 kPa and a maximum flow rate of 100 m^3/h per pump were equipped with in-line standard dampeners to reduce pressure pulsations and reduce peak pressures. The delivery of an average working pressure by the pump-dampener system relies on the constrain that peak values do not reach 1000 kPa.

In order to verify the pump and pipeline performance operating data were analyzed by LKAB during authentic conditions in a 600 m long pipeline with the discharge located 50 m below the pump elevation. In summary, operating experiences and test results showed that continuous and semi-automated around the clock operation roughly corresponds to a maximum average delivered pressure of 400-700 kPa and flow rates of 35 to 55 m^3/h per pump, i.e. the 100 m^3/h requirement was not met. This delivery rate can only be obtained close to the thickening facilities at pressures of 150-200 kPa. The detailed experiences and test results are planned to be published elsewhere.

The thickener operation, pipeline distribution and placement of thickened tailings form a system which should be designed to deliver the required performance with slurry properties that give a deposited tailing that does not segregate, and which does not produce bleed water after deposition. Theoretically thickened tailings which does not segregate should form a uniform beach slope without concavity. However, some concavity occurs due to hydraulic processes along the length. Practically, in this instance uniform slopes of about 3 % with most tailings deposited within 400 m in the central and northern parts of the TSF, respectively, were obtained after about eight months of nearly continuous operation at 70% with the 24 m thickener as illustrated in Figure 5.

In order not to erode established slopes during downtimes at the thickeners or the beneficiation plants a by-pass pipeline for both thickeners was arranged together with a ditch inside the TSF to the discharge, see Figure 1.

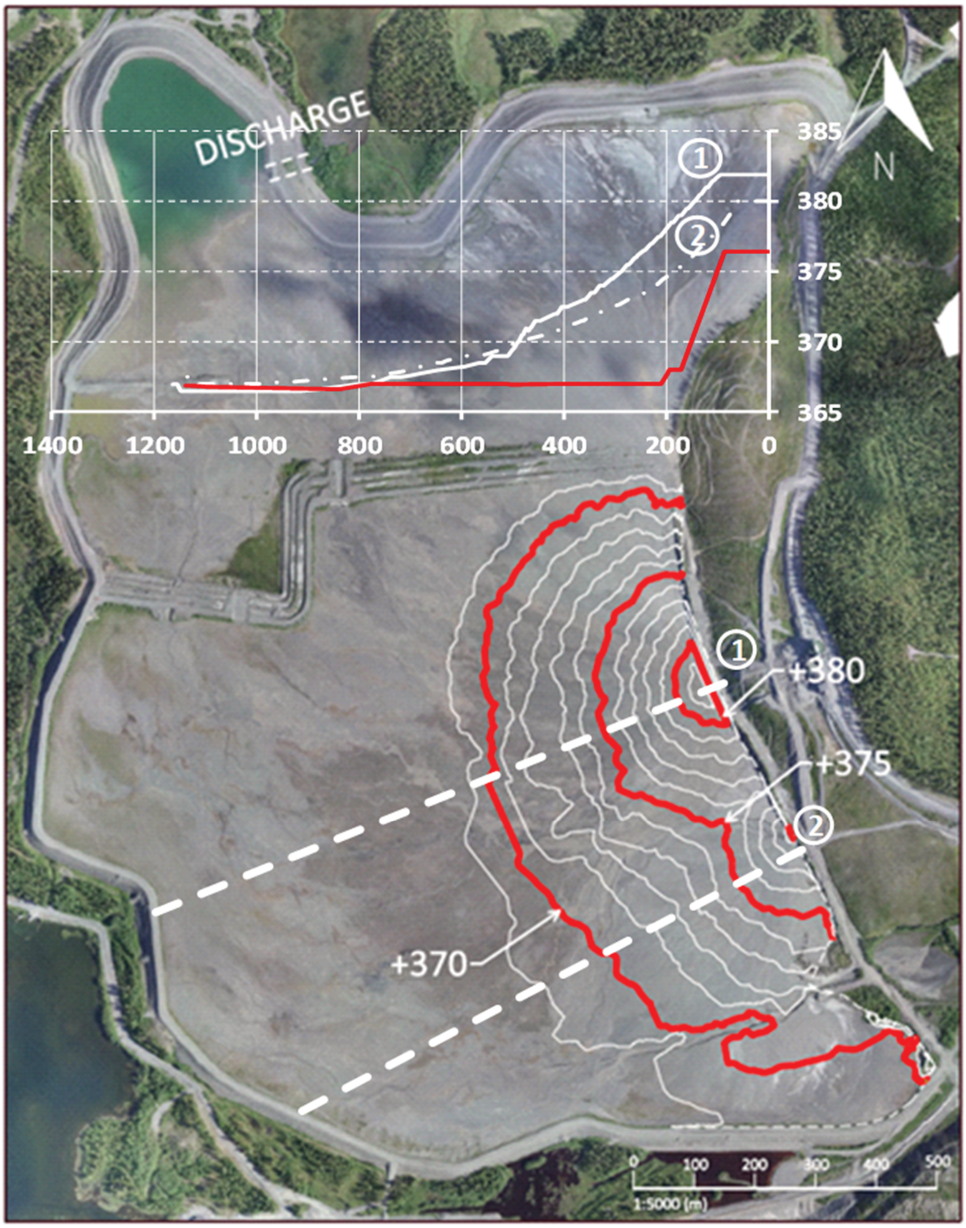

Figure 5 The spreading of deposited thickened tailings, including deposition profiles, June 2017

The last three years of tailings placement has been concentrated northward toward the northeast corner and along the hillside in the thickener area. The cone has just extended slightly toward the central part and a moderate concavity is about to be levelled out through adapted filling about 200-300 m from the TSF eastern boundary at the hillside.

CONCLUSIONS

It is concluded that a solids concentration by mass of about 70% could consistently be delivered and that stable beach slopes of around 3% were achieved. In the performance evaluation procedure, the following system components related to controls and measurements were considered to be of central importance.

Stable and well-functioning flocculant handling, preparation and feeding systems are essential for effective use of the polymer and to reach the required high solids concentrations and an overflow water of sufficient quality.

LKAB analyses of the 18 m thickener function at varying feed flows indicated that there was not sufficiently long residence time to build a substantially high bed within the thickener. Pressure measurements at the bottom and on two intermediate levels provided additional information for estimations of the mass balance and residence time and the building up of a bed. It seemed that the pumps draw the thickened slurry too fast because the pump-control was coupled to the incoming slurry only and there were no reliable underflow slurry flow rate measurements available.

In the 24 m thickener the instrument for bed level detection worked at times but after a while the standard method was to use a slurry-filled bottle on a rope to find the bed level, i.e. a relative indication of the zone with higher solids content. This manual measurement on an icy bridge on top of the thickener was found to be problematic during winter. Use of basic meters for mass balance and reliable instruments for measuring the bed height are needed to control the residence time.

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