Application of Albion Process™ on a Complex Feed Containing Base and Precious Metals

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1. Abstract

As reserves of high-grade, easily accessible ores decline, it is becoming increasingly important to treat complex feeds and recover multiple target metals, and to identify approaches that will achieve this is a cost-effective manner. Hydrometallurgical treatment of sulphide based material allows for a balance between costs, recovery, and flexibility in final product selection. Glencore Technology's hydrometallurgical solution to the treatment of sulphide ores is the Albion Process™, comprising two main steps. The first step involves ultra-fine grinding using the IsaMill™, which minimises the potential for passivation of the leaching sulphide and increases surface area for oxidation during the Albion Process™ leach. The second step is the oxidation of the finely ground sulphide concentrate utilising the HyperSparge™ for oxygen injection in Glencore Technology's Oxidative Leach Reactors (OxiLeach™). The Albion Process™ operates autothermally at atmospheric pressure, making it a straightforward and safe alternative to other oxidative leaching options for treating complex concentrates which contain base metals along with precious metals hosted in the sulphide matrix.

This paper describes an application of the Albion Process™ treating a complex polymetallic ore containing multiple base metal sulphides as well as refractory gold and silver hosted within the sulphide matrix. The designed plant will operate as a treatment hub and accept various concentrates from a number of mines as they come online as well as providing the flexibility to toll treat feed. This highlights the simplicity, yet flexibility, of the Albion Process™ and its ability to achieve high extraction of the base and precious metals despite variability in feed. The paper will also detail options for downstream recovery of the metals to produce saleable products.

2. Introduction

Maximising metal recovery and minimising operating and capital cost has always been a primary focus for mining and mineral processing projects. With increasing demand and decreasing availability of easily accessible metals however, recovering the most value from ore while simplifying the flowsheet and minimising environmental impact is only becoming more important. Glencore Technology's hydrometallurgical solution for this issue is the Albion Process™.

JSC Altynalmas have been developing a number of gold deposits in Kazakhstan. However, some of the deposits also contain elevated levels of base metals and consequently Altynalmas began investigating processing options that would allow for the recovery of both precious and base metals. The Albion Process™ currently has multiple installations around the world which process gold and base metals separately, however there is currently no existing operation for which both precious and base metals are targeted for recovery. Using the Altynalmas Mizek project as the basis, this paper will describe an application of the Albion Process™ for treating a complex polymetallic feed containing both precious and base metals. Mizek is a Gold-Copper-Zinc Mineral resource located in East-Kazakhstan.

Going forward, the designed plant will operate as a treatment hub to accept various concentrates from a number of deposits.

3. The Albion Process™

The Albion Process™ was developed by Glencore in 1994 and is a globally patented technology comprising two steps. The first step is ultra-fine grinding using the IsaMill™ to minimise potential passivation of the leaching sulphide and increase surface area available for oxidation during the Albion Process™ leach. The second step comprises oxidative leaching of the finely ground sulphide concentrate utilising the HyperSparge™ for oxygen injection in Glencore Technology's Oxidative Leach Reactors (OxiLeach™) which operate auto thermally at atmospheric pressure.

The oxidative leach can be operated under a range of pH conditions, varying from acidic to neutral and has been commercialised in zinc and gold with five plants currently in operation. These have been reported on extensively (Hourn & Turner, 2010; Hourn & Turner, 2012; Voigt, Hourn, & Mallah, 2016; Senshenko, Aksenoz, Vasiliev, & Seredkin, 2016). When Albion Process™ leaching is applied under acidic conditions, base metals are leached into solution while pyrite, arsenopyrite and other gold bearing minerals are oxidised to break down the sulphide matrix, rendering the precious metals amenable to downstream cyanidation. A subsequent thickening stage then directs the leach solution to downstream processing (SXEW, precipitation, etc.) for the recovery of base metals, whilst the solid leach residue (containing the precious metals) is directed to the cyanide leach. This combination makes the Albion Process™ ideal for treating complex polymetallic concentrates which contain base metals along with precious metals that are finely disseminated through the sulphide matrix.

4. The HyperSparge™

The HyperSparge™ is a proven and cost-effective sparging system for delivering air, oxygen, or other process gases for leaching or oxidation processes and is a key component of the Albion Process™ oxidative leach reactors. It uses an alloy steel injection lance fitted with a hard-wearing ceramic nozzle to inject a concentrated super-sonic jet of gas into the process solution or slurry. The supersonic gas jet enters the process stream at velocities in excess of 400 m/s, creating a region of very high local shear and fine bubbles, resulting in very efficient mass transfer and therefore high gas utilisation efficiency.

5. Testwork

5.1 Test Conditions

Head characterisation of the Mizek concentrate indicated the predominant minerals were pyrite (57%) and sphalerite (22%), with smaller amounts of copper minerals (9%) also present, yielding a copper-zinc rich concentrate. Due to the presence of the base metals, the testwork was completed under acidic conditions.

Acidic conditions however are not typically conducive to pyrite oxidation, which exhibits slower kinetics at low pH. For this reason 72 hours was selected as the residence time for the acid Albion Process™ oxidative leach.

Precipitation testwork for copper and zinc recovery was conducted using limestone and lime respectively to adjust the pH and precipitate the metals.

To maximise extraction of the precious metals, the solid residue remaining after the acidic leach was subjected to an additional 24-hour alkaline Albion Process™ leach.

5.2 Gold recovery results

To determine the impact of grind size on the sulphide oxidation, grind sensitivity testwork was conducted at grind sizes ranging between 80% passing 6 to 12 µm. The optimum operating point was determined to be 80% passing 8 µm which achieved 96.7% sulphide oxidation. This level of sulphide oxidation increased recoveries of gold and silver from 28.9% and 25.3% to 95.2% and 95.4% respectively post Albion Process™. This represented a 66.3% uplift in recoverable gold and highlighted the refractory nature of the gold and the suitability of the Albion Process™ to liberate this locked gold. Figure 1 summarised the uplift in gold recovery across the stages of the Albion Process™, from the as-received sample through fine grinding and oxidative leaching.

5.3 Copper and Zinc recovery results

The acid Albion Process™ leach resulted in 99.5% zinc and 91.8% of copper extracted into solution, at a sulphur oxidation of 96.7% (Figure 2).

Testwork showed 90.7% of copper was able to be precipitated using limestone to maintain pH at 4.5. The subsequent precipitation stage indicated that 100% of zinc was using lime to maintain the pH at 7.

While this method for metal recovery leads to co-precipitation of gypsum and subsequently diluted concentrate grades, previous work completed by Glencore Technology (Voigt, Hourn, 2017) has indicated that calcium-based alkalis can be used to achieve high grade concentrates by exploiting the particle size difference between the gypsum and metal precipitates.

Glencore Technology offer a performance guarantee for scale up from testwork to full scale.

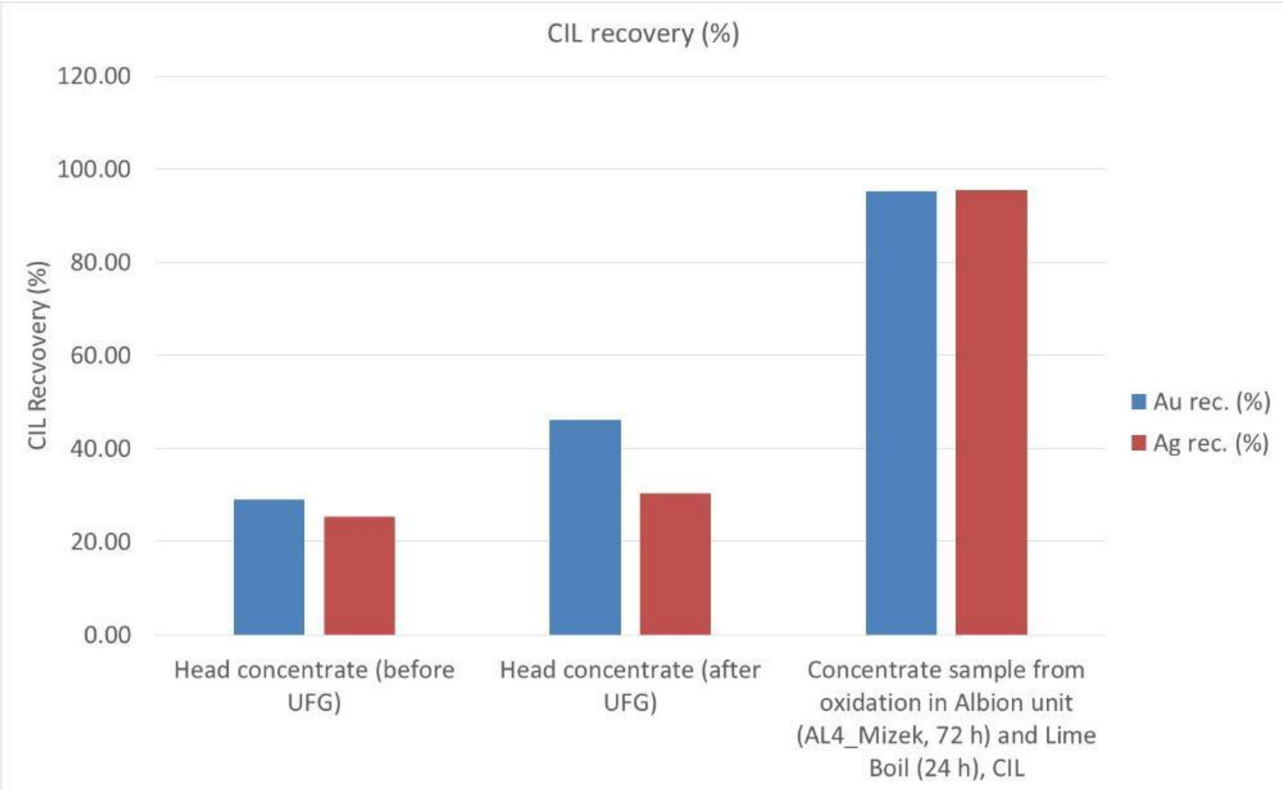

Figure 1 CIL Recovery of Gold and Silver through Albion Process™ Stages

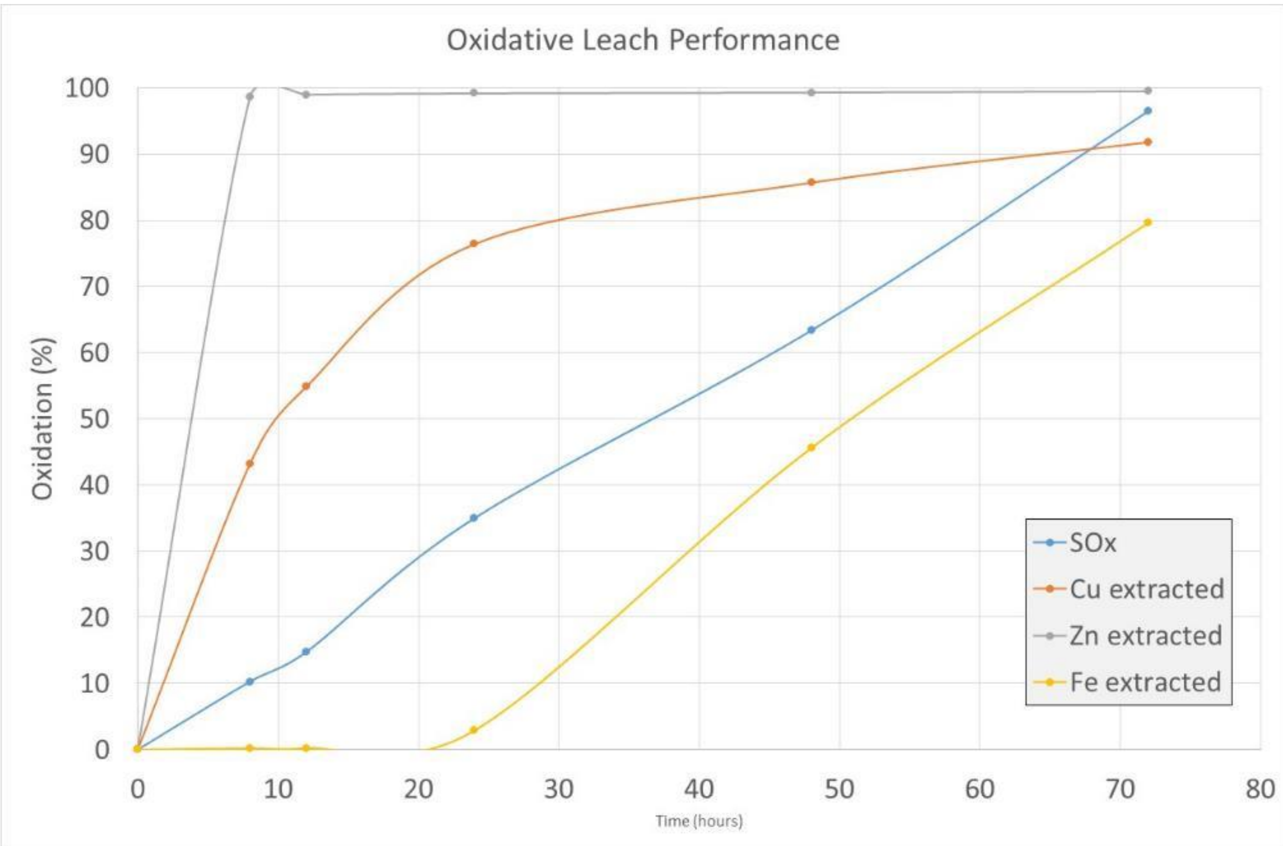

Figure 2 Oxidative Leach Performance

6. Process Description

Based on the testwork completed, Glencore Technology commenced development of a flowsheet to treat the concentrate and recover precious metals as well as the zinc and copper present. The proposed flowsheet broadly included the areas summarised below, with Figure 3**¡Error! No se encuentra el origen de la referencia.** showing the more detailed block flow diagram:

- IsaMill™ ultrafine grinding
- Albion Process™ acidic oxidative leaching
- Iron control
- Alkaline Albion Process™
- Copper Recovery
- Zinc Recovery

6.1 IsaMill™ Ultrafine Grinding

The IsaMill™ circuit (Figure 4) produces a finely ground concentrate as feed to the acid Albion Process™ circuit. Fine grinding prevents passivation of the mineral in the leach circuit and allows the leach to operate at atmospheric pressure. Concentrate is ground as a slurry, with the IsaMill™ operated in closed circuit in this case.

Concentrate slurry will be fed to the IsaMill™ circuit via the IsaMill™ Cyclone Cluster. The underflow will gravitate to the IsaMill™ Feed and the overflow will gravitate to the IsaMill™ Thickener.

Finely ground concentrate from the IsaMill™ Thickener underflow will be transferred to and stored in a storage tank.

6.2 Albion Process™ Acidic Oxidative Leaching

The purpose of the Albion Process™ acid oxidative leach circuit is to oxidise the sulphide matrix of the concentrate and solubilise the economic base metals under conditions of low pH.

The concentrate slurry will be transferred via a ring main to the acid Albion Process™ circuit, consisting of Glencore Technology's OxiLeach™ Reactors. The ring main will have capacity to dose into any of the first three reactors. This will allow continual feed to the leach even with one of these tanks taken offline for maintenance, and also allow partial parallel feeding to the leach as a strategy to minimise foaming if required.

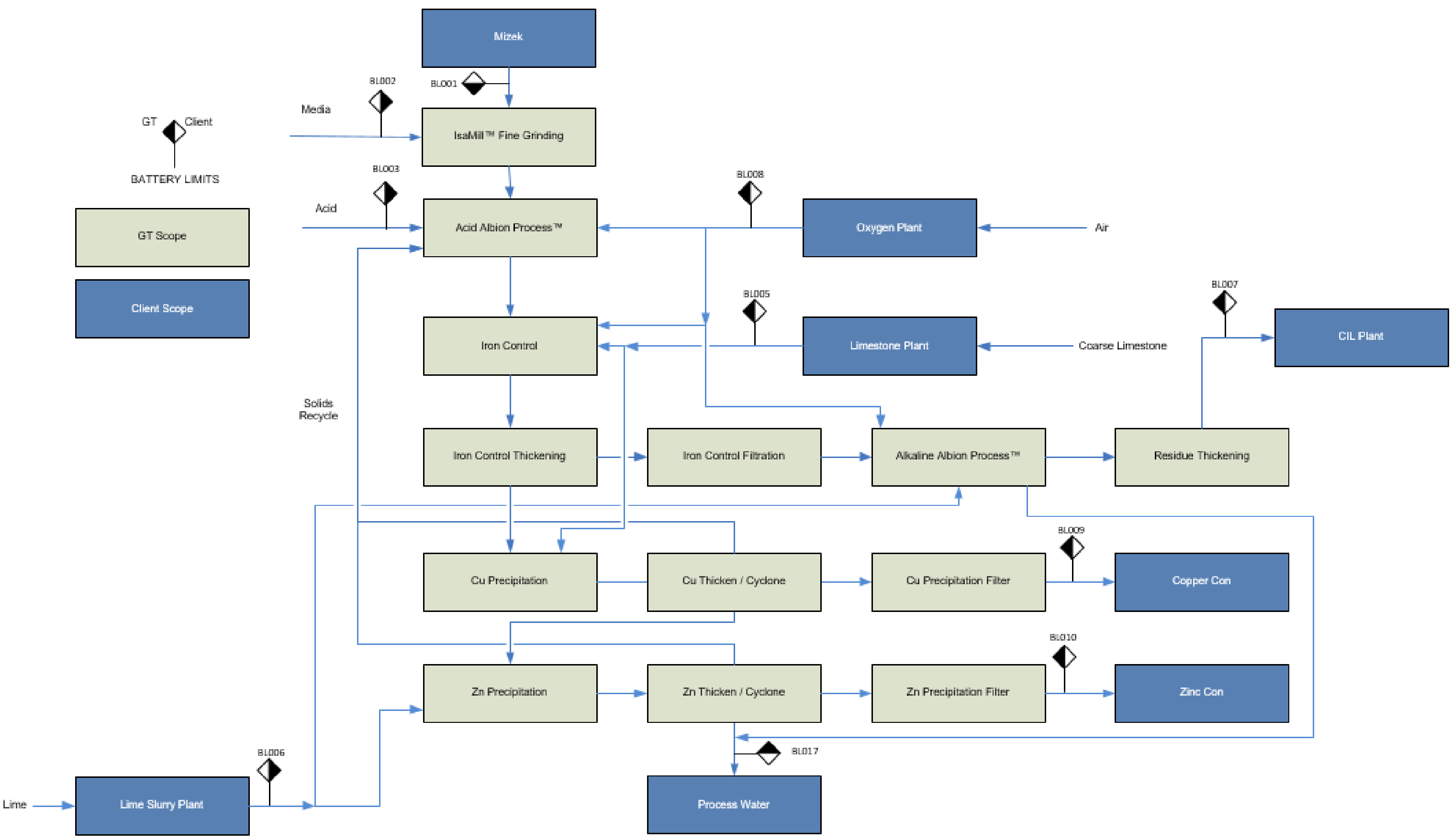

Figure 3 Albion Process™ Block Flow Diagram

Figure 4 IsaMill™ Fine Grinding Plant

Slurry transport between the reactors is via gravity flow, with a head differential between each successive reactor. Reactors will overflow into a launder arrangement for feeding the subsequent reactors, and a slurry riser will be installed in each reactor to minimise bypassing within the reactor train. All reactors will be fitted with bypass launders to allow any reactor to be removed from service for maintenance without interruption to the continuous process operation.

Each OxiLeach™ Reactor will be agitated by a centrally mounted agitator fitted with dual hydrofoil impellers. The impeller assembly is designed to provide the required gas hold up and solution pumping rate to ensure efficient reaction within the reactor.

The acid leach circuit will operate under atmospheric conditions, but all reactors will be covered with lids to minimise evaporative losses and improve oxygen uptake efficiency.

The Acid Leach circuit will operate autothermally. The leaching reactions will be exothermic, and the slurry temperature will be maintained by the heat of reaction, negating the requirement for external heat sources.

The pH in the Oxidative Leaching Reactors will be controlled within the range 0.8 – 1.5 by the addition of a 410 gpl acidic solution.

Oxygen will be added to each reactor via banks of

Figure 5 Albion Process™ Oxidative Leaching Train

HyperSparge™ oxygen spargers. The sparger banks are designed to balance the sparger and agitator power input to provide the most efficient oxygen mass transfer. Each sparger will have a specially designed insertion assembly to allow live withdrawal of the spargers for maintenance. This will minimise reactor downtime.

Process water will be added to the leach train to replace water losses through off gas humidification as required to maintain the target slurry density.

6.3 Iron Control Circuit

The Iron Control circuit will neutralise the discharge from the Albion Process™ Oxidative Leach Reactors to reduce the iron and acid levels prior to residue thickening and filtration. Other leached impurities such as aluminium and arsenic are also removed in the Iron Control circuit.

Like the Albion Process™ reactors, the iron control circuit will operate under atmospheric conditions, but all reactors will be covered with lids to minimise evaporative losses and improve oxygen uptake efficiency.

The pH in the Iron Control Reactors will be controlled within the range pH of 1.8 to 2.2 by the addition of limestone slurry to each reactor.

Discharge slurry from the Iron Control circuit will gravitate to the Iron Control Thickener. Overflow from the Iron Control Thickener will be directed to the Copper Precipitation Circuit.

Underflow from the Iron Control Thickener will be filtered and sent to an alkaline Albion Process™ reactor.

Overflow from the Iron Control Thickener will provide the feed to the Copper Precipitation Circuit.

6.4 Alkaline Albion Process™

The purpose of the Albion Process™ alkaline oxidative leach circuit is to oxidise the pyrite remaining in the residue reporting from the previous acidic leach stage, to render the precious metals amenable to downstream cyanidation. The alkaline Albion Process™ Reactor utilises hydrated lime slurry to increase the pH to 10, which assists in maximising oxidation of precious metal containing sulphide minerals.

The reactor will be agitated by a centrally mounted agitator fitted with dual hydrofoil impellers.

The alkaline reactor will operate under atmospheric conditions but will be covered with a lid to minimise evaporative losses and improve oxygen uptake efficiency.

Oxygen will be added to the reactor via HyperSparge™ oxygen spargers. The sparger banks will be designed to balance the sparger and agitator power input to provide the most efficient oxygen mass transfer. Each sparger will have a specially designed insertion assembly to allow live withdrawal of the spargers for maintenance. This will minimise reactor downtime.

Discharge slurry from the alkaline reactor will gravitate to the alkaline leach thickener. Thickener underflow will be transferred to the CIL circuit for gold and silver recovery.

Overflow from the thickener will be returned to the process water system.

6.5 Copper Recovery

The Copper Precipitation circuit will consist of standard OxiLeach™ reactors which will be re-purposed as precipitation reactors. The reactors will run in series and be interconnected by launders to allow the slurry to flow by gravity through the train. All copper precipitation tanks will be fitted with bypass launders to allow any tank to be removed from service for maintenance.

Limestone slurry will be dosed into each Copper Precipitation Tank to achieve a terminal pH of 4.5 in the third tank. Limestone will be dosed off a central ring main via an automated control valve.

The pH adjustment using limestone will precipitate the copper out of solution, with the residual sulphates forming gypsum crystals through this process. Recycling of these gypsum crystals will encourage their growth and enable a clear size and density distinction from the precipitated copper product.

A cyclone will be used to separate the coarse gypsum crystals from the fine copper product to maximise copper in the final concentrate.

The cyclone overflow product will be directed to the copper filter for dewatering of the final product.

The cyclone underflow, containing most of the gypsum and the remainder of the copper minerals, will operate on a ring main supplying two streams. The majority of the cyclone underflow will be pumped back into the first Copper Precipitation Reactor as a seed recycle for the continued growth of the gypsum crystals, with the remaining portion transferred back to the final Albion Process™ OxiLeach™ Reactor to recover any residual copper minerals.

The final product from the circuit will be ~30% w/w moisture Brochantite/Antlerite copper concentrate. This resultant concentrate is a suitable product for feed to either an ISASMELT™;

- The turbulently agitated slag bath of the ISASMELT™ furnace allows for incorporation of all phases into the molten melt and therefore allows for treatment of this material.

Or Vanyukov furnace;

- The agitated bath at the feed addition point that is present in the Vanyukov furnace technology will allow for it to process these materials as long as they are fed to the furnace together with the normal concentrate feed.

6.6 Zinc Recovery

Overflow from the Copper Precipitation Thickener will provide the feed to the Zinc Precipitation Circuit.

The Zinc Precipitation circuit will consist of our OxiLeach™ reactors which will be re-purposed as precipitation reactors.

The tanks will run in series and be interconnected by launders to allow the slurry to flow by gravity through the train. All Zinc Precipitation tanks will be fitted with bypass launders to allow any tank to be removed from service for maintenance.

Lime slurry will be dosed into each Zinc Precipitation Reactor to achieve a terminal pH of 7 in the third reactor. Lime will be dosed off a central ring main.

The pH adjustment will precipitate the zinc out of solution, with the residual sulphates forming gypsum crystals. Recycling of these gypsum crystals will encourage their growth and enable a clear size and density distinction from the precipitated zinc product.

A cyclone will be used to separate the coarse gypsum crystals from the fine zinc product to maximise zinc in the final concentrate.

The cyclone overflow will be directed to the zinc filter for dewatering.

The cyclone underflow, containing most of the gypsum and the remainder of the Zinc minerals, will operate on a ring main supplying two streams. The majority of the cyclone underflow will be pumped back into the first zinc precipitation reactor as a seed recycle for the continued growth of the gypsum crystals, with the remaining portion transferred back to the final Albion Process™ OxiLeach™ Reactor to recover any residual Zinc minerals.

The final product from the circuit will be ~30% w/w moisture basic zinc sulphate concentrate. The resultant concentrate is a common by-product and feed for smelting operations.

The proposed overall plant layout as described is shown in Figure 6.

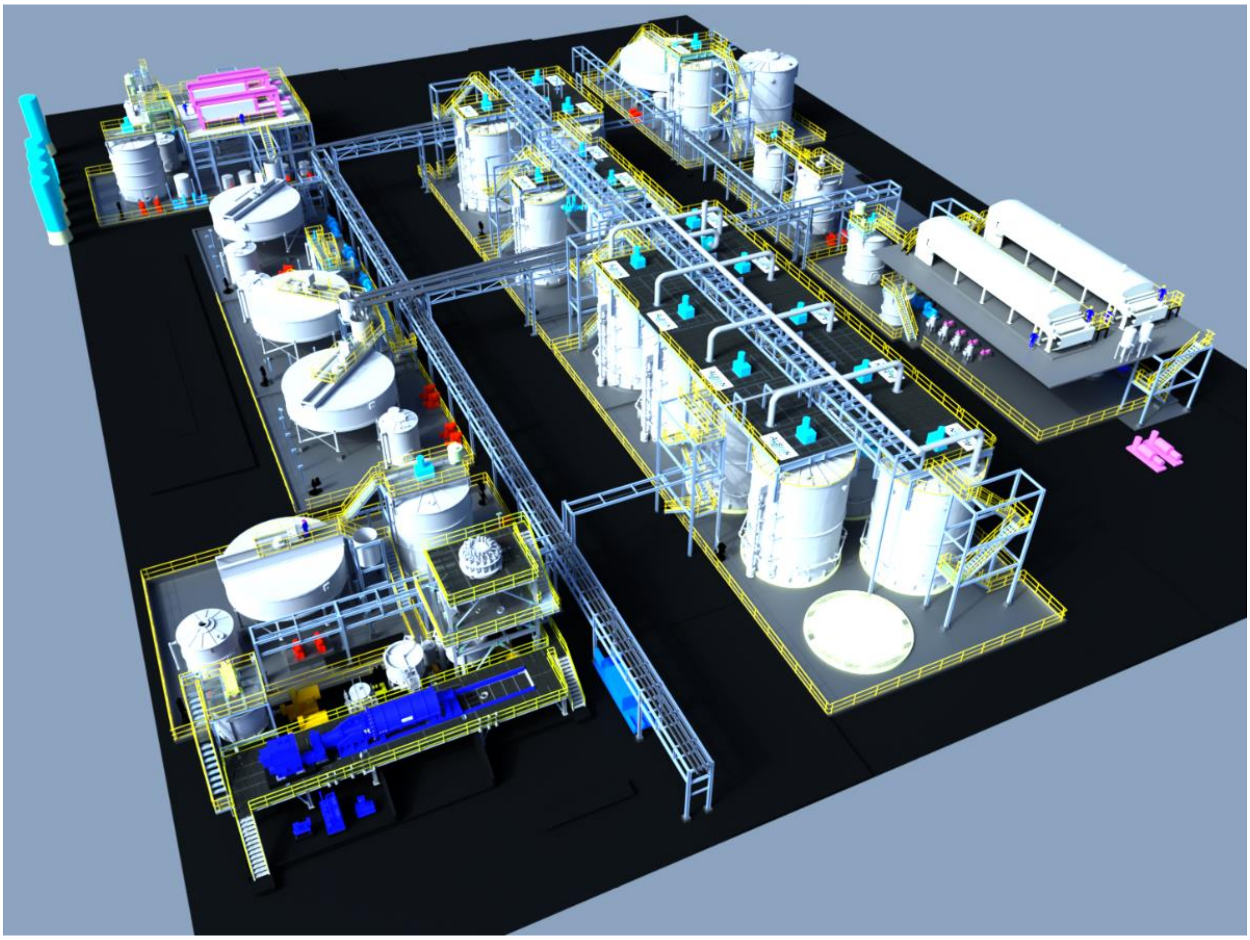

Figure 6 Overall Albion Process™ Plant Layout

7. Downstream Processing Options

This project focussed on producing precipitate concentrates from the base metals, but other final product options also exist. In the case of the Mizek project, with a bulk leach product containing copper and zinc sulphate in solution additional downstream processing options could include, but are not limited to:

- Copper removed via a solvent extraction (SX) circuit before proceeding to electrowinning for production of copper cathode. After which the pH of the raffinate from the copper SX circuit could be increased in precipitation reactors via the use of lime to precipitate basic zinc sulphate concentrate.

- Modification of the iron control circuit to ensure minimal iron is remaining in solution. Downstream of the iron removal, solution can be directed to a solvent extraction circuit for extraction and stripping of zinc to produce a zinc sulphate product. The pH of the raffinate from the Zinc SX circuit could then be increased in precipitation reactors via use of limestone to precipitate brochantite/antlerite copper concentrate.

- Modification of iron control circuit to ensure minimal iron is remaining in solution. Copper removed via a solvent extraction circuit before proceeding to electrowinning for production of copper cathode. Raffinate from the copper SX circuit then directed to a secondary solvent extraction circuit for extraction and stripping of zinc to produce a zinc sulphate product.

8. Benefits of the Albion Process™

Due to the nature of how the Albion Process™ operates, it offers a number of advantages over other leaching technologies.

Previous investigations have shown oxygen consumption is lower for the Albion Process™ when compared to medium temperature pressure oxidation (MT-POX) (SNC Lavalin, 2009). This occurs as the Albion Process™ typically does not require 100% sulphide oxidation and there is high oxygen usage efficiency afforded by the HyperSparge™ and impeller design in the OxiLeach™ reactors. This results in lower capital cost associated with the oxygen plant as well as lower ongoing operating costs.

As the Albion Process operates autothermally and at atmospheric pressure, power input is also decreased in comparison to POX (Alymore, 2012), improving costs and lowering environmental impact. Adding to the environmental benefit, the Albion Process™ was also shown to use significantly less water than MT-POX (SNC Lavalin, 2009).

The autothermal and atmospheric nature of the operation has the additional benefit of not needing any pressure reduction or heat removal. This contributes to a more stable process that simpler to operate.

Albion Process™ availability is also very high due to:

- The oxidative leaching train consisting of multiple reactors in series which are interconnected with launders, each with a bypass. This launder system allows individual reactors to be taken out of operation while online.
- The HyperSparge™ design allows removal and replacement while online.

These features give the ability to maximise throughput even during periods of maintenance.

9. Conclusions

The Albion Process™ has been successfully commercialised in both base metal applications and precious metal applications and is proven to be a safe, cost effective, steady, and reliable method for extracting valuable metals from sulphide feeds.

The Mizek project however has highlighted the opportunity for the Albion Process ™ to be applied to a complex feed containing both base and precious metals, whilst remaining cost effective and efficient in operation. The testwork provided extremely positive results increasing CIL gold recovery from 28.9% to 95.2% and silver recovery from 25.3% to 95.4%. Simultaneously the Albion Process™ leach achieved base metal extractions of 91.8% copper and 99.5% zinc into solution, for subsequent downstream processing.

These results are backed by Glencore Technology's performance guarantee for scale up of the Albion Process™.

These results combined with the simple flowsheet and standard downstream recovery options for precious and base metals have shown that the Albion Process™ is an ideal option for processing not only single metal feeds, but complex polymetallic feeds which contain multiple valuable metals.

10. Acknowledgements

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12. Professional Profile

Laurie McDonnell is a hydrometallurgist at Glencore Technology. He has extensive operational hydrometallurgical experience, specifically in oxidative leaching of sulphides and downstream treatment of base metals.

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