Fine Flotation Tailings Dewatering: Reducing Water Consumption in a Gravity Gold Recovery Circuit

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ABSTRACT

Due to a necessary change in particle size to improve Au-recovery in the gravity and flotation circuit of an 800 tons per day mill in the State of Sonora, Mexico, the Owner was required to engineer and install a concentrate regrind circuit. Upon installation of the vertical regrind mill in Q2 2015, Au-recovery improved by 15 %. However, finer grinding resulted in unintended consequences within the mill's tailings dewatering circuit. The existing equipment was unable to cope with the greater quantity of fine solids now present in the tailings. Process and mechanical stress accumulated within the circuit as fine solids passed through the screening media, into the sump pump and back to the thickener via the cyclone overflow. In this paper, we have defined this process as a "recirculating load" of fines. Problems quickly manifested such as (i) lower equipment availability, (ii) poorer dewatering performance (throughput and efficiency), and (iii) higher operating costs. In Q4 2015, these inefficiencies were reconciled through re-directing the fine tailings thickened underflow to CECMS' CX-Series 80m^2 ceramic disc-vacuum filter. By filtration of particles down to 1.5 μm in size, the CX-Series filter restored the dewatering circuit's normal operations by discharging fine solids, as a <16 % w/w residual moisture filter-cake, into a separate waste stream for transport and final disposal. By producing a clean stream of filtrate, i.e. water, at <200 ppm TSS, the filter supplements 25 % of the fresh process water consumed by the gravity concentration equipment. At this project, fine tailings dewatering, using the CX-Series filter, has offset a total of 15 % of the fresh process water consumption in the mill, equal to 9,360 m^3 of net monthly savings.

INTRODUCTION

In this case-study, we present a successful response in mitigating the impact of an unexpected presence of a finer distribution of solid particles than was included in the design in the mill's tailings dewatering circuit. Reapplication of this design to circuits with similar problems, could be one solution to the macro-level problem of declining ore grades and finer grinding that will continue to complicate conventional water management practices and current equipment in tailings dewatering circuits. Through the application of ceramic disc-vacuum filtration using a 1.5 μm pore-size membrane, the circuit was restored to proper operation through collection and discharge of the fine solids. By drastically improving the recovered filtrate quality to <200 ppm TSS, a direct water return line was between the ceramic filter and gravity circuit process-water feed tank. In doing so, water was returned without clarification from the filtration system to supplement 25 % of total required process water in the gravity circuit. Removal of the fines from the dewatering circuit successfully disrupted the recirculating load and allowed for restoration of proper thickener operation, settling rates, and overflow water clarity. In summary, the installation of the filter has reduced the mill's fresh water consumption by a total of 15 %.

THE PROJECT: OPERATIONS & PROCESS PLANT

The Project's mining and heap leach ("HL") operations reached commercial production in Q2 2005. Numerous expansion projects have been undertaken to grow crushing grinding capacity up to approximately 18,000 tons per day ("tpd"). In addition to ongoing HL operations, an underground satellite deposit of high-grade gold mineralization was defined between 2009 and 2012. To support processing of this high-grade material, an 800 tpd mill with gravity and flotation concentrate recovery was built at a cost of USD$ 20 million. Production of underground ore began in Q3/Q4 2014, with name plate capacity achieved in Q1 2015.

Au-Recoveries and Response

While mill throughput targets were eventually attained after the receipt and installation of certain upgraded components, Au-recovery remained below the budgeted level. Au-recovery was negatively impacted by failing to achieve the appropriate mineral liberalization size. To meet budgeted recoveries, the Owner concluded that they required the installation of a regrind circuit to undertake finer grinding than was achievable by the existing equipment in the crushing circuit (i.e. cone crusher and vertical shaft impactor). Testing and engineering for the sizing of a vertical grinding mill in Q4 2014, with installation completed by Q2 2015. To achieve the appropriate mineral liberalization, the vertical mill reduced the p80 from 250 to 105 microns. This improved Au-recovery by 15 % to the budgeted level of 75 %.

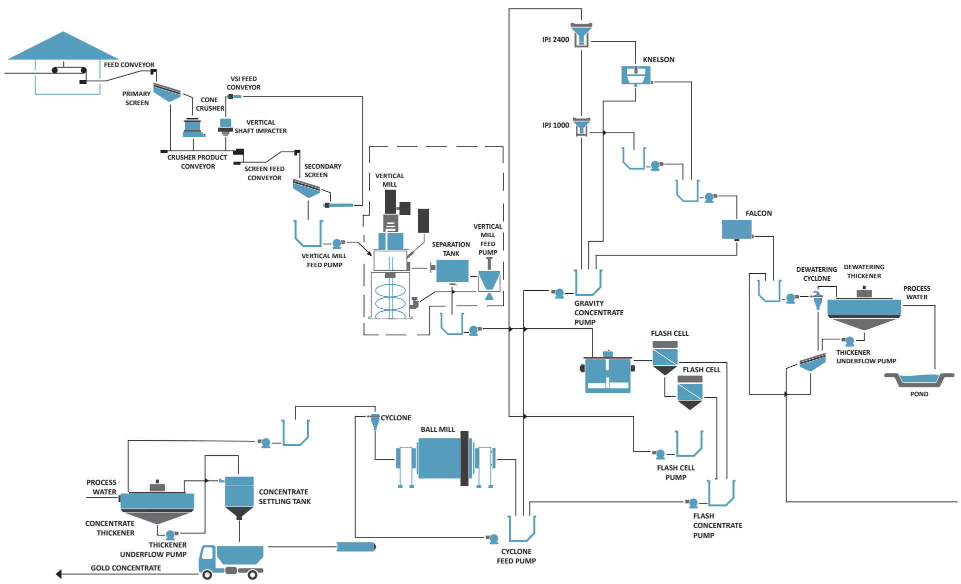

Figure 1 Gravity-Flotation Mill, Process Flowsheet

Unintended Consequences

The installation of the vertical grinding mill resulted in unintended consequences in the tailings dewatering circuit. The existing tailings dewatering equipment was not designed to accommodate such a large magnitude of fine solids (approx. p50 30 microns). Neither the tailings thickener, nor the coarse vibratory screen could function at their designed performance.

Recirculating Load

The dewatering screen was installed with a sieve size of 300 microns, meaning that any particle smaller than 300 microns could pass through the screen and would re-enter the circuit through the sump pump and be fed back into the cyclone for physical classification. Over time, more fines could accumulate into the circuit, because the thickener underflow ("TUF") also reported to the dewatering screen. In this paper, we refer to this process as a "Recirculating Load". As seen in Figure 2, this arrangement, "V1.0", formed an (almost) closed loop with limited ability for the equipment to discharge fines from the circuit.

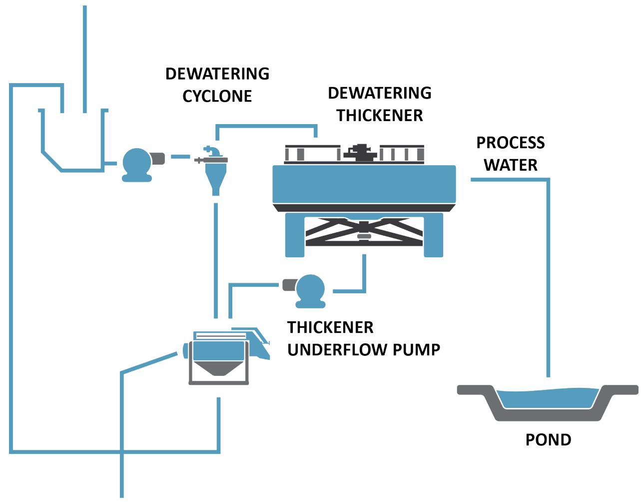

Figure 2 V1.0 Dewatering Circuit, Screen Co-Disposal (i.e. "Recirculating Load")

Quantifying the Impact

As fine solids accumulated in the dewatering circuit, they formed a disproportionate fraction of total solids, distorting the particle size distribution of tailings to become finer over time. Fines were unlikely to exit the circuit, and the existing equipment began to show escalating signs of stress and decreasing performance. The following observations were made in the circuit:

- Higher residual moisture content of 'coarse' tailings being dewatered by the dewatering screen;
- Poor settling characteristics and increased consumption of flocculant in the thickener;
- Poor (i.e. 'dirty') filtrate quality/clarity achieved in thickener overflow ("TOF");
- Accumulation of fine solids in thickener bed, causing higher torque on rake arms;
- Declining thickener availability due to mandatory manual cleaning at regular intervals;

Thus, the average operating cost for the tailings dewatering circuit increased after the installation of the vertical mill.

DESIGNING A SOLUTION

To remedy the issues prevalent in the dewatering circuit, fines were needed to be recovered from the circuit and to discharge them separately as a new waste stream.

Thickened Underflow Slurried Tailings Storage Facility

The first action taken was to redirect the TUF away from the Dewatering Screen and pump the material directly to a slurried tailings storage facility ("TSF"), as shown in Figure 3, built near the mill. Due to constrictions of the site layout and limits on land use, the small-scale TSF was constructed with substantially less than life-of-mine ("LOM") storage capacity. To increase capacity to LOM-storage, dam embankment raises were to be required at additional capital cost. Moreover, the fines solids settled in the pond at a slower than expected pace. Poor consolidation of the fines resulted in insufficient quantity and quality of water reclaimed from surface pumps placed in the TSF.

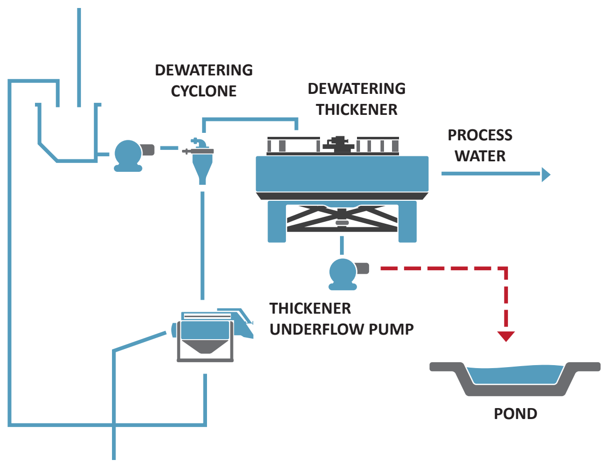

Figure 3 V2.0 Dewatering Circuit, Slurried Tailings Storage Facility

The Case for Further Dewatering

Due to the project's location in the east-central portion of the Sonoran Desert, ensuring the mill had sufficient quality and quantity of water was critical to its operational excellence. Therefore, fine tailings dewatering beyond the achievable density in the TUF provided an opportunity to conduct a cost-benefit analysis on an incremental capital investment. This trade-off scenario, initiated for investigating further dewatering (i.e. filtration), included the following dimensions:

- Potential impact to water balance by reclaiming more, higher quality water than what was achievable from the slurried TSF;
- Limitation of further, necessary slurried TSF embankment/capacity expansions;
- Recovery and discharge of fines for conveyor transport and heap leaching;
- Mitigation of further, incremental land-use by utilizing the HL facility as the fine tailings solid waste dump;

Upon review of the potential benefits from the dimensions stated above, an internal study to evaluate capital and operating costs of the Owner's tailings filtration alternatives was completed.

Filtration Testwork and Design

To quantify the value of dewatering the tailings thickener underflow, the Owner engaged multiple vendors to undertake filtration testwork with the following objectives:

- Evaluate the suitability of tailings slurry for method of filtration (vacuum, pressure etc.);
- Determine achievable rate of filtration while maintaining a residual filter-cake moisture content of no more than 16 % w/w;
- Recommend appropriate technology, provide optimum equipment set-up anticipated budgetary costs (capital/operating) and dewatering performance parameters;

The solid tailings samples provided to the vendors were characterized predominantly as quartz/silica minerals with a particle size distribution as summarized in Figure 4.

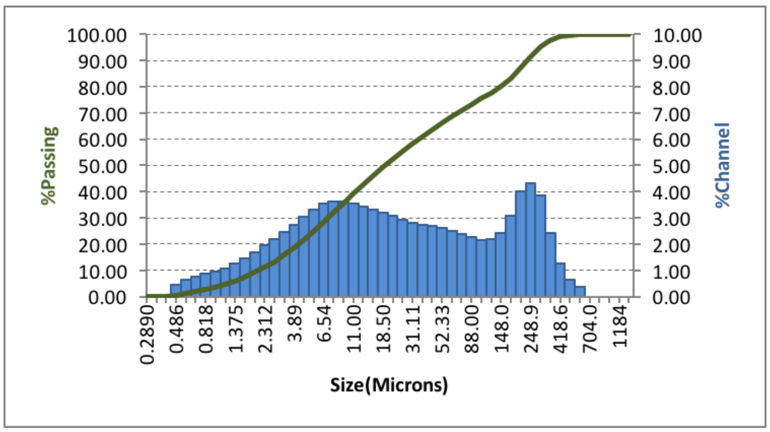

Figure 4 Solid Tailings Particle Size Distribution

Upon completion of testwork by the vendors the following conclusions were made:

- Horizontal vacuum belt filtration was deemed unsuitable due to poor retention of fines (filtrate turbidity > 1000 NTU), declining rates of filtration above 10 mm filter-cake thickness, and minimum achievable moisture measured at 24 % w/w;
- Membrane chamber filter press technology was deemed suitable due to adequate retention of fines and residual filter-cake moisture content of 16 % w/w;
- Ceramic filtration was deemed suitable due to optimum retention of fines (filtration turbidity <200 ppm of TSS) using a 1.5-micron pore size membrane, achievable residual filter-cake moisture contents of 16 % w/w, and filtration rates of 0.47 t/h/m^2.

Filtration Equipment Selection

Testwork summaries were collected by the Owner and compiled to form a selection matrix that included physical equipment characteristics, adherence (i.e. compatibility) to the fine tailings produced by the mill, processing characteristics specific to each equipment, and economic characteristics established by each vendor. From this multi-variable analysis, including such factors as equipment energy consumption, and time for fabrication, CECMS was selected for provision of its CX-Series ceramic disc-vacuum filtration system to dewater the mill's gravity-flotation Au-tailings.

Filtration Design

Through bench-scale testing, CECMS established a scope of design to act as control for incoming process variables and slurry characteristics. These set of controls, as summarized in Table 1 act as qualifying criteria to produce a set of performance expectations for the CX-Series filter.

Table 1 Filter Feed Characteristics

Process Data	Unit	Avg.	~	Design
Material Characteristics:				
Feed Material Description			Gravity/flotation tailings – primarily silica and quartz minerals (minimal clay-like particles)	
Solution Temperature	°C		20 – 26	
Solution pH			8	
Feed:				
Solids Mass Flow - Nominal	t/h	33		37.7
Slurry Mass Flow - Nominal	t/h	55		62.83
Slurry Vol. Flow - Nominal	m^3/h	34.22		39.10
Slurry Percent Solids	% w/w	60		60
Solids Specific Gravity	-		2.7	
Slurry Specific Gravity	-	1.61		1.61
Particle Size:				
F80	µm	148		148
F50	µm	30		30
Operating Conditions:				

Site Elevation	mASL	1,342

CX-Series dewatering performance specifications as established in the filtration design have been summarized in Table 2.

Table 2 CX-Series Filtration Design

Process Data	Unit	Value
Suggested Equipment		CX5-80
Required Filtration Area	m^2	80
Filter-Cake Product:		
Slurry Mass Flow – Nominal	dmtph	37.7
Productivity (Minimum)	$t/h/m^2$	0.471
Residual Moisture Content	% w/w	12-16
Equipment Availability	%	85
Filter-Cake Thickness	mm	9-10

FILTRATION OUTCOMES

Fine Tailings Filtration

Since commissioning in December, 2015, the CX5-80 ceramic disc-vacuum filtration system has been successfully recovering fine solid material directly from the TUF at the appropriate residual moisture content for conveyor transport to, and disposal in, the HL where it undergoes further leaching. Filtrate is being returned directly via pipeline from the filter's dual filtrate receivers to an intermediary process water tank. It is then pumped to the fresh water inlet of the gravity circuit's equipment. Tailings are being dewatered to form a filter-cake that is 9 – 10 mm thick, and <16 % w/w in moisture content. This allows for appropriate discharge and conveyor transport without slumping. The filter-cake is then blended with crushed ROM ore from the low-grade open pit, agglomerated with cement to maximize leaching rates, and conveyed for placement within the HL Facility. The current process flowsheet diagram for the dewatering circuit equipment arrangement can be referenced in Figure 7.

Water Recovery

When in operation, the filter can recover 13 m³/hr. of clear filtrate from the TUF. This filtrate is returned to the gravity circuit where it offsets approx. 25 % of total fresh water consumption. There is no secondary clarification or treatment required. From this process, the mill has an annualized savings of 15 % of total water consumption. Due to the aridity of the Sonoran Desert, this accounts for a significant increase in life expectancy of the local aquifer used jointly by industry and the local municipality.

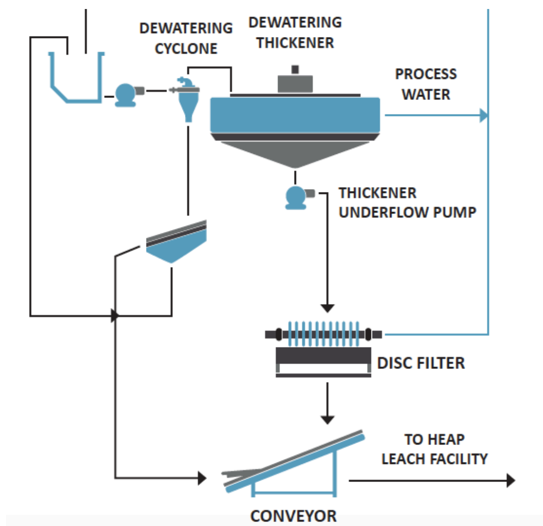

Figure 5 V3.0 Dewatering Circuit, Tailings Filtration

Tailings Storage Footprint

The mill's tailings are now effectively separated into its solid and liquid components. Recovered water from the tailings feed is sent back to the mill, and recovered solids are sent to the HL Facility. While the original TSF has not been de-commissioned to act as an emergency disposal catchment for slurried tailings, no further embankment or capacity increases during the LOM. This project has neutralized the Owner's physical footprint of its tailings production.

CONCLUSION

Through implementation of an innovative and cost-effective dewatering technology solution, the Owner has optimized the process flowsheet to maximize water recovery, neutralize the mill's tailings footprint and ensure proper operation of the entire dewatering circuit through filtration and removal of fine solids. The capital investment required for the installation of the CX-Series filter has allowed for an average monthly savings of 9,360 m³ of fresh process water consumption. On an annual basis, this equates to the volume of 45 Olympic size swimming pools.