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Sarcheshmeh Copper Mine paste plant design, start-up and early operation overview

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Abstract

Sarcheshmeh Copper Mine paste plant was commissioned mid-2012 to re-thicken 95,000 tonnes of tailings per day. Due to the arid climate of this area and increasingly tough legislation on water resource preservation, this plant has been designed to minimise water losses in the tailings storage facility as well as to improve the tailings deposition in the main disposal area. Having been partially thickened by high rate thickeners at the concentrator plant, 40-42% solids (by weight), slurry gravitates via a concrete channel and pipe to the paste plant. The paste plant discharges tailings with 60% solids (target design figure) to the head of two main valleys running down to the tailings dam. The plant consists of twelve 24 m diameter paste thickeners in two rows, flocculant plant, reclaim water pump station and main pipe line. In order to achieve maximum performance along with flexible operation in this plant, several key issues have been taken into account in the plant design, which is briefly presented in this paper. Similar to other process plants, during plant start-up there have been many issues. Thickener underflow flow control, thickener feed, and the sealing of the concrete cones that form the base of the thickener tanks are the other areas of discussion in the paper. The paper discusses the difficulties and challenges associated with the paste plant commissioning and early operations. Moreover, summarised operational records including thickener underflow density, flocculant usage, and water recovery improvement are presented.

1 Introduction

Sarcheshmeh Copper Mine is located in Kerman Province southeast of Iran. The National Copper Industries Company (NICICO) owns this plant, which commenced operation with production of 14 million tonne per year in 1975. The operation consists of flotation, smelting and refinery facilities to produce copper cathode and it was planned to double the copper production through a series of expansion projects.

However, there were several hurdles that hindered the implementation of the expansions and the most challenging one was water supply. South-eastern Iran has a very arid climate and water is scarce. In addition, this area is an agricultural region and this industry supports the local and national economy. Therefore, water use in the region is strictly managed and the proposed expansion at Sarcheshmeh had to take into account the need for water preservation and recycling.

The Sarcheshmeh paste plant along with a series of water preservation projects made the expansions feasible. The paste plant consists of twelve 24 m diameter paste thickeners that have been designed to produce thickened tailings at minimum 59% w/w. This plant was commissioned in 2012, and this paper outlines the design and commissioning challenges associated with what is believed to be the largest paste thickening plant for hard rock tailings in the world. Besides that, the early experience and results will be presented.

2 The Sarcheshmeh tailings thickening scheme

The tailings disposal management scheme for Sarcheshmeh Copper Mine is designed to treat the tailings from the original plant, Phase I and II expansions. The total tonnage to the plant, once all expansions come on stream, would be 32.5 million tonnes per year.

The tailings from the concentrators are dewatered in five 122 m diameter thickeners with underflow solids concentration of 38-45% w/w. Three of these thickeners were associated with the original plant and are planned to be upgraded to high rate thickeners with modifications to the drive mechanism and feedwell system. The remaining two were designed in the first place as high rate thickeners, and were constructed after each expansion phase to treat the additional tailings. The maximum flocculant addition in the conventional and high rate thickeners is 2 and 10 g/t, respectively.

Before disposing of the material into the tailings dam, tailings pass through a concrete channel followed by a pipeline with an on-ground route length of almost 7 km to get to the paste plant. The trapezoidal open-top concrete channel with varying slope of 1-1.75% transports the tailings from the conventional/high rate thickeners to a take-off drop box. From this point, tailings then gravitate through a 1,000 mm diameter steel pipe to the paste plant, where tailings are further thickened up to 60% w/w. In Figure 1, the tailings management system elements are shown.

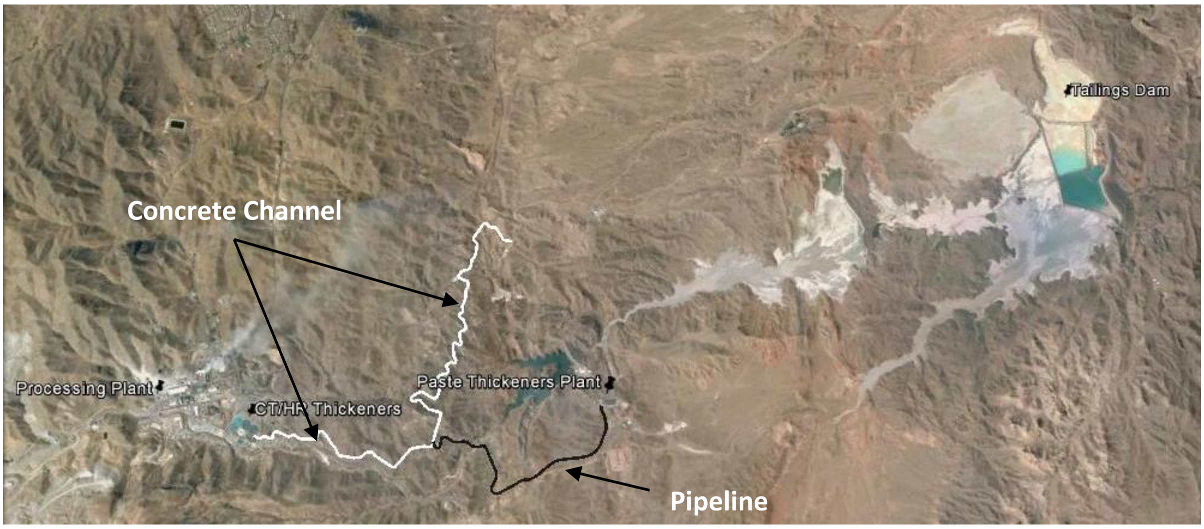

Figure 1 Sarcheshmeh tailings management facility elements

3 Testwork

Tailings testing to assess the material involved laboratory and pilot plant testing. Laboratory testing was undertaken in order to determine the flocculant type and dosage, optimum feed solids concentration, maximum achievable solids concentration and underflow rheology. The laboratory testwork was followed by pilot testing to confirm the semi-continuous test findings from the laboratory testwork and to confirm the thickener performance with a wider range of feed conditions than is possible from a single sample.

Based on the results from the testwork, twelve 24 m diameter paste thickeners were offered by the supplier. Overall tank height is about 18 m with a side wall of 10 m. A summary of the design parameters used to size the thickeners is as follows:

Paste plant feed (normal/design)	3,949/4,150 t/h
Unit area	0.057 m^2/t/d
Optimum feed solids	15% w/w
Flocculant dosage	25 g/t
Underflow density	min 59 % w/w, target 60% w/w

Underflow yield stress	100-150 Pa
Particle size	
○ d100	1,180 µm
○ d80	120 µm
○ d50	35 µm

4 Paste plant design features

The general features of the paste plant were previously described by MacNamara et al. (2011). Figure 2 shows a plan view of the paste plant as designed and constructed. The thickeners are arranged in two parallel rows of six tanks each which are fed by one distribution tank. Thickened underflows are transferred individually through 250 ND steel pipe to either of two concrete drop boxes constructed on the sides of site layout. It was envisaged that by splitting total flow into two lines running down to the tailings dam, a steeper beach slope will be achievable.

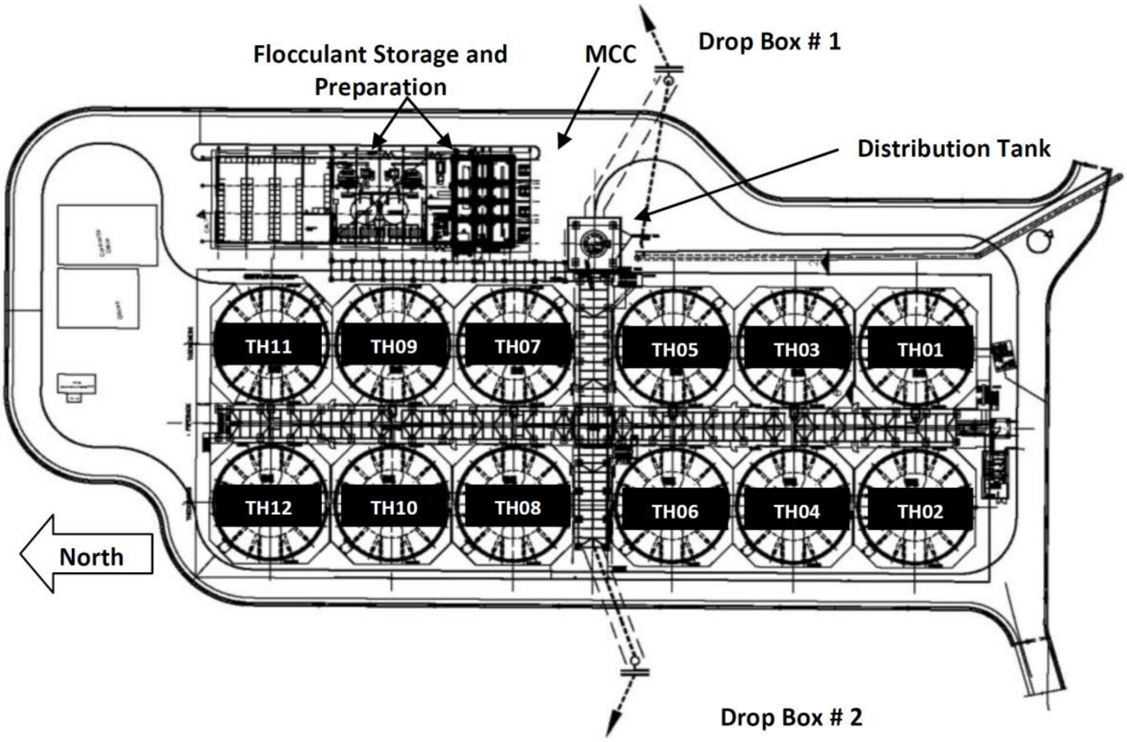

Figure 2 Paste plant general arrangement

The key component of a multiple thickener plant is an even distribution of the feed between the operating thickeners. To achieve this in the Sarcheshmeh paste plant, a bottom–central entrance distribution tank with a combination of pipes and channels is employed. The distribution tank feeds the twelve outlets arranged peripherally in the bottom of the tank to take feed to each of the thickeners individually (Figure 3). The thickeners' feed lines are part pipes and part launders. Given that the even distribution occurs if the thickeners' feed lines all have the same head loss, the pipe part of the feed lines to each thickener must have the same length provided that the pipes are full flow.

This type of flow distribution employing a bottom-discharge tank and pipes requires a minimum flow depth inside the tank to be able to feed the outlet pipes in full flow fashion. At the end of each pipe from the distribution tank, therefore, there is an orifice choke to make sure that there is a minimum depth of 1 m of slurry in the distribution tank. After the orifice plate, the feed system converts into a launder which runs down to the thickeners where the system converts back to a pipe arrangement for feeding into the feedwell.

Figure 3 Distribution tank piping to the thickeners

Another key issue in thickener operation, especially in paste thickeners operation, is accurate control of flocculant addition. The flocculant addition is calculated based on the dry tonnage being fed to each thickener. To measure the dry tonnage, a most common approach is to measure the feed flowrate and feed slurry specific gravity and calculate the actual tonnage.

To obtain the volumetric flow rate to each thickener, the launder part of the feed lines is fitted with an ultrasonic depth indicator to measure the flow depth. Knowing the flow depth from the ultrasonic measurement and the launder slope, the average velocity of flow can be calculated using open channel flow model such as Manning (Chow 1959). The feed flowrate in the channel can then be calculated from the flow cross-sectional area and the flow velocity.

To measure the feed density to the thickeners, a bleed line was taken from one side of the distribution tank, which fed into a standard centrifugal pump. This pump then circulates a small stream of feed back to the distribution tank through a simple standard density gauge.

5 Commissioning

The paste plant was commissioned in 2012 with 21 Mtpa (two thirds of total capacity). Therefore, a maximum eight thickeners were able to treat such tonnage. However, all twelve thickeners were ready to be commissioned. Hence, the extra four thickeners could be used as stand-by units, which was very helpful during the commissioning phase.

During the commissioning, typical of process units in the start-up phase, a series of challenges were faced. Many of those were minor issues solved with a little effort. In this paper, we only highlight the several hurdles which were judged to be of more interest to the reader.

5.1 Thickener underflow control

Consistent underflow and rheology can be obtained if there is an appropriate control on the discharge line from each thickener. Such control can be achieved by flow control valves or VFD-fitted pumps that are linked to instrumentation such as a flowmeter and density gauge.

Figure 4 illustrates the arrangement of pumps and pipes beneath each thickener in the plant. The underflow of each thickener consists of a re-circulation line and a discharge line, both fitted with individual centrifugal pumps. On the inlet side of the discharge pump, two isolation knife gate valves (one manual and one pneumatically actuated) are installed. In-pipe instrumentation on the discharge line consists of a magnetic flow meter and a nuclear density gauge. The intended method of discharge flow control was to use the VFD to adjust the pump speed with feed-backs from underflow density, flow rate and bed level.

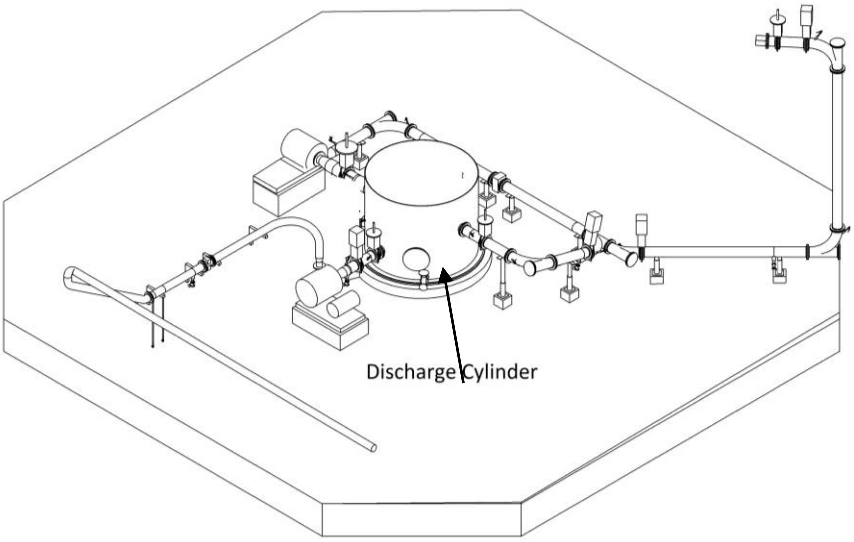

Figure 4 Thickener underflow systems

During the commissioning, it was found that the discharge flow control system installed was incapable of any sort of control. It was almost impossible, even when the pump was turned off, to maintain flow in the desired range because of excessive available static head at the discharge pump inlet. The situation was even worse for the thickeners with the shorter discharge pipe lengths as friction losses were lower. The length of discharge pipe from pump inlet to the discharge point varies with thickener location and changes from 75-150 m.

In Figure 5, for the thickeners with the longest underflow pipe line length (about 150 m), the pressure gradient required to discharge tailings underflow at varying flow rates is shown. With the available pressure head from the thickener, a flow of 775-800 m^3/h can gravitate through the pipe to the drop boxes, and it can be double this when the pipe length is halved. For normal operation, maximum flow must be no greater than 400-450 m^3/h.

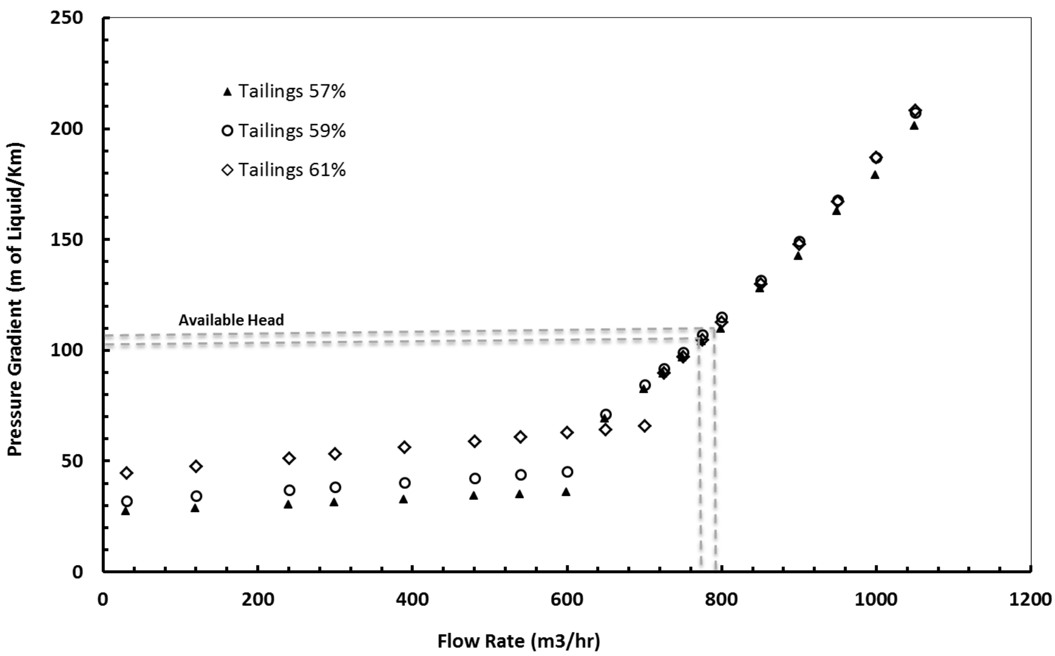

Figure 5 Underflow pipe pressure gradient versus flow rate (150 m pipe length)

To mitigate this challenge, an additional resistance on the downstream side of discharge pumps needs to be added. This could be provided by choking the pipe with orifices or using smaller pipe. In order to rectify this issue temporarily during the preliminary stage of commissioning, installation of an orifice plate at the end of the discharge pipes with the pumps in operation was adopted. However, for a permanent solution, a modification employing a combination of pinch valve and orifice choke (varying sizes for thickeners with different locations in the layout) is being considered. For this case, since the underflow discharge pump would not operate anymore in normal operation, pump by-pass lines will be installed thereby saving the cost of pump maintenance and power consumption.

5.2 Thickener feed flowrate

Flocculant addition to the tailings is based on the dry tonnage reporting to each thickener. As explained above, dry tonnage is calculated from density measurement and flow rate, which are obtained from flow level measurement inside the launders that take material to the thickeners.

There were initial difficulties with this approach. A fully established flow in the short launders was not achievable. The orifices which were designed to maintain a minimum level in the distribution tank caused a very chaotic flow in the initial section of the launders (Figure 6). As a result, it led to the recording of high fluctuations that were not reliable as an indicator of flow rate. It should be noted that this issue was only associated with thickeners number five and seven (Figure 2) where the launders are about 10 m long and shorter than the others.

Initial attempts to overcome this problem involved adjusting the pipe work to decrease the length of the entrance-affected channel flow. Adjusting the orifice alignment and orifice size were also tried. But because of supercritical flow in the channel and high turbulence caused by the orifices, a fully established flow could not be achieved over such a short length.

Finally, it was decided to install clamp-on ultrasonic flow meters on all of the pipes feeding the launders. This type of flow meter can be installed without any modifications to the pipes and are most applicable for pipe with a maximum diameter of 500 mm.

Figure 6 Fully chaotic flow through the launders

5.3 Concrete tank leakage

The most challenging matter confronted in this project was the design, construction and sealing of the thickener tanks. The design of the tank was based on a concreted cone supported on concrete walls and then topped with a steel side wall. In spite of client and consultant reservations, the turn-key contractor believed it was the best choice because of the following:

- The availability of suitable steel for the construction of the thickener tanks, in particular for the tank bases.
- The skills required to weld very thick plates over multiple runs to a high degree of repeatability.

During construction, difficulties were encountered with respect to constructability and tank sealing. Figure 7(a) shows scaffolding, formworking and steel bar bending during the construction. The very high density of reinforcing bars and the steep cone angle (30°) meant that concrete compaction by vibration was difficult and often not very effective. This led to all of the thickeners experiencing leakage problems through the concrete cone. The leaks that were revealed during initial hydrostatic testing with water appeared to have been successful sealed by various applications and injection of epoxy paints and other proprietary products. But when commissioning switched to tailings slurry, the leaks reappeared. It was concluded that the coarse material in the tailings was abrading and destroying the seal.

It was essential that the leakage be prevented due to the risk of damage to the mechanical and electrical equipment, instrumentation installed under the cone, as well as possibly the structure. Further application of a wide range of sealant and injection materials, applied both internally and externally, continued to be ineffective. Finally, an internal steel plate lining was installed and solved the problem.

(a)

(b)

Figure 7 (a) thickener tank cone construction; and (b) water leakage after commissioning

6 Early operation

Performance of a paste or high density thickener is often evaluated by comparison of the solids concentration of the underflow compared to the design figure. However, in addition to settlement behaviour, the operation of such thickeners is mainly dependent on the rheology of the material, and underflow solids concentration may not be the most appropriate indicator of thickener performance. Therefore, we may need to take the rheology of material into account when evaluating thickening operations rather than just the solids concentration. However, for this paper, because additional rheological testing has not been undertaken since the commissioning of the thickeners, we are only able to present the available data for solids concentration.

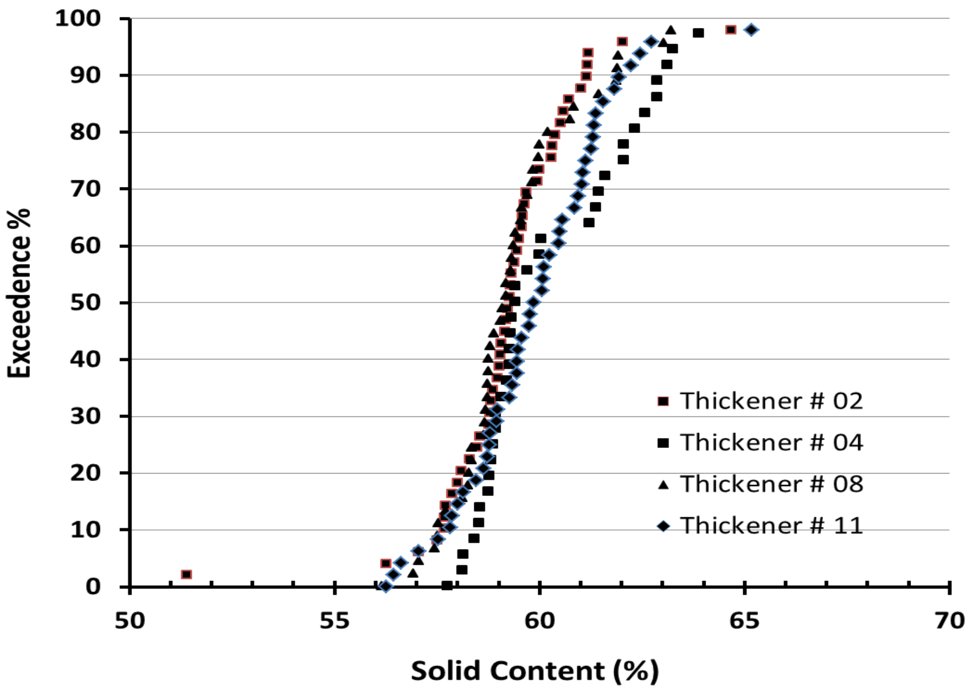

Figure 8 Thickener underflow solid concentration distribution

Figure 8 shows the daily averaged solid concentration of several thickeners for a period of two months. Although the median solid concentration is greater than the minimum of 59% and has met the design figure of 60% for much of the time, almost 20-30% of the time the underflow density was below the minimum target figure.

In terms of flocculant consumption, a usage of slightly over 30 g/t is reported which is higher than the design figure (25 g/t). It should be stated that the type of flocculant being used is different from that used in the laboratory and pilot testing, and this may result in increased flocculant consumption.

Water recovery improvement was also reported since commissioning of the paste plant. It is believed that this is because of a decrease in water losses through evaporation in the tailings dam as a result of the disposal of highly concentrated thickened tailings. The real data for fresh water consumption shows a saving of 0.2 m^3 of water per tonne of ore to date. However, since this is almost entirely dependent on reducing evaporative losses, a longer period of operational experience is needed to properly quantify this benefit.

7 Conclusion

Sarcheshmeh Copper Mine paste plant is a water and tailings management project that was designed and constructed to improve water recovery. The facility consists of twelve 24 m diameter paste thickeners that thicken the underflow from high rate thickeners from 40% w/w to a minimum of 59% w/w.

During the design period, serious consideration was given to achieving a consistent underflow including even feed distribution between thickeners, thickener feed lines and flocculant addition. Thickener tank construction was also an issue that was intensively studied during the engineering phase.

Nevertheless, a number of difficulties were confronted during the plant commissioning. Thickener underflow control, even feed distribution, and concrete cone water leakage were the most challenging. These have all been rectified or are under modification.

The early operation results in the last one to two years indicate a satisfying performance by thickeners. The median solid concentration is greater than the minimum of 59% w/w solids and has met the design figure of 60% w/w for much of the time. However, almost 20-30% of the time the underflow density was below the minimum target. It is hoped that this can be improved with increasing operational experience. The water recovery is improved to date by 0.2 m^3 per tonne of ore. Flocculant consumption is more than the target figure of 25 g/t by around 5 g/t.

Acknowledgements

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