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ALBION PROCESS
GENERIC DEVELOPMENT PROGRAM
PA900-XT-DD5510

Revision	Date Revised	Description/Comment	Signatures		
			Originator	Checked	Approved
0	2/07/2012	Initial Issue	M. Hourn	D Mallah	

1 General Albion Process™ Description

The Albion Process™ is a combination of ultrafine grinding and oxidative leaching at atmospheric pressure. The feed to the Albion Process™ is a concentrate containing base or precious metals, and the Albion Process™ is used to oxidise the sulphide minerals in the concentrate and liberate these metals for recovery by conventional means.

The Albion Process™ technology was developed in 1994 by Xstrata PLC and is patented worldwide. There are two Albion Process™ plants currently in operation, one in Spain (4,000 tpa zinc metal) and one in Germany (18,000 tpa zinc metal). A photograph of the Albion plant in Germany is shown in Figure 1. A third Albion Process™ plant is operating in the Dominican Republic to treat a refractory gold/silver concentrate, producing 80,0000 ounces of gold annually. Xstrata Technology are currently completing the design and supply of an Albion Process™ plant for the GPM Project in Armenia. Procurement has begun for this project, with civil works on site advanced. The GPM Gold Project will commission in March, 2013. A fifth Albion Process™ plant for the Certej refractory gold project in Romania is in final Permitting stages.

The first stage of the Albion Process™ is fine grinding of the concentrate. Most sulphide minerals cannot be leached under normal atmospheric pressure conditions. The process of ultrafine grinding results in a high degree of strain being introduced into the sulphide mineral lattice. As a result, the number of grain boundary fractures and lattice defects in the mineral increases by several orders of magnitude, relative to un-ground minerals. This introduction of strain lowers the activation energy for the oxidation of the sulphides, and enables leaching under atmospheric conditions. The rate of leaching is also enhanced, due to the increase in mineral surface area.

Leaching under atmospheric conditions is low cost, and robust, with plants that require simple maintenance. Atmospheric leach plants are commonly used for processing of oxide gold ores and roasted zinc concentrates, and the technology is well proven and understood.

Fine grinding also prevents passivation of the leaching mineral by products of the leach reaction. Passivation occurs when leach products, such as iron oxides and elemental sulphur, precipitate on the surface of the leaching mineral. These precipitates passivate the mineral by preventing the access of chemicals to the mineral surface.

Passivation is normally complete once this precipitated layer is 2 – 3 μm thick. Ultrafine grinding of a mineral to a particle size of 80% passing 10 – 12 μm will prevent passivation, as the leaching mineral will disintegrate prior to the precipitate layer becoming thick enough to passivate the mineral. This is illustrated in Figure 1.

After the mineral has been finely ground, the slurry is then leached in agitated tanks, and oxygen is introduced to the leach slurry for oxidation. In the Albion Process™ the leaching tanks are designed to operate at close to the boiling point of the slurry, and no cooling is required. Leaching is carried out autothermally, and the temperature of the leach slurry is set by the amount of heat released by the leaching reaction. Heat is not added to the leaching vessel from external sources. The excess heat generated from the oxidation process is removed by direct evaporative cooling.

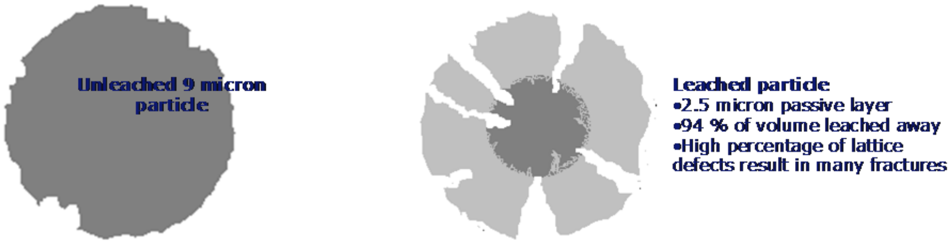

Figure 1
Mechanism of Passivation of Sulphide Minerals

After the mineral has been finely ground, the slurry is then leached in agitated tanks specially designed by Xstrata, known as the Albion Leach Reactor. In the Albion Leach Reactor oxygen is introduced to the leach slurry for oxidation at supersonic velocity to improve mass transfer efficiency. The Albion Leach Reactor is designed to operate at close to the boiling point of the slurry, and no cooling is required. Leaching is carried out autothermally, and the temperature of the leach slurry is set by the amount of heat released by the leaching reaction. Heat is not added to the leaching vessel from external sources, and excess heat generated from the oxidation process is removed through humidification of the vessel off gases.

2 Ultrafine Grinding and the IsaMill™ Technology

Ultrafine grinding requires a different type of milling action than in a conventional ball mill, due to the fine nature of the grinding media required. In most ultrafine grinding mills, an impeller is used to impart momentum to the media charge. Media is agitated through stirring, and the resulting turbulent mixing overcomes the tendency of fine media to centrifuge. Abrasion is the major breakage mechanism in a stirred mill. The common aspects of a stirred mill are a central shaft and a series of impellers attached to the shaft. These impellers can be pins, spirals, or discs.

In stirred mills, two configurations are common. In the first, the mill shaft and grinding elements are set up vertically within the mill. This type of configuration is limited in size to typically 750 kW of installed power or less.

This limitation is brought about by the large break out torque imposed on the impeller located at the base of the media charge, due to the compressive load of media sitting vertically on the impeller.

In the second configuration the mill shaft is aligned horizontally within the mill chamber. This configuration, which is used in Xstrata's IsaMill™ technology, is more cost efficient at motor sizes in excess of 500 kW. There is very little break out torque required to begin to agitate the media charge, which limits the motor size to that required for grinding only.

The IsaMill is a large-scale energy efficient continuous grinding technology specifically developed for rugged metalliferrous applications. Xstrata supplies the IsaMill technology to mining operations around the world, with over 100 mills installed in 9 countries worldwide. The IsaMill uses a very high energy intensity of 300kW/m^3 in the grinding chamber, resulting in a small footprint and simple installation. The IsaMill can be scaled up directly from small scale laboratory tests. IsaMill's are installed in more than two-thirds of the world's ultra fine grinding metalliferrous applications.

The grinding media size for the IsaMill™ is within the range 1.5 – 3.5 mm. Media can come from various sources, such as an autogenous media screened from the feed ore, silica sands or ceramic beads.

Xstrata will provide the IsaMill as a packaged IsaMill Grinding Plant, consisting of the slurry feed and discharge systems, as well as the media handling system and all structural steel and platforms. Some of the IsaMill Grinding Plant mechanical components are shown in Figure 2. The IsaMill Grinding Plant incorporates all of Xstrata's operational and installation experience gained from over 100 IsaMill installations, and ensures a rapid installation and trouble free commissioning.

The IsaMill™ will contain up to eight discs on the shaft, with each disc acting as a separate grinding element. The operating mechanism for the IsaMill is shown in Figure 4. The slurry residence time distribution through the mill approaches perfect plug flow with virtually no short circuiting. This allows the IsaMill™ to be operated in open circuit without the need for cyclones. The resulting particle size distribution is very narrow, resulting in very high leach recoveries with no coarse minerals that will otherwise travel through the leach train without complete oxidation.

The IsaMill is currently available in the following models:

- M1000 (500 kW), capable of throughputs in the range 10 – 16 tonnes per hour
- M3000 (1200 kW), capable of throughputs in the range 20 – 35 tonnes per hour
- M5000 (1500 kW), capable of throughputs in the range 30 – 55 tonnes per hour
- M10000 (3000kW), capable of throughputs in the range 60 – 100 tonnes per hour

The IsaMill™ produces a sharp size distribution in open circuit, as the feed must pass through multiple distinct grinding zones in series before reaching the Product Separator. This plug flow action ensures no short circuiting, and efficiently directs energy to the coarser feed particles.

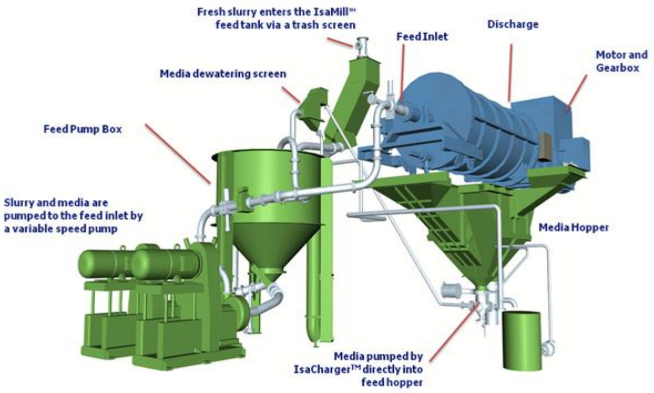

Figure 2
IsaMill™ Key Components

The Product Separator is a centrifugal separator at the end of the mill shaft that spins at sufficient rpm to generate over 20 "g" forces, and this action is responsible for the sharp classification within the mill. The IsaMill™ can be operated in open circuit at high slurry density, which is a key advantage for the leaching circuit, as the entry of water to the leach is limited, simplifying the water balance.

The IsaMill™ uses inert grinding media that produces clean, polished mineral surfaces resulting in improved leaching kinetics. A steep particle size distribution is produced in the mill, with very little coarse material. The 98 % passing size in the mill is typically less than 2.5 times the 80 % passing size, and very little coarse material enters the leaching circuit, resulting in very high leach recoveries.

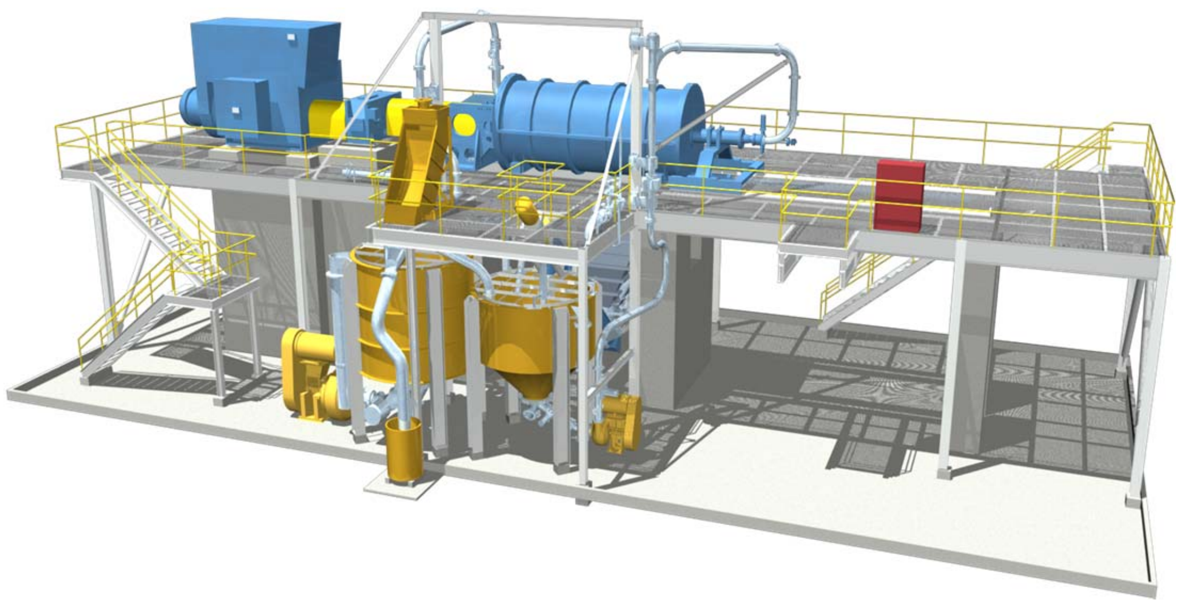

Figure 3
IsaMill™ Grinding Plant Layout

The IsaMill™ is the highest intensity grinding technology available (>300kW/m^3), also the most compact, with a small footprint and low profile. The IsaMill™ is oriented horizontally, with the grinding plant accessed by a single platform at an elevation of approximately 3 m. Access to the mill and maintenance is simplified by the low operating aspect of the IsaMill™ and the associated grinding plant. Maintenance of the IsaMill™ is similar to routine maintenance for a slurry pump.

The internal rotating shaft is counter-levered at the feed inlet end so the discharge end flange and grinding chamber can be simply unbolted and slid off using hydraulic rams. A shut down for inspection and replacement of internal wear parts takes less than 8 hours. Availability of 99% and utilisation of 96% are typical of the IsaMill™.

Scale-up of the IsaMill™ is straight forward. Laboratory test results are directly scaled to commercial size with 100% accuracy. The IsaMill™ has a proven 1:1 direct scale-up to reduce project risk.

The grind size employed for a nickel-cobalt sulphide concentrate will typically be in the range 12 – 14 microns. At this grind size the cobalt and nickel recovery to leach solution would be expected to be over 98 %, and the anticipated specific energy demand would be 35 – 45 kWh/tonne of concentrate.

3 Oxidative Leaching

After the sulphide mineral has been finely ground, it is then leached under atmospheric conditions in an oxidative leach consisting of interconnected Albion Leach Reactors. The Albion Leach Reactor is an atmospheric leaching tank that has been designed by Xstrata Technology to achieve the required level of oxygen mass transfer to facilitate oxidation of the sulphide feed at low capital and operating cost.

The oxidative leaching circuit in an Albion Process™ leach plant is similar to a conventional cyanide leach plant, with the Albion Leach Reactors connected in series with a launder system that allows gravity flow of the slurry through the leach train. All Albion Leach Reactors are fitted with bypass launders to allow any reactor to be removed from service for periodic maintenance. This is a low cost leaching system that is simple and flexible to operate, and the overall availability of the leach train is 99%.

Oxygen is injected into the base of the Albion Leach Reactors using a series of HyperSparge™ supersonic injection lances. The design of the HyperSparge™ injection system is carried out in conjunction with the design of the agitation system to ensure high oxygen mass transfer rates are achieved in the reactor. The agitator unit power is moderate, and the reactor is typically designed to achieve a blend time of 1 minute in the tank. The impeller tip speed is chosen in combination with the HyperSparge injection velocity to provide the required mass transfer.

The Albion Leach Reactor has a corrosion resistant alloy steel shell and base, supported on a ring beam or raft foundation. The tank aspect ratio is designed to achieve high oxygen transfer rates and capture efficiencies. Xstrata Technology has developed fully modular tank shell systems, which can be rapidly installed on site in one third the time of a field welded tank and at much lower costs. The Xstrata modular reactor designs require no site welding. The modular Albion Leach Reactor is shown in Figure 4.

The reactor is fitted with a centrally mounted agitator consisting of one or more hydrofoil impellers. The agitator sizing and impeller geometry is chosen by Xstrata Technology using in-house correlations and testwork data to provide sufficient power to meet the oxygen mass transfer requirements in the leach vessel, as well as provide adequate solids suspension and gas dispersal. Impeller arrangements and spacing are also designed to assist in foam control within the vessel. The agitator is mounted off the tank shell, and modular maintenance platforms and structural supports are provided as part of the Albion Leach Reactor.

Key design aspects of the agitator, such as the solidity ratio, the impeller diameters and tip speeds and the overall pumping rate are determined in combination with the design of the oxygen delivery system to provide the optimum mass transfer rates in the reactor.

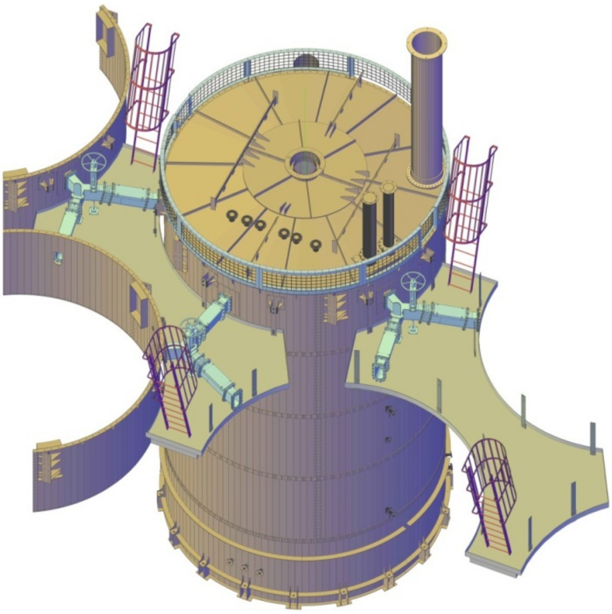

Figure 4
Modular Albion Leach Reactor

The oxygen delivery system on the Albion Leach Reactor consists of Xstrata's Technology's HyperSparge supersonic oxygen injection lances, which are mounted circumferentially around the reactor, close to the base. The HyperSparge™ is mounted externally to the tank, and penetrates through the tank wall using a series of sealing assemblies. This novel design means that no downtime is incurred for maintenance of the oxygen delivery system, as all HyperSparge units can be removed live for inspection. The high gas capture efficiencies achieved by the HyperSparge™ system results in low gas rates entering the Albion Leach Reactor, and so there is little or no correction to the drawn power for the agitator. Aeration numbers are typically less than 0.025.

The HyperSparge™ injects oxygen at supersonic velocities, typically in the range 450 – 550 $m.s^{-1}$. The supersonic injection velocities result in a compressed gas jet at the tip of the sparger that incorporates slurry via shear resulting in very high mass transfer rates within the Albion Leach Reactors. The unique design of the HyperSparge means that the agitator power required for the Albion Leach Reactors is much lower than is required in a conventional system. Oxygen capture efficiencies of 85 % or higher are achieved in Albion Plants within the Xstrata group using the HyperSparge system. A typical HyperSparge assembly is shown in Figure 5. The high jet velocities at the tip of the HyperSparge keep the nozzle clean and eliminate blockages.

The HyperSparge can be incorporated in an overall oxygen control system, consisting of in-stack off gas monitoring and control of the HyperSparge delivery pressure. The oxygen control system is used to maintain high oxygen capture efficiencies within the Albion Leach Reactor.

Exhaust gas from the oxidative leach is inert, and so the Albion Leach Reactor is fitted with sectional lids and an off gas stack to vent steam from the vessel to a safe working height. As the

Albion Leach Reactors operate at close to the boiling point of the slurry, significant water vapour is released from the vessel with the exhaust gas, which assists in overall process water balance. The off gas stack is designed as a natural chimney to vent this exhaust gas to a safe working height. The exhaust gas it typically vented, however condensers can be fitted if required to recover the evaporated water.

Each Albion Leach Reactor has modular Internal baffles to assist mixing and prevent slurry vortexing, as well as a modular slurry riser to prevent slurry short-circuiting and assist in transport of coarser material through the leaching train.

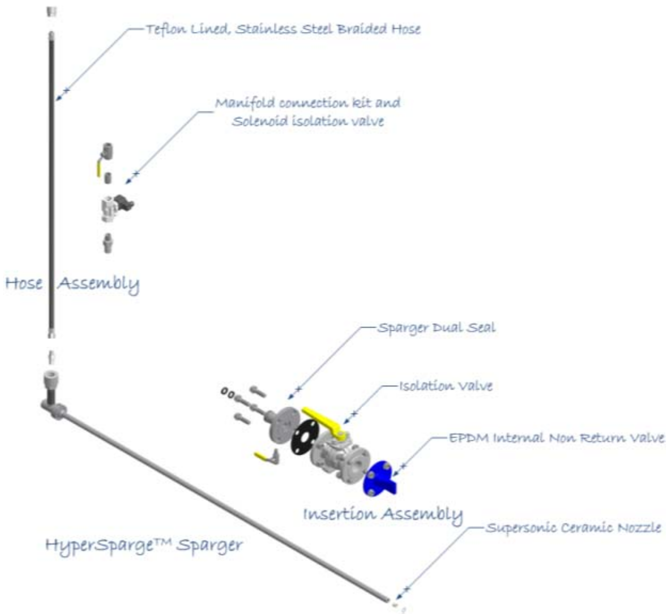

Figure 5
HyperSparge System

The Albion Leach Reactors are connected to each adjacent reactor via a launder system to transport slurry between the reactors. The launders are designed according to sound hydraulic principles and accommodate both slurry and foam transport, preventing build up in the leach train.

No internal heating or cooling systems are required in the Albion Leach Reactors. The vessel is allowed to operate at its equilibrium temperature, which is typically in the range 90 – 95°C. Heat is provided by the oxidation of the sulphide minerals, with heat lost from the vessel by humidification of off gas. No direct or indirect temperature control is required, simplifying tank construction and maintenance. No external cooling towers or flash vessels are required.

4 Development Program Overview

A typical development program for an Albion Process project would proceed in five Phases:

Phase 1 – Proof of Concept Class 5 (AACE) Engineering Study
Phase 2 - Scoping Level Evaluation Testwork Program and Class 4 (AACE) Engineering Study
Phase 3 - Pre-Feasibility Level Evaluation and Class 3 (AACE) Engineering Study
Phase 4 - Feasibility Level Evaluation and Class 2 (AACE) Definitive Feasibility Study
Phase 5 – Project Implementation as a Lump Sum Plant Design and supply package from Xstrata Technology

The Phase 1 Proof of Concept program consists of a Class 5 (AACE Guidelines) order of magnitude capital and operating cost estimate for an Albion Process plant based on a preliminary concentrate throughput and analysis provided by the client. Limited testwork is required as part of Phase 1, and all data is based on the Xstrata Technology database. It is possible to generate a Phase 1 Class 5 Engineering Study based on a client's concentrate analysis only if insufficient sample is available for testwork.

The Phase 2 Scoping Level Evaluation Testwork Program would evaluate the IsaMill ultrafine grinding and oxidative leach unit operations only, as these are the heart of the Albion Process. Downstream unit operations are not normally tested as part of this level of evaluation.

This stage of testwork normally requires 10 - 20 kg of concentrate to complete, with a duration of 12 – 16 weeks. The cost of the scoping study ranges from $AUD 30 – 45 000, depending on the actual scope of work. On completion of this testwork program, Xstrata Technology can then complete a Class 4 (AACE Guidelines) Engineering Study on the Albion Process Plant to an accuracy of ± 35 %, with additional costing of the fully integrated flowsheet to a lower level of accuracy. This Engineering Study could be used for detailed project evaluation as is and for comparison of various technologies or flowsheet options.

The Phase 3 Pre-Feasibility level work program expands on the scoping study. Additional concentrate types can be evaluated to provide data on the process for each defined concentrate type within the life cycle of the project. Testwork would also be carried out on downstream impurity control, such as iron and arsenic precipitation, as well as solid/liquid separation. Where metal recovery options are to be investigated, then testwork to define the preferred flowsheet is carried out at this stage. The Pre-Feasibility stage of testwork normally requires 20 – 50 kg of each concentrate type to complete, with a duration of 12 – 18 weeks. The cost of the Phase 3 testwork would range from $AUD 100 – 200 000, depending on the actual scope of work. The aim of the Pre-Feasibility level testwork is to finalise a flowsheet from concentrate through to metal or final product production, as well as to provide sufficient data to support a Pre-Feasibility level capital and operating cost estimate for the Albion Process plant. On completion of this testwork program, Xstrata Technology are then in a position to complete a Class 3 (AACE Guidelines) Engineering Study on the Albion Process Plant and integrated flowsheet to an accuracy of ± 25 %.

The Phase 4 Definitive Feasibility Study involves testwork and further engineering. Phase 4 level testwork involves continuous operation of a fully integrated pilot plant with the flowsheet identified in the Pre-Feasibility work program. This pilot involves all unit operations from concentrate ultrafine grinding through to metal or final product production, and has a closed water balance. This stage of testwork normally requires 500 - 2000 kg of concentrate to complete, with a duration of 12 - 16 weeks of continuous operation. All unit operations would be tested by vendors where possible. The cost of the Feasibility level testwork ranges from $AUD 1 – 2 million, depending on the actual scope of work. The aim of the Feasibility level testwork is to provide all process data necessary to support a feasibility level capital and operating cost estimate to be compiled for the Albion Process plant.

In parallel to the pilot plant program, Xstrata Technology also issues a complete Class 2 (AACE Guidelines) Engineering Study on the Albion Process Plant and integrated flowsheet to an accuracy of ± 10 %. This study involves bringing the level of engineering in the project to a completion level in the range 45 - 55 %.

On completion of Phase 4 of the project, Xstrata Technology offers to the client a Lump Sum design and supply package to supply all plant and equipment for the project, as well as all engineering.

Phase 5 of the project involves the Implementation of the project, including completion of all engineering, procurement of all equipment, piping, valves, instruments, control systems and structural steel and supply of entire plant as modular sections to the project site for construction.

More detail on the Scope of Work for each development stage is outlined in Section 2. A description of the Classes of Engineering Study carried out by Xstrata Technology as part of the development program is outlined below in Table 1. All Engineering Studies follow the guidelines outlined in the AACE International Recommended Practice No 18R-97 Cost Estimate Classification System.

Table 1
Classes of Engineering Study

Level of Testwork	Class of Estimate	Purpose	Accuracy	Level of Project Completion
Phase 1	Class 5 Order of Magnitude Estimate	Concept Screening	Low Range = -20 to -50 % High Range = 30 to 100 %	0-2%
Phase 2	Class 4 Study Estimate	Concept Study	Low Range = -15 to -30 % High Range = 20 to 50 %	1-15%
Phase 3	Class 3 Definitive Estimate	Budgeting	Low Range = -10 to -20 % High Range = 10 to 30 %	10-40%
Phase 4	Class 2 Detailed Estimate	Control Estimate or Bid Preparation	Low Range = -5 to -15 % High Range = 5 to 20 %	30-70%
	Class 1 Check Estimate	Tender	Low Range = -3 to -10 % High Range = 3 to 15 %	50-100%

5 Development Phases

Refer to schedule document

5.1 Phase 1 Scoping Level Evaluation and Class 5 Engineering Study

5.1.1 Evaluation

The deliverables on completion of the Scoping Level evaluation would be:

- AACE Class 5 Capital and Operating Cost Estimate for the Albion Process plant to an accuracy of ± 45 %, including the following deliverables:
    - Process Design Criteria
    - Block Flow Drawing
    - Capital Cost Estimate to an accuracy of ± 45 %
    - Operating Cost Estimate to an accuracy of ± 35 %

5.2 Phase 2 Scoping Level Testwork

5.2.1 Objectives

The objective of the scoping level testwork is to prove the concept of the Albion Process for the concentrate of interest. The idea of the program is to test the process on a single indicative concentrate within the battery limits of the fine grinding mill and oxidative leach only, to minimise the cost to the client. This phase of the testwork also provides a design package of sufficient detail to support a ± 35 % Pre-Feasibility level capital and operating cost for the Albion process and an estimate at a lower level of accuracy for any downstream metal recovery plant, to allow the client to evaluate the economic merit of the project.

The scope of work involves:

- Ultrafine grinding of the concentrate sample to a range of particle sizes, with a plot of specific energy demand Vs grind size developed for the concentrate. Typically three concentrate sizes are tested.

- Oxidative leaching tests on the three samples of ground concentrate at varying 80 % passing sizes under the Albion Process leach conditions to determine the best grind size for metal recovery. Tests are carried out at 10 litre scale and consume approximately 1000 grams per test. Progressive samples are collected from the 10 litre test at varying oxidation levels in the range 40 – 80 %.

- Evaluation of a lime boil on completion of the oxidative leach testwork to improve cyanide consumption.

- Cyanide leaching testwork for refractory gold concentrates.
    - A full bottle roll CIL test would be carried out on the final residue. CIL testwork could be carried out at a constant set of conditions, at relatively high free cyanide level.
    - LeachWell/BLEG tests would be carried out on a sample of the finely ground feed concentrate and a sample of the unground concentrate plus the interim samples collected at varying levels of oxidation.

5.2.2 Deliverables

The deliverables upon completion of the scouting testwork program are:

- A Technical Memorandum for the testwork program outlining the testwork campaign and all results including the following data:
    - Specific energy requirements in the ultrafine grinding circuit
    - The preferred size for feed to the oxidative leach
    - Acid and oxygen requirements in the oxidative leaching circuit
    - Residence time requirements in the oxidative leaching circuit

- AACE Class 4 Capital and Operating Cost Estimate for the Albion Process plant to an accuracy of ± 35 %, including the following deliverables:
    - Block Flow Drawing
    - Process Flow Drawings
    - Process Design Criteria
    - Work Breakdown Structure
    - Mass and Heat Balance
    - Equipment List
    - Reagent and Utilities Demand
    - Manpower Roster
    - Capital Cost Estimate (Albion Plant) to an accuracy of ± 35 %
    - Capital Cost Estimate (Non Albion Plant) to an accuracy of ± 45 %
    - Operating Cost Estimate to an accuracy of ± 35 %

5.3 Phase 3 Pre-Feasibility Level Testwork

5.3.1 Objectives

The objective of the Pre-Feasibility level testwork is to develop an integrated flowsheet for recovery of metal to a saleable product. This phase of the testwork also provides a design package of sufficient detail to support a ± 25 % Pre-Feasibility level capital and operating cost for the Albion process and downstream metal recovery plant, to allow the client to evaluate the economic merit of the project.

The scope of work involves:

- Collection and analysis of site data that will impact on plant capital and operating costs, including the following:
  - Site water analysis (Process and raw)
  - Site reagent analysis, specifically limestone and acid
  - Site climatic conditions
  - Site seismic conditions

- Testing of different concentrate types to develop a broader process model for design of the leach plant and reagent requirements. This testing involves ultrafine grinding and oxidative leaching of each concentrate type under conditions determined in the scouting work program.

- Diagnostic Leaching testwork on each concentrate sample to determine gold deportment.

- Collection and analysis of site limestone or alternative alkali samples:
  - Comprehensive analysis
  - Acid consumption test
  - Work Index testing and Abrasion index testing
  - Test the reactivity of the site limestone sample

- Ultrafine grinding of the concentrate sample to a narrow range of particle sizes, with a full signature plot developed for each concentrate sample for final IsaMill sizing. The target grind size will have been identified in the Phase 1 testwork program, and an optimised IsaMill sizing determined prior to this testwork. The potential for soluble gold losses in hyper saline site waters would be identified with analysis of all discharge slurries.

- Oxidative leaching tests on the samples of ground concentrate at varying oxidation levels under the Albion Process leach conditions to determine the best grind size for metal recovery.

  The oxidation range will have been identified in the Phase 1 testwork, and so these oxidative leach tests will focus on this oxidation range.

  Tests are carried out at 60 litre scale and consume approximately 5000 grams per test. The 60 L oxidative leach test allows sufficient interim samples to be taken for full CIL bottle roll cyanide leach tests. Phase 3 oxidative leach testwork should use site limestone samples.

A lime boil would be incorporated on completion of the oxidative leach test if the results of the phase 1 testwork program warranted.

- Cyanide leaching testwork for refractory gold concentrates.
  - A full bottle roll CIL test is carried out on the final residue of each oxidative leach test, and all interim samples collected at varying levels of oxidation to provide a comprehensive matrix of with gold recovery against oxidation level.
  - A comprehensive analysis of a representative final cyanide leach solution for environmental and cyanide destruction purposes
  - A CIL optimisation program on a sample of representative oxidised residue at the preferred oxidation level. The following variables would be examined:
    - Pre-aeration
    - CIL Vs CIP
    - Free cyanide level
    - Cyanide leaching of the unground feed material
- Testwork to develop a circuit for impurity control, such as iron and arsenic precipitation from rich leach solutions ahead of metal recovery by either SX/EW or via intermediate precipitation;
- Thickening and filtration testwork on the neutralised slurry for sizing of the solid/liquid separation circuit, carried out with vendors if required by the client. Alternatively, standard laboratory test procedures can be used to provide indicative design data.
- Preliminary viscosity testwork on samples of process slurries to determine slurry type (Newtonian/Bingham). Testwork will be carried out at ambient and operating temperatures for each sample. Viscosity testwork should focus on shear rates in the range 0 – 100 Pa.s as this range is most applicable to agitators.
- Environmental testing of process residues as required in the region where the project is located.
- Testwork on metal product and subsequent product quality for base metals projects

5.3.2 Deliverables

The deliverables on completion of the Pre-Feasibility level testwork program would be:

- A Technical Memorandum outlining the testwork campaign and all results
- Xstrata Technology AACE Class 4 Capital and Operating Cost Estimate for the Albion Process plant to an accuracy of ± 35 %, including the following deliverables:
  - Block Flow Drawing
  - Process Flow Drawings
  - Process Design Criteria
  - Work Breakdown Structure

- Mass and Heat Balance
- Equipment List
- Reagent and Utilities Demand
- Manpower Roster
- Capital Cost Estimate to an accuracy of ± 35 %
- Operating Cost Estimate to an accuracy of ± 10 %

5.4 Phase 4 Definitive Feasibility Level Testwork

5.4.1 Objectives

The objective of the feasibility level testwork would be to provide a design package of sufficient detail to support a ± 10 % Feasibility Study for the Albion Process plant for detailed engineering and design. This would be achieved through the operation of a continuous fully integrated pilot plant that would include all unit operations proposed in the commercial flowsheet. The scale of the pilot plant would be determined on consultation with the client, however pilot facilities are available in the following sizes:

10 kg/day of concentrate
20 kg/day of concentrate
100 kg/day of concentrate
1000 kg/day of concentrate

Daily cyanide leaching testwork will be carried out on all pilot plant products for refractory gold concentrates. All pilot facilities can be integrated with SX/EW for cathode production for the treatment of base metals concentrates.

All design data would be tested under continuous operation. The battery limits for the pilot plant are typically:

- Thickened flotation concentrate, prior to ultrafine grinding
- Filtered or thickened oxidative leach residue for cyanide leaching
- Final metal product for base metals concentrates

The objectives associated with the individual unit operations tested in the pilot would be as follows:

- Determine the optimum particle size distribution for the ultrafine grinding stage to allow a metal recovery in excess of 96 % from the finely ground concentrate.
- Achieve a 30 day operating period in the oxidative leach with an average combined metal recovery in excess of 95 - 98 %.
- To collect reagent consumption data in the ultrafine grind, leach, iron control and bleed neutralisation circuit for the following reagents to an accuracy of ± 10 %
    - Ultrafine grinding specific energy demand
    - Grinding media in the ultrafine grinding stage

- Oxygen in the oxidative leaching stage
- Sulphuric acid in the leaching stage
- Limestone in the iron control stage or neutral leaching stage
- Lime in the cyanide leach, if applicable
- Cyanide in the cyanide leach, if applicable
- Flocculent (Thickening and Filtration)

- To provide sufficient representative sample for vendor evaluation of all key unit operations, inclusive of:
  - Ultrafine grinding
  - Materials (coupon) testing for alloy steels
  - Thickener vendor testing
  - Slurry pump rheology testing
  - Filter vendor testing
  - Agitator vendor testing
  - Materials handling testing if required and Coupon testing for corrosion and materials choices
  - Viscosity testwork on samples of process slurries to determine slurry type (Newtonian/Bingham) as well as the plastic and dynamic viscosity. The shear stress will be measured as a function of shear rate and hence the viscosity as a function of shear rate will be obtained. Testwork will be carried out at ambient and operating temperatures for each sample. Viscosity testwork should focus on shear rates in the range 0 – 100 Pa.s as this range is most applicable to agitators.

5.4.2 Deliverables

The deliverables on completion of the pilot plant would be the following:

- A Definitive Feasibility Study from Xstrata Technology
- A Lump Sum plant design and supply offer from Xstrata Technology
- Plant engineering design at a level of 30%
- A comprehensive Technical Memorandum outlining the pilot plant campaign and all results.
- Vendor reports outlining design information on the following key unit operations
  - Ultrafine grinding
  - All thickening unit operations
  - All filtration unit operations if required

- Mixing requirements in the leach circuit
- Mass Transfer in the oxidative leach
- Viscosity data for pumping and mixing duties

- Xstrata Technology AACE Class 2 Feasibility Study for the Albion Process plant to an accuracy of ± 10 %, including the following deliverables:
  - Block Flow Drawing
  - Process Flow Drawings
  - Process Description
  - Utilities Flow Drawings
  - Utilities Specifications and Descriptions
  - Mechanical Equipment Specifications
  - Mechanical General Arrangement Drawings
  - Civil and Structural Arrangement Drawings
  - Piping and Instrument Drawings
  - Process Control Philosophy
  - 3D plant model
  - Process Design Criteria
  - Utilities Design Criteria
  - Work Breakdown Structure
  - Mass and Heat Balance
  - Equipment List
  - Valve List
  - Instrument List
  - Pipeline Listing
  - Drive Listing
  - Sing Line Drawings
  - Reagent and Utilities Demand
  - Manpower Roster
  - Construction Schedule
  - Capital Cost Estimate to an accuracy of ± 10 %
  - Operating Cost Estimate to an accuracy of ± 10 %
  - Full material take-offs for all disciplines
  - A Lump Sum Design and Supply offer from Xstrata Technology to the client for the Albion Process plant and associated plant areas.