First Commercialisation of the Albion Process™ for Copper

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ABSTRACT

Sable Zinc Kabwe Limited ("**Sable**") is a base metal processing plant two km south of Kabwe Town in Central Province, Zambia. The region has a rich history in mining and minerals production, being a major lead and zinc producer from the 1900's up to the mid-1990's. In 2006, a copper plant was built at the Sable processing site to treat third party copper and cobalt ores and concentrates. The current flowsheet is based on whole ore leaching, solvent extraction and production of 8,000 tpa LME Grade A copper cathode. The plant is currently on care and maintenance and Glencore Plc ("**Glencore**") has taken the opportunity to convert the plant to an Albion Process™ plant to treat local concentrates unsuitable or uneconomic for smelting. The Albion Process™ plant comprises an M100 IsaMill™ operating in acidic conditions such that raffinate from the downstream process is recycled back to slurry the concentrate delivered to site thus maximising copper tenor in solution and reducing water consumption. The finely ground concentrate is then fed to existing stainless steel leach reactors converted to Albion Process™ duty by fitting HyperSparge™ supersonic oxygen injectors. The leach product is then directed to the existing solid / liquid separation equipment and onto copper and cobalt recovery circuits.

The plant was designed based on testwork of a nominal concentrate, however, a flexible approach to design allows the treatment of a wide range of concentrates. This positions the Albion Process™ plant at Sable a regional treatment facility for feed that is not economic to treat by conventional means.

INTRODUCTION

The Sable Zinc Kabwe Limited ("**Sable**") process plant is located 2km south of Kabwe town and 140km north of Lusaka in Central Province, Zambia. In 1902 rich deposits of zinc and lead were discovered with mines and processing plants operating in and around the town until mid-1994. In 2000, the Kabwe Mine tailings dams were sold to Sable , a newly established company, as part of a purchase deal for other plots and facilities. Up until 2004, Sable produced zinc cathodes in an SX/EW plant treating wash plant tailing material. In 2004, Sable was acquired by the South African mining company Metorex Limited ("**Metorex**") and in 2006 a copper/cobalt SX/EW plant was built to produce copper cathode from malachite ore supplied from the Democratic Republic of Congo. In 2011, Jinchuan Group International Resources Co. Ltd acquired Metorex and Sable was in turn sold to a subsidiary of Glencore Plc ("**Glencore**").

Glencore placed Sable on care and maintenance in November 2014 due to a decline in commodity prices coupled with the cash flow restrictions caused by the withholding of Value Added Tax refunds in relation to Rule 18(1)(b) by the Zambia Revenue Authority.

In 2015, Glencore evaluated the potential for the Albion Process™ to treat low grade concentrates that could not be treated by smelters due to a number of limitations including current blend fed to the copper smelter, low copper grade, low fuel content due to non-sulphide content, high cobalt content and high impurities such silica or alumina. Testwork was performed on a range of samples to make an assessment of process flexibility and, critically, copper and cobalt recovery.

Following this successful testwork, a decision was taken to convert the existing Sable copper/cobalt plant to an Albion Process™ plant capable of treating copper/cobalt concentrates containing refractory minerals such as chalcopyrite ($CuFeS_2$) and carrollite ($CuCo_2S_4$). The conversion will make use of existing infrastructure such as the stainless steel oxide leach tanks, the cobalt recovery circuit and the copper SX/EW plant. The plant nameplate is 16,000 tonnes per annum LME Grade A copper cathode. Cobalt will be recovered through the existing carbonate precipitation process.

The Albion Process™ is an atmospheric leaching process to oxidise refractory gold and base metals concentrate in a ferric/ferrous sulphate system for downstream recovery to final products. The technology is provided globally by Glencore Technology ("**GT**"). The process comprises two steps. The first is an ultra-fine grinding step performed in an IsaMill™ to grind the mineral concentrate down to a size where reaction products in the oxidation step to do not passivate the mineral surface and inhibit leaching. The second step is the oxidation of the ultra-fine ground concentrate through supersonic injection of oxygen with GT's HyperSparge™. The process runs at atmospheric pressure, autothermally and under mildly acidic conditions.

In the case of base metals such as copper, the solubilised metals are then recovered from solution by SX/EW. In the case of refractory gold the oxidised slurry is subjected to cyanidation or an equivalent process for gold and silver recovery.

The Albion Process™ has been commercialised in zinc and gold with five plants in operation and reported on extensively (Hourn & Turner, 2010; Hourn & Turner, 2012; Hourn et al., 2014; Voigt et al., 2015; Senshenko et al., 2016). The Albion Process™ installed at Sable will be the first commercialisation for leaching of copper and cobalt.

This paper describes the testwork development program and the process engineering performed to convert the Sable plant including the first application for an IsaMill™ operating in raffinate. The paper then describes the Sable Albion Process™ Plant and estimated project schedule.

DEVELOPMENT PROGRAM

In development programs for the Albion Process™, both technical and economic aspects of a potential project are evaluated to determine if it should be progressed to the next stage of development. Glencore Technology follows a development program in accordance with the Association for the Advancement of Cost Engineering International ("**AACEI**") Recommended Practice No. 18R-97 (Christensen and Dysert, 2005), which has been summarised in Table 1.

Table 1 AACEI Project Development Stages

Class of Study	Purpose	Accuracy LL (%)	Accuracy UL (%)	Project Completion (%)	Testwork
Class 5	Go / No-Go	-50 to -20	+30 to +100	0 - 2	Bench x 1
Class 4	Pre-Feasibility	-30 to -15	+20 to +50	1 - 15	Bench x 5
Class 3	Feasibility	-20 to -10	+10 to +30	10 - 40	Bench x 10
Class 2	Fixed Bid Prep	-15 to -5	+5 to +20	30 - 70	Pilot / Demo
Class 1	Execution	-10 to -3	+3 to +15	50 - 100	-

Each class of estimate represents a more detailed level of engineering study and a corresponding level of testwork to support the engineering study. In the case of the operation of pilot and demonstration plants, this is not required to perform detailed engineering and project execution since GT can obtain all design information from batch tests while still providing performance guarantees. Pilot and demonstration plant operation is normally completed to satisfy the risk management requirements of companies or financiers of projects.

At the Class 5 level of study, GT can make a reasonable evaluation of the suitability of the Albion Process™ for a project based on the approximate feed mineralogical and elemental composition, combined with our process experience without the need for testwork. Using a database of capital costs and operating information about the project, an estimate for capital and operating costs for a project can be quickly established. A subsequent Class 4 level study is then completed, supported by a preliminary testwork program, performed at a certified Albion Process™ testwork laboratory. The Class 4 level study provides a go/no-go evaluation of and the project and confirms key design information such as preliminary plant sizing, the extent of oxidation and metal recovery.

Since the Sable Albion Process™ Plant would treat a range of concentrates, four representative concentrates were obtained from the region and subjected to Albion Process™ testing at HRLTesting in Albion, Queensland.

Support Testwork

Four concentrate samples (A – D) were obtained from third party suppliers which reflected the typical quality available on the local market. The analysis of each concentrate is shown in Table 2.

Table 2 Analysis of Third Party Concentrates

Component	A (%)	B (%)	C (%)	D (%)
Cu	27.7	39.3	28.5	34.5
Fe	7.5	5.7	4.9	8.4
Co	0.04	0.03	3.2	3.7
S Total	5.6	8.5	12.4	18.7
S Sulphide	5.6	7.5	11.8	18.7
Carbonates	6.4	8.4	7.5	12.1
Malachite	23.7	31.1	12.1	10.2
Digenite	8.2	9.8	11.8	-
Chalcopyrite	9.3	15.2	16.2	14.2
Brochantite	7.9	15.1	8.8	-
Carrollite	-	-	8.5	9.8
Pyrite	-	-	-	4.5
Djurleite	-	-	-	13.1
Bornite	-	-	-	17.8
NS Gangue	50.9	28.8	42.6	30.4

The concentrates selected for testwork attracted significant smelter penalties due to either a relatively low fuel content or high insolubles content. Several of the concentrates also contained high cobalt grades which cannot be recovered in the smelting process. Low grade material has been previously tested and found to be well suited to treatment in Albion Process™ conditions (Voigt et al., 2016). The emphasis on this testwork was prove the performance and economics of these concentrates not suited to conventional flowsheets and determine the amenability of the sample to treatment in the Albion Process™.

A summary of the results for copper and cobalt extraction is shown in Table 3. Recoveries are expressed as recovery through the Albion Process™ leaching stage rather than overall plant recovery.

Table 3 Testwork Results

Component	A	B	C	D
Albion Cu Rec (%)*	98.9	99.2	99.5	99.3
Albion Co Rec (%)*	94.7	96.6	95.9	94.7
Sulphide Oxidation (%)	83	74	93	77
Leach Completed (h)	12	12	36	36
Test Residence time (h)	48	48	48	48

For all of the concentrates, the copper recoveries were at least equal to or better than would be achieved in a smelter even when considering the whole plant flowsheet. This is not unexpected since the Albion Process™ achieves over 99% copper recovery in samples where all the copper is present in primary sulphides rather than a mix of primary and secondary sulphides.

Importantly, the samples did not contain pyrite which is required to catalyse the decomposition of chalcopyrite in other atmospheric leaching processes.

Another important feature of the testwork was cobalt recovery. For concentrators where copper and cobalt cannot be economically separated or for concentrators that produce a cobalt by-product with high copper content, the Albion Process™ represents an option where both minerals can be recovered. This is expected to become increasingly important as cobalt demand continues to grow, placing upward pressure on prices.

The leach residence time was driven primarily by cobalt recovery, as the leaching kinetics for the carrolite minerals were slightly slower than for chalcopyrite. Copper recovery in samples C and D was maximised within 24 hours. Samples A and B contained less refractory materials and negligible cobalt.

Engineering Study

An Engineering Study was also prepared based on the testwork results. Unlike a greenfield engineering study estimate, the basis of the study was the conversion of existing facilities at the Sable site and to provide recommendations for new equipment that would need to be installed.

Important considerations from the testwork were incorporated in the design:

- Extent of sulphide oxidation – to size the oxygen plant and prepare the mass and energy balance
- Leach residence time – to allow sufficient leach capacity for different feed materials can be treated and ensure target copper and cobalt recoveries can be achieved
- Grind size and IsaMill™ size – the plant will be treat concentrates in the future which may have unknown grind characteristics and so the IsaMill™ needed to be flexible to respond to these variations
- Water balance – the IsaMill™ was configured to mill in raffinate to manage circuit wide water balance and copper tenor
- Acid soluble copper – it was found that some of the samples tested had up to 50% water soluble copper, and would need to be considered in the leaching profile and in the IsaMill materials of construction
- Variable feed – the plant will treat varying concentrates grades which could impact on plant performance if not scheduled and blended properly. Will need to blend the feeds to ensure that sufficient fuel is present in the concentrate
- Variable sulphide contents – the plant will treat concentrates containing varying levels of copper sulphides and oxides. Oxides do not require ultra-fine grinding, and so may at times bypass the IsaMill™. Oxides also contain minimal fuel value, which may impact the oxidative leach operating temperature.

A Block Flow Diagram for the Sable Albion Process™ plant and metal recovery circuits is shown in Figure 1.

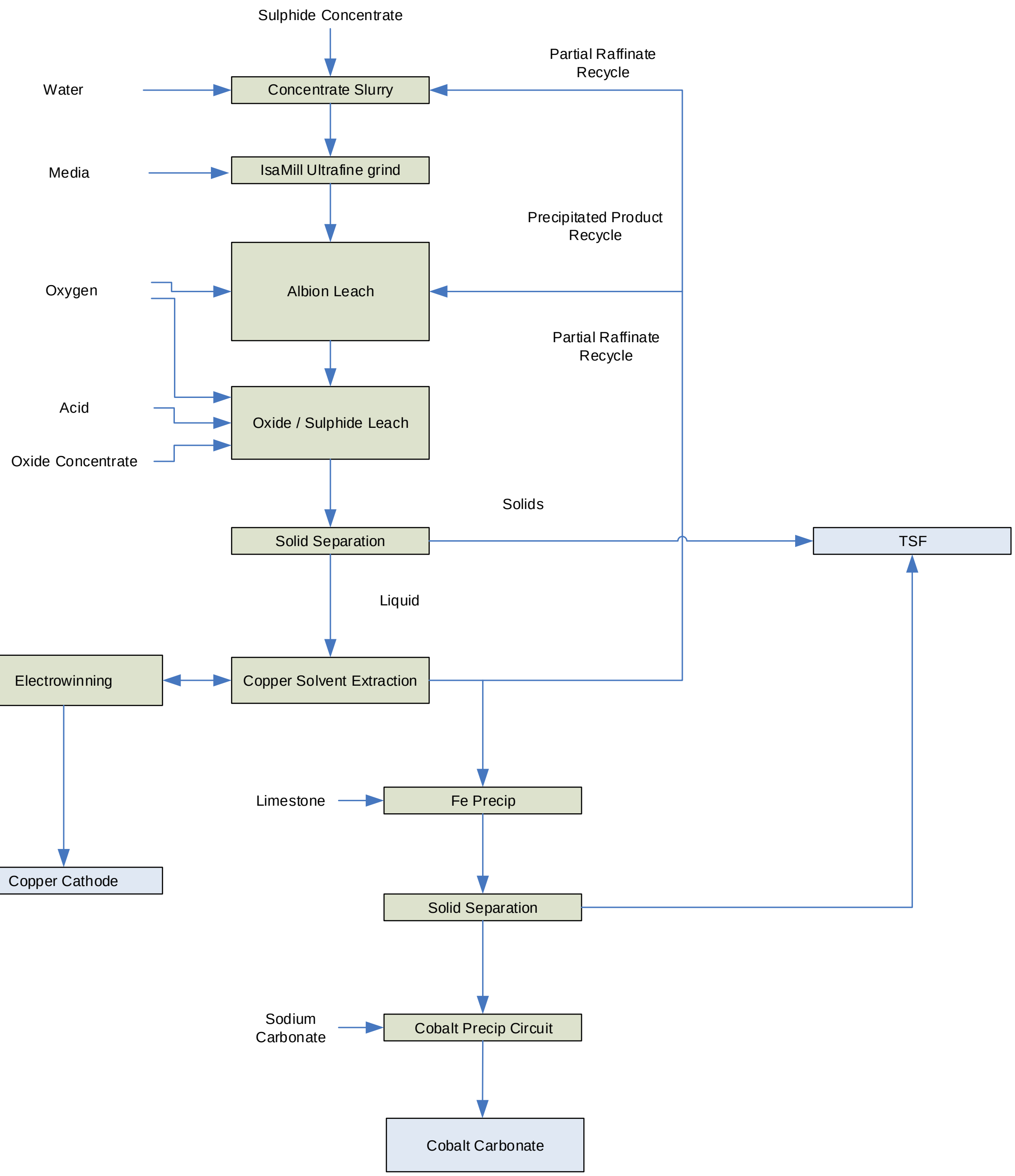

Figure 1 Sable Albion Process™ Plant Block Flow Diagram

Concentrate will be first slurried in raffinate and water in an agitated tank. The tank will be fed with via a hopper and conveyor on a batch wise basis depending on level. During the slurrying process some copper will leach out of the concentrate into solution.

The M100 IsaMill™ will be continuously fed and grinds the concentrate down to a p80 of 12 to 14µm, depending on the feed type. The IsaMill™ shell will be 316L stainless steel and all wetted parts materials selected to ensure performance in the acidic conditions.

The IsaMill™ will discharge directly into the first of five stainless steel oxidative leach reactors. The leach reactors will be covered with a roof and fitted with an exhaust stack. Dual bladed agitators shall be installed with appropriately sized agitators for gas dispersion and pumping duty. Oxygen shall be injected at the base of each leach reactor with the GT HyperSparge™ supersonic gas injector. Slurry will flow by gravity to downstream reactors with a launder system that will allow bypassing in the event of a maintenance event.

Depending on the leach profile, the relatively fast leaching oxides shall be added later down the leach train into leach tank 3 or 4 via a hopper and conveyor. Slurrying of the oxide material was avoided to manage the water balance. At this stage, supplementary acid may need to be added along with additional raffinate. Generally the acid demand of the system is met through in situ generation of acid from the chemical reactions and the acid credit from the raffinate.

After copper and cobalt is leached from the slurry into solution, a solid / liquid separation step produces solids that are disposed of in the Tailings Storage Facility. The copper rich solution is directed to the copper solvent extraction plant. The majority of the raffinate is recycled to the process. A bleed is taken from the raffinate to recover cobalt.

The bleed solution will first be neutralised with limestone to remove residual iron. The bleed solution, now containing mainly cobalt, will be directed to a carbonate based precipitation process for recovery of cobalt carbonate.

The rich electrolyte from solvent extraction is directed to the electrowinning plant for recovery of LME Grade A copper cathode.

From Figure 1, nearly all equipment required for the Albion Process™ is existing at the Sable facility. Three new stainless steel leach tanks, an M100 IsaMill™ and a small oxygen plant are the new equipment items required.

The main design criteria for the project are outlined in Table 4.

Table 4 Sable Albion Process™ Design Criteria

Criteria	Units	Nominal	Minimum	Design
Total Throughput (Sulph + Ox)	tpa	25,792	7,738	29,661
Total Throughput	tph	3.2	0.96	3.7
Copper Grade	%	25%	15%	35%
% of feed as sulphides	%	50%	50%	50%
Total Copper Units	tpa	6,448	1,161	10,381
Specific Energy for Fine Grinding	kWh/t	25	18	35
Oxidative Leach Residence Time - Sulphides	h	36	24	48
Terminal Cu Tenor	gpl	35	35	35
Raffinate Cu Tenor	gpl	4	4	4

A mass and energy balance was developed to assess a variety of concentrates based on the testwork results, vendor data and existing plant parameters at Sable. The mass and energy balance was used to develop a detailed Process Design Criteria set which was then used to build an equipment list and electrical load list.

The equipment list was then compared to existing equipment on site and a final equipment list and process flow drawings were developed.

A cost estimate was then prepared from the engineering study and input to an economic model showing the project significantly exceeded the investment criteria for a Glencore project.

SABLE ALBION PROCESS™ PLANT

The result of the Class 4 engineering study was then built upon to improve the cost estimation to a Class 3 level including improvement in the mass and energy balance to assess a wider range of feed materials and ensure equipment sizing was correct.

The Sable Albion Process™ Plant main equipment list and sizing is included in Table 5, highlighting where there is existing equipment for utilisation at the Sable facility.

Table 5 Main Equipment List

Equipment Name	Number	Size	Duty	Existing?
Concentrate Reslurry Tank	1	Vol - 10m^3	Slurry sulphide concentrate	Yes
IsaMill	1	M100	Fine grinding sulphide cons in acidic conditions	No
Oxidative Stainless Steel Leach Tanks	5	Vol - 100m^3	Leaching sulphide and oxide concentrate	Yes - 2 from 5
HyperSparge™ oxygen injectors	5	Nozzle - 4mm	Supersonic injection of oxygen	No
Oxygen Generator	1	10 tpd	Generate oxygen for leach process	No
Thickener	1	24m diameter	Thicken residue for filtration	Yes
Horizontal Belt Filter	2	Filt. Area - 44m^2	Solid/liquid separation	Yes
Tailings Storage Facility	1	-	Storage of solids	Yes
Copper SX/EW Plant	2	1500 tpm ea	Recovery of LME Grade A copper	Yes
Cobalt Precipitation Plant	1	50 tpm	Recovery of cobalt concentrate	Yes

Table 5 shows that the capital intensity of converting existing equipment to Albion Process™ duty is relatively low.

The existing plant had two of the five stainless steel oxidative leach tanks required. The existing stainless steel leach tanks were fabricated from duplex alloy 2304 which is suitable for the oxidative ferric leach duty and was the material used for the new tanks. For consistency the new leach tanks were made to the same dimensions and specifications as the existing ones.

In addition to the new tanks a small oxygen generator and an M100 IsaMill™ were also required. The M100 IsaMill™ was modified for the duty of operating in raffinate. This allows significant operational flexibility since the plant water balance is easier to manage, less total bleed is required and more acid from the raffinate can be utilised.

Oxygen mass transfer calculations suggest that the existing oxide leach agitators may not be optimum for efficient oxygen mass transfer. While the HyperSparge™ should contribute most of the power input required, contingency has been included to upgrade the agitators if this is required at a later time.

A high level schedule for the project including project development is shown in Figure 2.

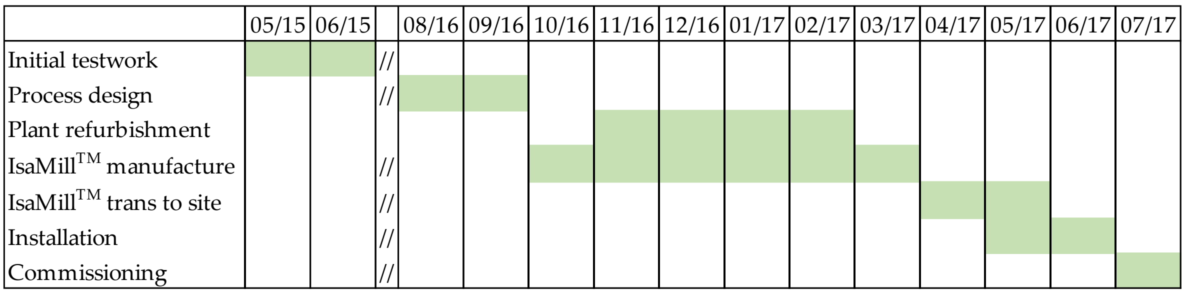

Figure 2 High Level Project Schedule

The schedule is driven by the time for manufacture of the IsaMill™ and transport to site. The other equipment lead times fall within this period. All refurbishment of existing equipment will be completed before the IsaMill™ is delivered to site.

In light of this, much of the equipment pre-commissioning will be completed before the IsaMill™ arrives at site. Based on the commissioning and ramp-up time of less than three months for a full Albion Process™ plant at GPM Gold in Armenia, the Sable Albion Process™ Plant should be commissioned within one month (Voigt et al., 2015).

CONCLUSIONS

The development Albion Process™ plant at Sable to treat locally available concentrates that are unsuitable for conventional treatment routes has been described. The economics of the project are very strong due to the utilisation and conversion of existing equipment. It is expected once the plant is established that it will provide an example of how existing equipment can be converted or with a small capital investment new equipment can be installed to treat refractory copper concentrates and integrated into an existing SX/EW flowsheet or plant site.

The Albion Process™ enters an exciting new period with the first commercial installation for leaching copper and cobalt concentrates becoming operational in early 2017. A further update will be provided upon commissioning.

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