1. Albion Process™ Development Program Overview

A development program for an Albion Process™ project typically occurs in five Phases. Each phase comprises two components:

1) Testwork Program to determine the amenability of the process to the feed, collect design data and address metallurgical risks

2) Engineering Study to allow design and cost estimating to occur.

Invariably the testwork and engineering activities feed into each other in an iterative design process within each phase and between phases to another. All Engineering Studies follow the guidelines outlined in the AACE International Recommended Practice No 18R-97 Cost Estimate Classification System. The five phases are expanded below:

Phase 1 – Amenability Testwork Program and Class 5 (AACE) Engineering Study

Phase 2 – Scoping Testwork Program and Class 4 (AACE) Engineering Study

Phase 3 – Pre-Feasibility Level Testwork Program and update of Class 4 study to Class 3 (AACE) Engineering Study (Basic Engineering)

Phase 4 – Feasibility Level Testwork Program and Class 2 (AACE) Feasibility Study (Detailed Design)

Phase 5 – Project Implementation

The testwork activities within each phase are summarised in Table 1. The Albion Process™ can be broadly applied in two operating regimes. The first is Neutral Albion Process™ Leaching (NAL) in which the leaching step is operated at near neutral (pH 5.5) conditions primarily for the oxidation of pyrite and downstream recovery of gold and silver with cyanidation. The second is Acid Albion Process™ Leaching (AAL) in which the leaching step is operated under acidic conditions (pH 1.0) primarily for the treatment of base metal concentrates. The AAL system requires more extensive testwork to parameterise because more factors affect the leach performance including acidity, dissolved iron levels, total dissolved solid levels, deportment of sulphur etc.

The study phases below are provided as a guideline and a general description and all detail can be provided on a project specific basis. Activities within each phase will run in parallel and can potentially overlap to compress project schedule. For example the oxygen plant is the longest lead time item at approximately 50 weeks. The oxygen plant would be sized on the completion of Phase 3 and could be ordered accordingly. Phase 3 is equivalent to a Basic Engineering Phase and Phase 2 is equivalent to the Detailed Design Phase.

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Table 1
Project Development Summary – Testwork and Engineering

Study Phase	Testwork Program	Approx. Sample Mass	Approx. Testwork Duration	Engineering Study	Class Level	Accuracy	Design Completion	Study Purpose
1	Amenability	500g	8 wks	Order of Magnitude Estimate	5	Low = -20 to -50 % High = 30 to 100 %	0-2%	Fast Fail
2	Scoping	20 kg	12 – 16 wks	Scoping Study Estimate	4	Low = -15 to -30 % High = 20 to 50 %	1-15%	Technology trade-off
3	Pre-Feasibility	20 – 50kg	12 – 18 wks	Pre-Feasibility Study Estimate	3	Low = -10 to -20 % High = 10 to 30 %	10-40%	Budgeting
4	Feasibility	500 – 2000kg	20 – 30 wks	Feasibility Study Estimate	2	Low = -5 to -15 % High = 5 to 20 %	30-70%	Control Estimate or Bid Preparation
5	-	-	-	Execution	Execution	Execution	Execution	Execution

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. Amenability testwork is conducted at this stage, which is a fast fail indication to determine the amenability of the Albion Process™ to the feed material. The features of the testwork are that it is simple, low cost and requires as little as 300g of sample. The outcome of the test is to determine the extent of metal extraction and sulphide oxidation to determine if the assessment of Albion Process™ should proceed to the next phase. Limited testwork is required as part of Phase 1 and all data is sourced from the GT database. It is possible to generate a Phase 1 Class 5 Engineering Study based on a Client's concentrate analysis if insufficient sample is available for testwork.

The Phase 2 Scoping Testwork Program provides sufficient testwork data to prove the metal recoveries in the Albion Process™ and provide high level equipment sizing data for the IsaMill™ ultrafine grinding plant and the oxidative leach plant. Downstream unit operations are not normally tested as part of this level of evaluation. The sample quantity is driven by the generation of the IsaMill™ signature plot. On completion of this program, GT can then integrate test results to complete a Class 4 Engineering Study on the Albion Process™ Plant, with additional costing of the fully integrated flowsheet to a lower level of accuracy. This Engineering Study can be used for detailed project evaluation as is and for comparison between various technologies or flowsheet options.

The Phase 3 Pre-Feasibility Testwork Program expands on the scoping study. Additional concentrate types can be evaluated to provide variability 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 and rheology. Testwork for flowsheet optimisation should also be performed at this stage. 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. Test results from this test program enable GT to complete a Class 3 (AACE Guidelines) Engineering Study on the Albion Process Plant and integrated flowsheet to an accuracy of $\pm$ 25 %. Phase 3 Engineering is equivalent to the Basic Engineering Phase and following Client approval, long lead time items can be ordered such as the IsaMill™, steel for Albion Process™ leach reactors, oxygen plant, thickeners and limestone grinding plant.

The Phase 4 Definitive Feasibility Study involves testwork and further engineering. Normally, sufficient design data has been generated from testwork in Phase 3 and no further testwork is required. Testwork conducted in Phase 4 can be performed to address any remaining metallurgical risks such as generation of sufficient quantities of final product for evaluation of traders or if required a continuous pilot plant. The operation of a pilot plant is not required to collect design data and for GT to offer performance guarantees. Pilot plant operation is usually a requirement on the Client side especially when external financers are managing risk. When operated, the pilot involves all unit operations from concentrate ultrafine grinding through to metal or final product production, and has a closed water balance. The pilot can be run either in Brisbane or at the Client project site. Phase 4 Engineering is equivalent to Detailed Design Phase and following Client approval, medium lead time items can be ordered such as agitators and automatic valves.

In parallel to any additional testwork or operation of a pilot plant, GT also issues a complete Class 2 Engineering Study on the Albion Process™ Plant and integrated flowsheet to an accuracy of $\pm$ 10 %. On completion of Phase 4 of the project, GT can offer 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 remaining 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 typical Scope of Work and Deliverables for each development stage is outlined in Section 2. A development schedule is shown in Figure 1.

2 Development Phases in Detail

2.1 Phase 1 Amenability Testwork and Class 5 Engineering Study

2.1.1 Scope of Work

The objective of the Amenability Testwork is to provide a fast-fail assessment of a feed type for treatment with the Albion Process™. The testwork is simplified and based on a small sample size to reduce cost and improve turn around. Limited design data is collected and the objective of the testwork is to indicate if the process works or not.

The scope of work involves:

- Ultrafine grinding of the concentrate to 80% passing 10□m without collecting grind energy data
- Acid demand test to understand the gangue acid consumption
- Oxidative leaching for 72 hours without collection of any kinetic data
- Cyanidation of the leach residue for precious metals

2.1.2 Deliverables

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

- A Technical Memorandum for the testwork program outlining the testwork campaign and all results including the following data:
  - Test conditions
  - Gangue acid consumption
  - Base metals ultimate recovery
  - Precious metals recovery in the downstream cyanidation process
  - Sulphide oxidation
- A Class 5 level Capital and Operating Cost Estimate for the Albion Process plant to an accuracy of $\pm$ 45 %, including the following deliverables:
  - High level mass and heat balance
  - Process Description
  - Block Flow Drawing
  - High level Mechanical Equipment List
  - Reagents and Consumables schedule
  - Capital Cost Estimate to an accuracy of $\pm$ 45 %
  - Operating Cost Estimate to an accuracy of $\pm$ 35 %

2.2 Phase 2 Scoping Level Testwork and Class 4 Engineering Study

2.2.1 Scope of Work

The objective of the Scoping Level testwork is to prove the concept of the Albion Process™ for the feed material and to collect basic design data. 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 $\pm$ 35 % Scoping 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 generate an IsaMill™ signature plot for the sizing of the IsaMill™ plant

- Oxidative leaching tests on the three samples of ground concentrate at varying 80 % passing sizes 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 for assay, and if required for gold/silver recovery testwork. This testwork provides the specific leaching rate constant for the concentrate sample, and this is used for accurate sizing of the oxidative leaching circuit. Typically three concentrate sizes are tested.

- Evaluation of flotation of the oxidised residue for recovery of an elemental sulphur concentrate with precious metals (AAL only).

- Cyanide leaching testwork for refractory gold concentrates or for oxidised residues from base metals 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.

2.2.2 Deliverables

The deliverables upon completion of the Scoping Level testwork program are:

- A Technical Memorandum for the testwork program outlining the testwork campaign and all results including the following data:

    - IsaMill™ signature plot
    - 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

- A 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 Process™ Plant) to an accuracy of ± 35 %
    - Operating Cost Estimate to an accuracy of ± 35 %

2.3 Phase 3 Pre-Feasibility Level Testwork and Class 3 Engineering Study

2.3.1 Scope of Work

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 $\pm$ 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 2 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 2 testwork, and so these oxidative leach tests will focus on this oxidation range.

  Tests are carried out at 10 and 60 litre scale and consume approximately 1000 - 5000 grams per test. Varying slurry density, operating temperature and leach chemistry are tested to allow more complete kinetic modelling of the leach circuit.
- Cyanide leaching testwork for refractory gold concentrates or for oxidised residues from base metals 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 can 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.

- Rheology data is collected from relevant slurry streams for the purposes of agitator sizing and pumping calculations.

- 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 regulatory 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

2.3.2 Deliverables

The deliverables on completion of the Pre-Feasibility Level testwork are:

- A Technical Memorandum outlining the testwork campaign and all results

- A Class 3 Capital and Operating Cost Estimate for the Albion Process plant to an accuracy of $\pm$ 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 $\pm$ 35 %
- Operating Cost Estimate to an accuracy of $\pm$ 10 %

2.4 Phase 4 Feasibility Level Testwork and Class 2 Engineering Study

2.4.1 Scope of Work

The objective of the Feasibility Level test program is to provide a design package of sufficient detail to support a $\pm$ 10 % Feasibility Study for the Albion Process™ plant for detailed engineering and design. This is achieved through conducting any testwork to address any remaining metallurgical risks and/or the operation of a continuous fully-integrated pilot plant that includes all unit operations proposed in the commercial flowsheet. The scale of the pilot plant is 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 is carried out on all pilot plant products for refractory gold concentrates. All pilot facilities can be integrated with SX/EW circuit for cathode production in the extraction of base metal concentrates.

All design data is 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 operation are as follows:

- Determine the optimum particle size distribution for the ultrafine grinding stage to allow a metal recovery in excess of 98 % from the finely ground concentrate (AAL) or achieve target sulphide oxidation (NAL).

- Achieve a 30 day operating period in the oxidative leach with an average combined metal recovery in excess of 96 - 98 % (AAL) or at target sulphide oxidation (NAL).

- Collect reagent consumption data in the ultrafine grind, leach, iron control and bleed neutralisation circuit for the following reagents to an accuracy of $\pm$ 10 %

    - Ultrafine grinding specific energy required for scale up

- 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
- Flocculant consumption and type (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.

2.4.2 Deliverables

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

- A Definitive Feasibility Study from GT and/or the Clients engineering contractor
- A Lump Sum plant design and supply offer from GT for the Albion Process™ plant
- 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

- A 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
  - Single 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 GT to the Client for the Albion Process plant and associated plant areas.