SIMULATION FOR BALL MILL SIZING: THE PATH TO A SUCCESSFUL PLANT START-UP

A. Berton [1], A. Rousselet[2], H. Gilbert-Tremblay [1]

[1]*Soutex,*
357 rue Jackson,
Quebec, Canada G1N 4C4 – www.soutex.ca
*(*Corresponding author: aberton@soutex.ca)*

[2] *Ressources Robex*
rue 50, porte 901 Badalabougou
B.P. 1939 Bamako, Mali – www.robexgold.com

ABSTRACT

Robex Resources interrupted production at the Nampala Mine in September 2014 following throughput and gold recovery results which were below expectations during the first months of operation. After a thorough plant audit, an important brainstorming took place in order to identify an economical path to resume production. It was clearly identified that a significant investment was necessary at the concentrator prior to restarting the plant, namely the addition of a ball mill and a new elution system.

The mineral processing simulation software USIM PAC was used in order to simulate the grinding circuit in design. The simulations' outputs allowed the ball mill characteristics and the surrounding classification devices to be designed with more accuracy. Many ball mills available from second hand retailers were therefore studied in the simulated circuit. The chosen ball mill, which was in perfect condition, had the advantage of being available for rapid delivery on site.

The paper first describes the ball mill sizing method in comparison with the conventional Allis Chalmers method. It then describes the phase 2 concentrator start-up (that took place in 2016) with the commissioning of the ball mill, the classification circuit, the gravity concentration, the four (4) new carbon-in-leach (CIL) tanks, and the Zadra elution system (The phase 1 start-up took place in 2014). It finally provides production data compared to expected simulation data, as commercial production was reached in January 2017.

KEYWORDS

Plant start-up, Ball mill simulation, Equipment sizing.

INTRODUCTION

Designing a new concentrator or new equipment within an existing concentrator requires significant efforts to identify possible bottlenecks and their causes (i.e. limiting equipment or sectors) and accurate sizing of major equipment can have a tremendous impact on the economy of the whole project. In the presented case study, the ball mill was the critical equipment and oversizing it could have brought the Capex to a level where the project would not have gone through. Inversely, undersizing the mill could have resulted in lower production and therefore no economic viability for the project once it is in operation.

During engineering studies, equipment sizing often relies on a static mass balance and one-by-one sizing of all pieces of equipment. The sizing is then left to the equipment manufacturer or in the case of mills, evaluated with empirical models mostly relying on the Bond equations (Allis Chalmers method) [Rowland and Kjos, 1978]. This methodology shows the disadvantage of not considering interaction between equipment in a mineral processing circuit, especially when recirculation occurs. Also, it has the disadvantage of not using the more advanced grinding models that include the use of the whole particle size distribution as well as phenomenological components by only using limited parameters in the ore particle size distribution (i.e. the P_{80}). This can be explained by the lack of data that sometimes needs to be gathered in order to tune the more advanced models but also by the conservative mindset in mineral concentration engineering which does not always favor the use of process simulation. In many aspects of process engineering, Soutex has demonstrated its affinity to using simulation in order to size equipment with more accuracy, consider process variability, simulate complex systems, and study supply chain management (Berton et al., 2015).

Advanced simulation software such as MetSim [Holtzapple et al., 2013], JK SimMet [Napier-Munn et al., 1996], CEET [Dobby et al., 2001; Starkey et al., 2001] or USIM PAC [Brochot et al., 2006] are sometimes used in plant design. These softwares, enabling the simulation of the whole plant or a part of it, generally integrate effects of recirculation. For instance, the effect of modifying cyclone size or screen efficiency on a grinding circuit will directly impact the performances of the mill and therefore, the whole equipment sizing will have more coherence than sizing equipment one-by-one. Also, mineral processing tools show the ability of using more complex grinding models integrating either large databases (JK SimMet or CEET) or phenomenological models such as a kinetics approach (Austin et al., 1984; Herbst and Bascur, 1979).

The present paper presents a case where the conventional sizing method is compared to a plant simulation using a more complex model. The two approaches ended up with important differences in the ball mill sizing. The two approaches are compared and the high discrepancy between the methods in our case study is explained.

In the second section of the paper, the overall plant start-up and commissioning is presented. The start-up of new concentrators, extending from the commissioning of equipment to the production ramp-up, is a critical period where the processing circuit operations must be done in a structured and well controlled way to enable the gradual, safe and rapid achievement of production targets. Planning a new plant or new circuit start-up in a mine installation involves various risks, both at the economical and safety levels. Unprepared staff and equipment can lead to incidents that could threaten human safety as well as the environment. Moreover, a poorly prepared start-up can often lead to equipment break-down, production stoppages and delays, leading to important economic impacts, delaying commercial production and therefore affecting directly the profitability of new mining projects.

Over recent years, Soutex has been involved in the commissioning of various process plants or partial circuit commissioning in iron ore (Bloom Lake, Wabush Mine, IOC), in base metals (Canadian Royalties, Xstrata Raglan, BGM), in gold ore (Osisko Canadian Malartic, Goldcorp Eleonore, Detour Gold, IAMGold Essakane, AEM Meadowbank and Kittilä, Robex Gold) as well as in Potash (PotashCorp Cory and Sussex) and in Lithium (NA Lithium). Through these various experiences, a state of the art method was developed, in order to maximize the chances of success of processing plant commissioning and start-up (Berton et al., 2016). This integrated approach was also used in the case of the Nampala mine start-up, as the same engineers were involved in the design phase, the commissioning phase and currently in the production phase. The plant start-up was a success, the mill reaching commercial production only 6 months after the ball mill made its first rotations.

INDUSTRIAL CASE STUDY

Robex Resources is a junior gold exploration company that recently turn into a gold producer. The first plant start-up (phase 1) took place in the spring of 2014, with a simplified process where only fine ore was to be leached and gold recovered with a kettle-type elution/electrolysis column. The intent of such a flowsheet was to produce gold rapidly in order to fund the remainder of the plant through available cash flow. The process as it was first constructed is illustrated in Figure 1.

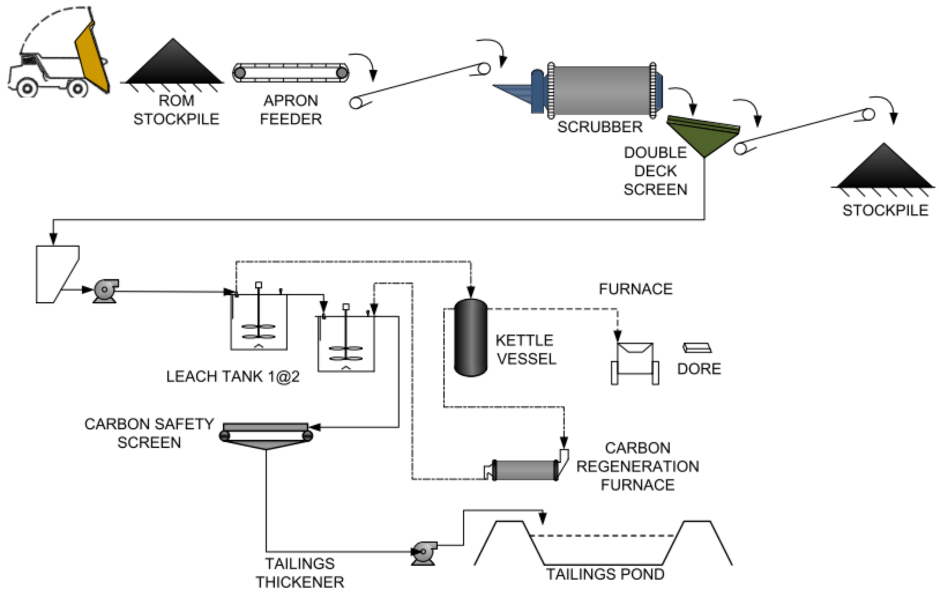

Figure 1 – Original Flowsheet at the Nampala Site

The process was supposed to stockpile the coarse fraction of the scrubber output for future processing in a modified concentrator. Following a few months of struggles to recover gold, an external audit was carried out by Metallurgists form Soutex, in order to highlight the process deficiencies. The problems highlighted by the audit included:

- Optimal liberation size not reached;
- Fine material being poorer in gold than coarse in the first months of production (reducing the feed grade);
- Too coarse material going into the CIL and sanding it;
- Short-circuit of CIL due to only two tanks and no downcomers;
- Retention time too low;
- Non-conventional strip and electrolysis system, not adapted to low grade operation such as at the Nampala site.

All taken separately, the listed problems were not unsolvable, but the addition of the many process risks made the concentrator operation very difficult. Over the first months of operation, the gold production was close to null, despite strong efforts from the operating team on site. In September 2014, production was stopped and most of the employees were sent back home. At this point, only a minimal crew was kept on site for minimal maintenance and safety. Considering the size of the problem and the economic environment at that time, it was not clear if the plant was ever going to start back up again.

A new study was then carried out on the Nampala concentrator in order to evaluate how the flowsheet could be upgraded in order to ensure viable economics in terms of throughput and gold recovery. Soutex was in charge of the process design and proposed major modifications to the flowsheet, including:

- A ball mill;
- Gravity concentration equipment;
- Hydrocyclones;
- Trash screen;
- Four (4) additional CIL tanks;

- A Zadra elution system (acid wash vessel, strip vessel and carbon water system);
- Two electrolysis cells;
- A new lime distribution system;
- New tailings pumping system;
- A new fresh water and process water system (storage and distribution);
- Upgrade of the power plant;
- New fuel storage and distribution system.

The proposed flowsheet for the second phase is presented in Figure 2 and Figure 3 illustrates the two comminution circuits, before and after expansion.

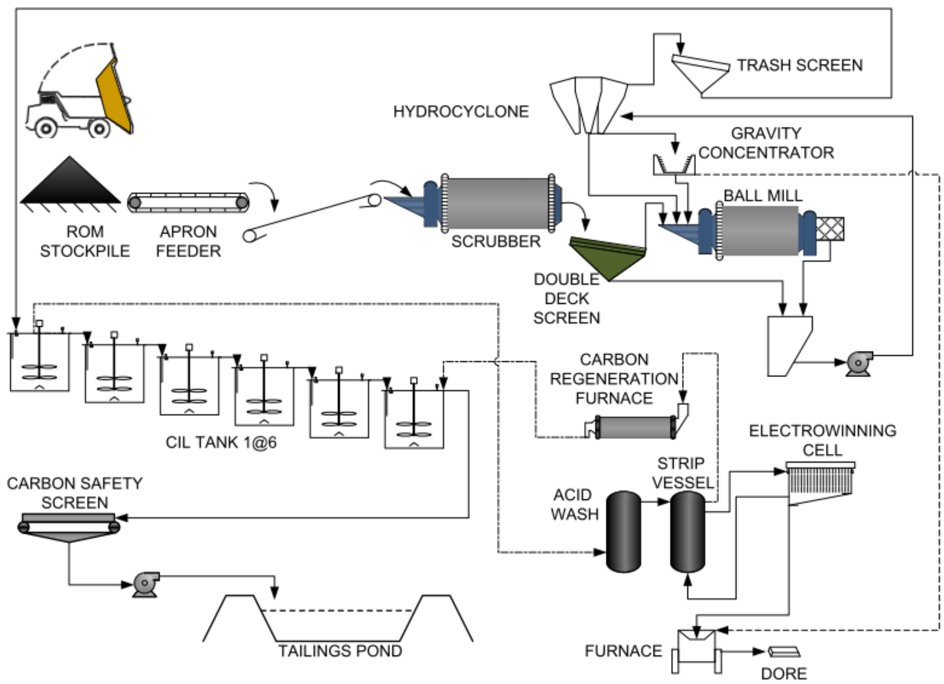

Figure 2 – Phase 2 Flowsheet at the Nampala Site

Figure 3 – Comminution Circuit - Before and After Phase 2 Expansion

Due to budget constraints, the study had to be completed very quickly and on very limited resources. The key element representing risk in the study was the ball mill, for which little testwork data was available since no mill was in the previous design. In addition, no drill cores were available for additional testing and no additional drilling was envisioned.

BALL MILL DESIGN CRITERIA

As mentioned in the previous section, the testing done on the ore related to grinding was almost non-existent. However, production data from the first months of operation was available, giving a fairly good idea of the ore particle size distribution and variability after the scrubber. Figure 4 shows the particle size distribution of the feed ore. This consists of an average ore mixing of the two main orebodies: laterite and saprolite. A large part of the material, especially when dealing with saprolite, is already fine enough after the scrubber stage. This atypical particle size distribution was a key feature in the results later obtained by the conventional Allis Chalmers method.

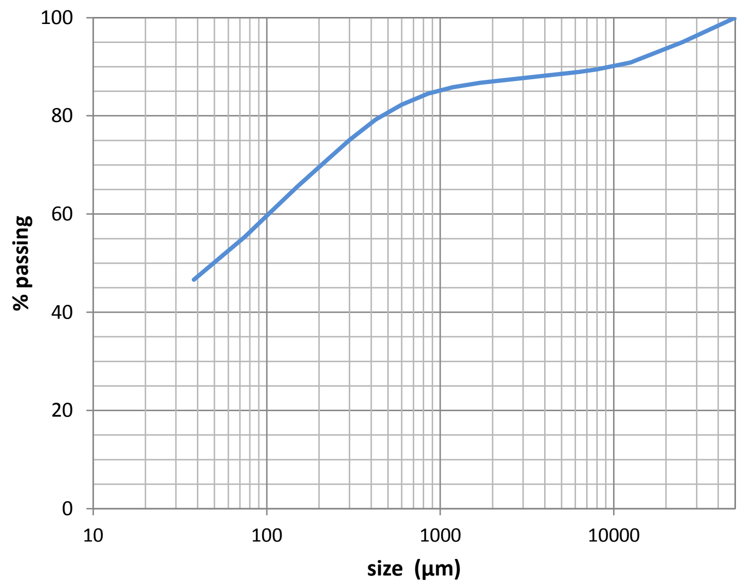

Figure 4 – Typical Particle Size Distribution of the Nampala Concentrator Feed

Table 1 shows the main design criteria that were used in the design of the ball mill. The Bond ball mill work index estimated shown in this table was provided by the client and was considered conservative. No Bond tests were made on the ore.

Table 1 – Engineering Design Criteria for the Ball Mill

Description	Value	Units	Source
F_{80} after the scrubber	462	µm	Operation
P_{99}	<300	µm	Testwork
P_{80}	<125	µm	Testwork
BWi	10-13	kWh/t	Client
Throughput	186	t/h	Objective
Throughput	4000	t/d	Objective
Discharge type	overflow		Standards

CONVENTIONAL BALL MILL SIZING

The conventional sizing method is based on the Bond energetic theories known as the Allis Chalmers method. The method calculates the size and the power draw of a mill with respect to the F_{80}, the P_{80} and the BWi. In addition to these parameters, numerous correcting factors are computed to take into account physical aspects such as dry grinding, open or close circuit, the diameter of the mill, if fine grinding is occurring, etc. It is important to notice that this method only considers one parameter of the particle size distribution and not the whole distribution. Table 2 shows the sizing results with the use of two different Bond ball mill indexes.

Table 2 – Sizing of the Ball Mill – Conventional Method

Parameter	Units	Low BWi	High BWi
BWi	kWh/t	10	13
Design Factor	%	30	30
Diameter	m	5.0	5.0
Length	m	6.0	7.0
Installed Power	kW	1300	1500

BALL MILL SIZING USING SIMULATION

The absence of a reliable Bond index evaluation and also the quite large ball mill obtained with the conventional sizing method led Soutex to try an alternative sizing method. This was possible thanks to the fact that in previous years, Soutex led simulation projects on similar ore also in West Africa allowing the building of valuable databases on ore which are a blend of saprolite, laterite and transition (ore mixing the properties of saprolite with much harder fresh rock). The realisation of this project allowed Soutex to calibrate a sophisticated phenomenological model using the kinetics approach (Austin et al., 1984; Herbst and Bascur, 1979). In this model, although the energetic approach is combined with the kinetic, no explicit Bond index is used. Instead, breakage functions and selection matrices are calibrated using operation data. The kinetic approach comes from the estimation of different kinetic constants for various populations (depending on size and species) resulting in different steady states.

The mineral processing simulator USIM PAC incorporates this type of model in an integrated simulation of the whole comminution circuit. Figure 5 shows the simulated comminution circuit.

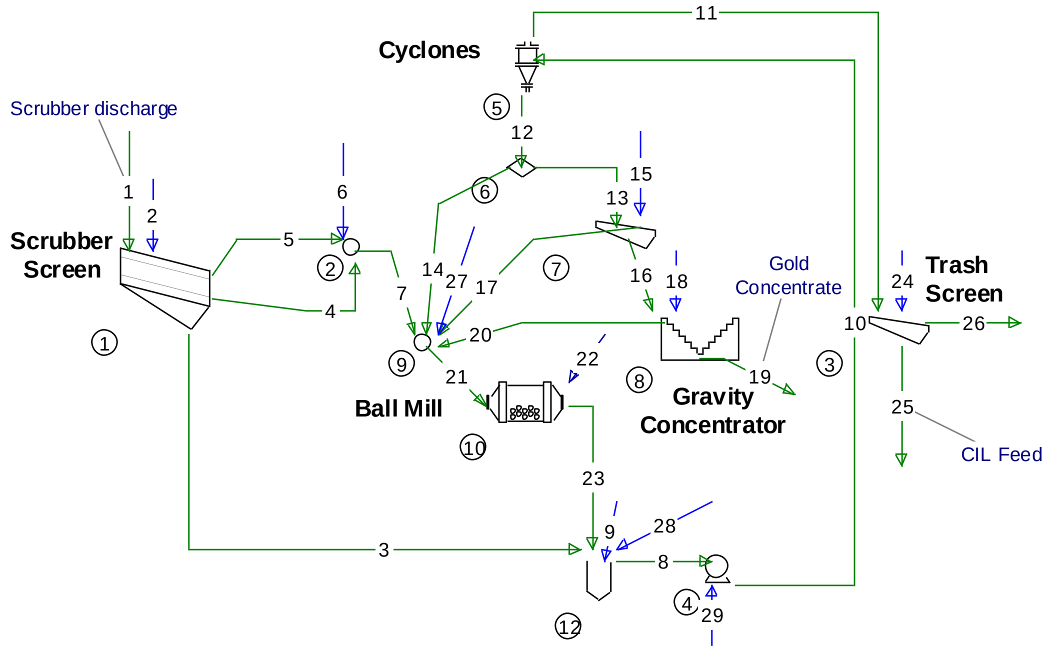

Figure 5 – Comminution Circuit Simulated in USIM PAC

The screen was tuned using operation data and the cyclones were tuned based on performances provided by manufacturers also using simulation. With the ball mill comminution model provided from another operation, only the ball mill size and operating parameters (ball charge, speed, etc.) needed to be adjusted.

In order to obtain the desired performances at the cyclone over flow (P_{80} of 125 µm), a much smaller mill was selected compared to the result of the conventional method (Table 2). The simulator indicated a power draw of 535 kW for a mill of size 2.9 m in diameter and 4.8 m long.

From this point on, available ball mills on the second hand market were searched in order to simulate real ball mills with their exact characteristics. Many ball mills were tested but one was rapidly identified as the most promising as it was in very good condition and offered a slightly bigger size then the minimal sizing simulated. The ball mill was a Polysius manufactured in 2006 but never used (planned for an application in a power plant in Tennessee). Using this ball mill's characteristics, various simulations were realised in order to produce scenarios, presented in Table 3. Case 1 represents the minimal sizing (not a real available ball mill), case 2 represents the Polysius simulated with normal ball charge and tonnage, resulting in a finer grind than designed. Case 3 works with a smaller ball charge in order to obtain the design P_{80} at the screen overflow and finally, case 4 produces the targeted grind with normal ball charge, but at a higher throughput.

Table 3 – Sizing of the Ball Mill – Simulation Approach

Parameter	Units	Case 1 Minimal Sizing	Case 2 Polysius Ball Mill	Case 3 Polysius Ball Mill	Case 4 Polysius Ball Mill
Throughput	t/h	186	186	186	230
Ball Charge	%	35	35	22	35
Diameter	m	2.9	3.2	3.2	3.2
Length	m	4.8	5.25	5.25	5.25
P_{80} (cyclone OF)	µm	125	106	125	125
Power Draw	kW	535	740	540	740
Installed Power	kW	650	850	650	850

BALL MILL SELECTION

The large gap between the conventional method and the simulation method left some engineers puzzled and therefore, a second set of sizing was then realised using the conventional method. This second experiment was made in the hypothesis that a perfect screening was possible before the ball mill and that the fine material would go straight to the CIL without any contact with the mill. Results of this second sizing are shown in Table 4.

Table 4 – Sizing of the Ball Mill – Conventional Method after Screening

Parameter	Units	Low BWi	High BWi
BWi	kWh/t	10	13
Design Factor	%	30	30
Throughput	t/h	44	44
F_{80} after Screening	µm	25000	25000
Diameter	m	3.2	3.4
Length	m	4.6	5.2
Installed Power	kW	600	750

After screening of the small particles, the remaining coarse ore requires a lot less grinding energy than what was calculated with the whole flow. This calculation is not rigorous but illustrates how the atypical particle size distribution illustrated in Figure 4 can bias the conventional way of calculating mill power. The conventional method works well when having a Rosin-Rammler type of distribution. The figures shown in Table 4 are therefore more in line with the sizing of the ball mill according to the simulation method.

Considering the low confidence in the Bond ball mill work index used in the conventional method and the similarity in the power calculated with the screened feed conventional method and the simulation method, the simulation method was preferred. It was also known that the ore used to calibrate the simulator was probably harder than the one to be processed at Nampala, being more in the lower layers of the pit (higher proportion of transition ore with respect to saprolite). This brought an additional security factor into the ball mill choice. The Polysius mill, with a 750 kW motor was selected according to the simulation presented in Table 3.

PLANT START-UP AND COMMISSIONING

Start-up of a mineral processing plant is complex and requires coordination between the complete plant crew, operation support team and equipment manufacturer representatives. Start-up therefore requires a clear organisation that everyone on the field is aware of, so that the decision path is well defined. This section describes the actions that should be undertaken before, during and after the start-up.

Before start-up: Engineering Verification

Some actions stem from the engineering study and involve a validation or a “reality check” of the construction in comparison to the engineering design criteria. Table 5 shows examples of actions that could be taken during this phase.

Table 5 – Engineering Pre-Start-up Actions

Description	Risk Involved	Action Cost
Validation of the design criteria through additional laboratory testing	Potential failure in the plant conception	Medium
Operating set-point definition based on design criteria	Uncertainty on operation “know how”	Low
Validation of alarm levels (protect equipment while allowing operation)	Potential deficiencies	Low
Validation of P&ID on the field	Potential deficiencies	Low
Validation of G.A. with the operation staff	Potential operation inefficiency	Low
Validation of G.A. with maintenance staff	Potential downtime	Low

Before start-up: Operating Documents

Operating documents for every piece of equipment are normally provided by the equipment manufacturers. However, this kind of document is generally maintenance oriented and rarely provides information that takes into account the global plant situation (how to operate a group of equipment together). Operating documents aim at presenting the specificity of the mineral processing plant in a way that could be understood by the operating personnel. To produce the operating documents, process engineers first studied engineering documents before being deployed on site in order to verify the details and point out additional information that could be included in the operating documents. This included interviewing plant personnel on site, testing the documents on dry runs and taking appropriate pictures to upgrade the documents. All these tasks have to be performed while keeping in mind the main objectives: the documents have to be use daily by the operators (operators have to accept them) in order to:

- Standardize the way the tasks are achieved;
- Make them more efficient;
- Ensure a safe and hazard free working space.

Table 6 shows a list of operating documents that should be produced before a plant is brought into operation.

Table 6 – Operating Documents Typically Delivered Before Start-up

Description	Size (pages)	Typical Quantity
Operating Procedures	3-10	40-100
Operating Manual*	40-80	5-15
Control Plan*	1-4	5-15
Production Reports	1-2	5-10
List of Operating Set Points	1-4	1-5

***** Not realised in the case of the Nampala mine

Training and Coaching

Tailor made training is suggested in mineral processing plants as there is no identical concentrator in the world. Training, like the operating documents, should be realised by people that have knowledge of the process as well as knowledge of the plant specificity. Table 7 shows a list of training actions that could be realised in order to maximize operating staff preparation during the crucial first months of operation.

Table 7 –Training Start-up Actions

Description	Method	Circumstances
Training lessons*	PowerPoint presentation	All cases
Quiz (exams)*	Questionnaires about training	New operating staff
Training session off-site*	Trainer with a group	Remote plant; not yet built; no infrastructure on site
Training tracking tool*	Database	Tracking of the personnel knowledge and training
Realisation of a plant dynamic simulator*	Process simulator replicating the plant behavior	Operating risks, either safety or financial
Training session on-site *	Trainer with a group	Construction allows practical examples to be tested in dry runs
Coaching	Trainer with a person or small group	Support to achieve daily tasks
Simulation session with operators*	Trainer with a person or small group	Reproducing crucial operating situations like in a control room

*Not realised in the case of the Nampala mine

Organisation

The start-up period involves a different organisation and hierarchy than the regular operation that will follow once the operation support team has left the plant. It is therefore very important to have the plant management to agree on this temporary chain of command and to have the employees on the floor aware of this organisation. Figure 6 shows this organisation at the Nampala concentrator.

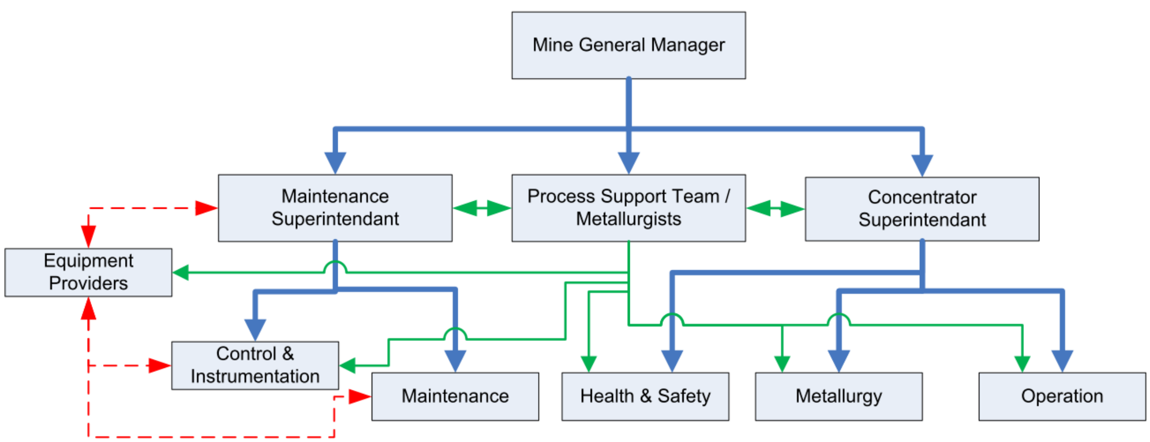

Figure 6 – Example of Organisation Path used during the a Start-up Phase at Nampala

Start-up Plan

The elaboration of a start-up plan consists in building a detailed decision tree, in which every important step of the start-up is detailed. In this scheme, operating set-points are given, various paths are possible depending on how the process is responding, steps for adding water, reagent, increasing throughput are described. This general document should not only help during the first start-up but also for any start-up after a major maintenance of the plant is made.

Coaching and Support

During the first weeks or months of the start-up, the operating support team should accompany the operating staff during their daily tasks (including control room operators). The operating support team is usually consulted for any important decision related to the process operation and they sometimes act as operator supervisors. Figure 7 illustrates the cooperation between operators, supervisors and the operation support team. The coaching period lasts as long as the operators are not totally independent in operating the plant or until some performance targets are reached.

Figure 7 – Example of Cooperation between the Support Team and the Operating Staff

Start-up

Before starting the concentrator operation with ore, it is common to test all equipment and sequences with water only. This strategy allows pumping to be tested, as well as the piping sealing, agitator, tailing systems, etc. This period of time can last between days and weeks, depending on the number of deficiencies that are identified. Once the tests with water are completed, a start-up with pulp is performed. This step consists in introducing ore into the plant for the first time then gradually increasing the throughput. This period requires attention and support 24 hours a day. Many incidents may occur. It is therefore important to always have qualified operating personnel available to make important decisions and react quickly in order to keep operations safe and preserve plant integrity. In addition to operating and coaching, the support team will, during the start-up phase:

- Keep a set-point tracking report;
- Make adjustments to the control plans;
- Lead sampling campaigns;
- Analyse process performances;
- Standardize sampling procedures and sample processing methods;
- Ensure good communication with equipment manufacturer personnel;
- Evaluate operator’s knowledge and progress;
- Put in place sampling inventory procedures for post-production validation.

COMMERCIAL PRODUCTION AND BALL MILL PERFORMANCES AT NAMPALA

Due to the fact that major pieces of equipment were already built from the phase 1 plant, it was possible to gradually commission the various new circuits. First, a mini-mill with a capacity of 200 kW was installed on a temporary structure in order to start pre-production with available equipment. During this phase, the two available CIL tanks were used, as well as the kettle-type elution vessel. This allowed the gradual training of new employees and safe equipment commissioning as the team could focus on one circuit at a time. As a bonus, additional production during the construction phase was achieved. Figure 8 shows the evolution of the commissioning, time zero being the date of the ball mill commissioning.

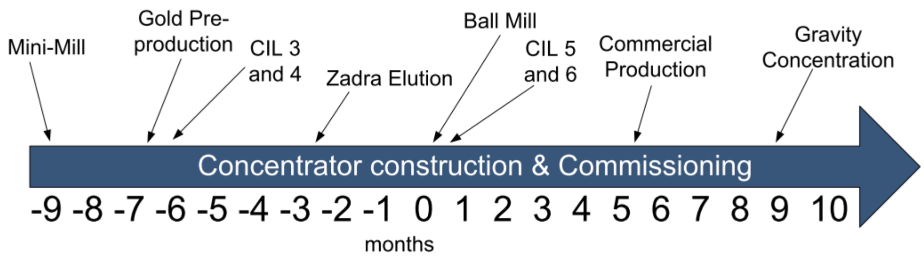

Figure 8 – Concentrator Commissioning Evolution

Thanks to the fact that the plant commissioning was spread out in time, Soutex' team could be reduced to only two full-time Metallurgists on site at the most. The former elution system did not allow the production to be sustained, even the mini-mill one. But as new CIL tanks were being put into production, room for gold storage in carbon was created. When the Zadra elution system was finally started, the carbon was well loaded allowing rapid gold recovery and welcomed cash flow. Figure 9 shows the first gold recovery at the electrolysis cells. At the start of the ball mill, the most crucial stage, the operating team was already used to the operation of the mini mill and cyclones and the CIL and the elution plant was on track, so the transition was smooth and commercial production was rapidly reached.

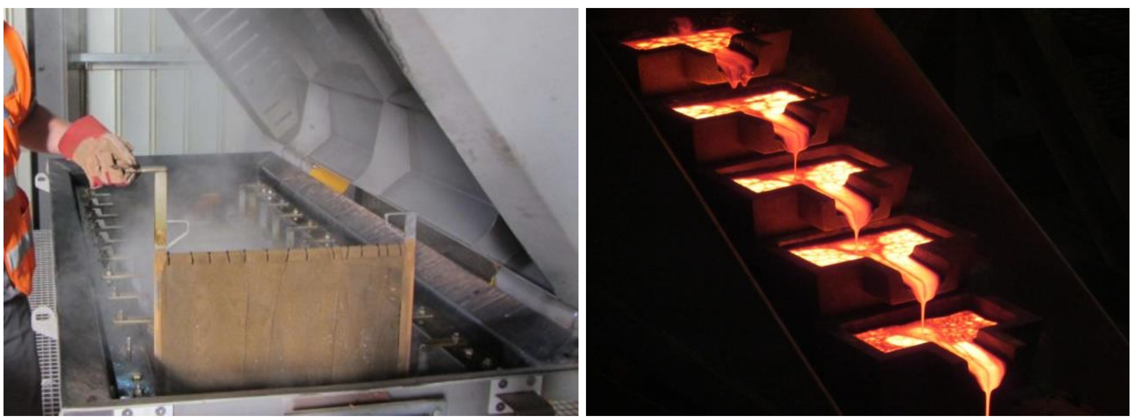

Figure 9 – First Gold Recovered at the Electrolysis Cells

Production Data

Figure 10 shows the concentrator production objectives (in dashed lines) and the evolutions of the same KPI (in plain lines). The daily tonnage objective and gold production were reached within six (6) months and the recovery has been close to the target since month 1. The availability has generally met objectives since month -1, except for major failures stopping the production for several days in a row (scrubber in month 1 and power plant in months 6 and 7).

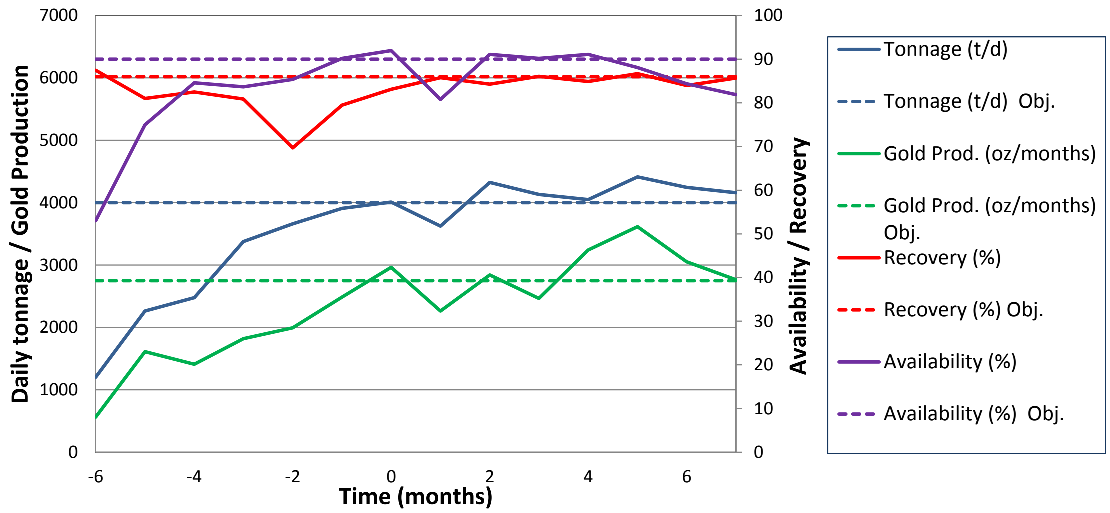

Figure 10 – KPI Objectives and Production Data

Ball Mill Performances

The ball mill responded very well to the ore present at Nampala. In the first months, the right mix between laterite and saprolite had to be found, as well as minor modifications to the circuit implemented in order to increase the tonnage (chutes, pumps, etc.). Operating with a full (35%) ball charge, the ball mill has the capacity to process more than what it was originally designed for, with peak days exceeding 5000 t/d (daily record of 6000 t/d). The P_{80} obtained also exceeds the objective being in the range of 100 µm.

The ball mill extra capacity allowed the operation to overcome the availability problems that recently occurred by increasing the tonnage. However, for the sake of optimal recovery, it was found that the daily tonnage should not exceed 5000 t/d, in order to maintain a good liberation and sufficient retention time in the CIL.

CONCLUSION

The start-up of a new concentrator always involves a certain level of risk that differs depending on many factors such as the size of the concentrator, the location, the company's financial situation and expected profit margin, the environmental and safety hazards as well as the staff preparation. The start-up of Nampala was not exempt of risk, due to the company's precarious financial situation after the phase 1 unsuccessful start, the uncertainties on the ball mill sizing and the still unexperienced operating team. With the dedicated and resourceful maintenance team, the fast learning operating team and the help of the metallurgical support team, Robex can now say that the phase 2 start-up phase is behind them and was a real success.

The simulation of the ball mill using USIM PAC and a more sophisticated model tuned on a similar ore was a success. The buffer capacity offered by the chosen ball mill is in line with simulation results and perfectly suits the concentrator needs given the present ore at the Nampala mine. The direct use of the conventional sizing method would have led to a ball mill which would have been too big, affecting both Capex and Opex outcomes and probably threating the project economics.

During the start-up phase, the choice of hiring an external team in order to provide process support remains at the discretion of each concentrator administrator, its tolerance to risks and financial imperatives. In the specific case of Nampala, the process support team, among many other factors, allowed a successful start-up, even reaching production and performance targets earlier than expected. The financial benefits associated with obtaining commercial production ahead of calendar for a gold mine surpass by far any additional costs associated with the very detailed and conscientious planning of the start-up. It also made the operation much safer, and relieved the managing and operating staff at the mine site from many eventual headaches.

ACKNOWLEDGEMENT

We would like to thank many contributors from Robex and Soutex: Abel Coulibaly, Benoit Côté, Anthony Rouleau, Jonathan Mercier, Benjamin Cohen, Simon Boudreau, Stéphane Castillo, Stéphane Brochot (Caspeo, USIM PAC), David Hiest, Stéphane Gamache, Danielle Bouffard and Pierre Roy.

REFERENCES

Austin, L.G., R.R. Klimpel and P.T. Luckie (1984). *Process Engineering of size reduction: ball milling*. AIME, New York.

Rowland C.C and D.M. Kjos (2002). Rod and Ball Mills, chapter 12 in *Mineral Processing Plant Design*, A.L. Mular et al. ed. SME Publ., pp 710-754.

Herbst, J.A. and O.A. Bascur (1979). A program for the simulation of steady state circuit behaviour. *Report of Department of Metallurgical Engineering*, University of Utah.

Brochot S., R.L. Wiegel. S. Ersayin and S. Touze (2006). *Modeling and Simulation of Comminution Circuits with USIM PAC*, Advances in Comminution, Ed. S.K. Kawatra, SME, Littleton.

Dobby, G., C. Bennett and G. Kosick (2001). Advances in SAG circuit design and simulation applied to the mine block model, *Proc. of SAG 2001 Conf.*, Vancouver, Canada, Vol. IV, 221-234.

Evans, G. (2001). A new method for determining charge mass in AG/SAG mills, *Proc. of SAG 2001 Conf.*, Vancouver, Canada, Vol. II, 331-34.

Holtzapple, A., J.T. Bartlett, M. Botz (2013). Life of mine process simulation from drill holes to net present value. *Society of Mining, Metallurgy & Exploration*, Denver.

Napier-Munn, T.J., S. Morrell, R.D. Morrison and T. Kojovic (1996). *Mineral Comminution Circuits: Their Operation and Optimisation*, ISBN 0 64628861, JKMRC.

Starkey, J., J. Robitaille, P. Cousin, J. Jordan and G. Kosick (2001). Design of the Agnico-Eagle Laronde Division SAG mill, *Proc. of SAG 2001 Conf.*, Vancouver, Canada, Vol. III, 165-178.

Berton A., S. Bellec and D. Roy (2015). Mitigating Brown Field Project Risks Using Advanced Simulations, *47th Annual Canadian Mineral Processors Operators Conference*, Ottawa, Ont., pp 136-147, January 20-22.

Berton A., J. Châteauneuf, S. Bellec, P. Champagne, S. Fortier (2016). Achieving a Great Start-up: Action Plan to Maximise Your Chances of Success. *48th Annual Canadian Mineral Processors Operators Conference*, Ottawa, Ont., p 113-125.