Gold Extraction
Process Development
Capability Statement
Company Overview

Australian Laboratory Services (ALS) commenced operations in Brisbane as ‘Australian Laboratory Services Pty Ltd’ in 1974 as a privately owned company providing analytical services for the oil shale and mineral exploration industries.

Australian Laboratory Services (ALS) provides a broad range of sophisticated, state-of-the-art services to four main market segments, with a total of 13 unique service offerings:

**Minerals** - Geochemistry | Metallurgy | Mine Site | Inspection

**Life Sciences** - Environmental | Food | Pharmaceutical
Animal Health | Electronics.

**Energy** - Coal | Oil & Gas

**Industrial** - Asset Care | Tribology.

ALS has demonstrated over 30 years of strong business performance with global revenues exceeding $1.5 billion. ALS continues to remain at the forefront of the testing services industry, building an enviable reputation as the provider of choice on a global scale.

Processing more than 20 million samples per year, our 13,000 staff operate from over 350 locations in 55 countries. We have laboratories strategically located around the world, operating in Australia, Asia, North America, South America, Europe, the Middle East and Africa; and are one of the largest analytical laboratory groups in the world.
**Introduction**

ALS Metallurgy is part of the ALS Group, a diversified and global analytical laboratory and testing services company.

ALS Metallurgy is the global leader in metallurgical testing and consulting services for mineral process flowsheet development and optimisation.

Extensive bench scale laboratory, large scale pilot plant facilities and expert metallurgists, provide mineral processing, hydrometallurgical, mineralogical and in-plant services to the global resources community.

Our metallurgical solutions are internationally recognised by the mining, engineering and financial sectors for all major commodities:

- Precious metals – gold, silver, platinum group metals
- Base metals – copper, cobalt, lead, zinc, molybdenum, manganese
- Iron ore – hematite, magnetite, goethite, itabirite
- Nickel – laterite and sulphide ores
- Uranium and thorium
- Rare earth minerals and other exotics
- Mineral sands
- Industrial minerals
- Tungsten and tin

ALS Metallurgy has an enviable reputation for delivering the highest quality extractive metallurgical testing service with accurate and timely data, expert support and a culture of safety and innovation.

**Quality**

ALS understands the value of data quality and integrity to exploration and mining companies. Our processes are designed to ensure clients receive the best quality assay data to assist informed decision making.

**Health, Safety and Environment**

Being an employee of ALS is about putting safety first. Globally, ALS is committed to a safe work culture.

**SAFETY MANAGEMENT**

As part of this global approach, ALS has developed an industry leading standard for managing health, safety and environmental issues.

**PROTECTION OF THE ENVIRONMENT**

ALS has Extensive procedures and policies to ensure Protection of the Environment. Specific procedures and policies address the following issues:

- Waste Management, Monitoring and Maintenance;
- Disaster Management plans for spills;
- Management of Solid waste, with recycling where possible.
The metallurgical response of gold ores and concentrates to an extraction process is determined by a programme of metallurgical testing and evaluation.

ALS Metallurgy’s gold extraction process development test work, at both laboratory and pilot plant scales, minimises your technical risks associated with the development of gold projects through well-planned, well-managed, and well-executed metallurgical testwork programmes.

Gold deposits currently being considered for exploitation are lower grade and increasingly more complex, so a complete understanding of the metallurgical response to extraction process options becomes even more important. Gold mineralogy in each ore deposit is unique and it is important to accurately consider the process mineralogy which can affect the gold extraction processing strategy.

ALS Metallurgy works with the international mining, engineering and financial sectors to develop and demonstrate successful gold extraction processing strategies by providing you with an accurate understanding and evaluation of the chemical, mineralogical and metallurgical factors.

The extraction and recovery of gold is becoming increasingly more complicated and involves nearly all the processes used in extractive metallurgy. ALS Metallurgy’s dedicated team of gold metallurgy experts are experienced in a range of gold ore types including free milling and refractory ores.

With industry leading expertise in geochemistry, mineralogy and metallurgy, the ALS Group can provide you with a wide range of services including:

**Exploration Services**
- Geochemical exploration services
- Geometallurgy
- Advanced mineralogy
- Scoping stage metallurgical testing

**Process Optimisation, Pre-Feasibility and Feasibility Services**
- Geometallurgy
- Ore variability studies
- Advanced mineralogy
- Metallurgical flowsheet development and optimisation
- Continuous pilot plant testing

**Production Support**
- Mine site laboratories
- Grade control and daily mill control analytical services
- Advanced mineralogy
Extensive Services

Chemical Analysis

Accurate assaying is critical to the success of any gold test work programme. With a state of the art analytical laboratory on-site at our metallurgical facility, ALS Metallurgy conducts fire assay, solution analyses for gold and silver, as well as carbon assays and gold by aqua-regia digest. Results are continually monitored by a system of QA/QC standards and external round robin checks.

Mineralogy

A complete understanding of how gold is contained within the minerals present in gold ores is required to successfully design and operate a gold extraction process for optimum efficiency.

We can fully characterize gold ores through comprehensive programmes including multi-stage diagnostic leaching, pre-concentration, process mineralogy and other complementary tests. When performed during the exploration and feasibility stages of the project, such information can identify and quantify key parameters that might influence the viability of a project. Information can be incorporated into geometallurgical models to assist with reserve and resource estimations and with mine production planning.

Information on the deportment of the gold assists the design of gold recovery circuits and, when done routinely, ensures continued optimization of existing processes and the ongoing profitability of the mining operation.

Apart from obtaining quantitative data on the gold minerals themselves, mineralogical data is also provided on the associated host rock minerals including potentially deleterious minerals such as preg-robbers and environmentally undesirable elements.

Sample Preparation, Screening and Analysis

Our extensive crushing, screening and splitting equipment ensures that accurate representative samples are produced. Test samples from a few kilograms to many tonnes can be prepared and treated. Particle size distribution determination can be conducted via screening methods. For finer particles, i.e. less than 38µm, cyclo-sizing can be conducted with the finer fractions being collected and assayed. Apparent relative density determinations and true SG determinations are also conducted.

Comminution

A range of tests are available for assessing the comminution parameters for gold ores:

- Autogenous media competency
- Bond abrasion index
- Bond ball mill work index
- Bond impact crushing work index
- Bond rod mill work index
- Comparative work index
- High pressure grinding rolls (HPGR) up to 10tph
- Inferred work index
- JK drop-weight test
- Levin open circuit grindability
- Pilot SABC (AG/SAG) up to 4tph
- Point load test
- SAGDesign (Starkey)
- SAG mill comminution (SMC) test
- Ultra fine grinding
- Unconfined compressive strength

Gravity Concentration

Gravity separation and concentration equipment are available to recover free gold prior to cyanidation. Spirals, tables, jigs, hydrocyclones, batch Knelson, batch Falcon, pilot scale Falcon concentrators, heavy liquid separation up to 4.05SG, amalgamation and intensive cyanidation (ILR) can be used to enhance the economics of gold recovery.

Pre-leach oxygenation treatment

Pre-leach oxygenation of ores that contain pyrrhotite and other labile sulphides is often carried out to satisfy the oxygen demand of leach slurries. This is not oxidation of sulphides as such but rather oxygenation of leach pulps. Often lead nitrate is also included at this pre-treatment stage.

Cyanidation – Free Milling Ores

Our fully equipped, dedicated gold laboratory provides specialised testing services for gold recovery by cyanidation in bottle rolls or mechanical agitation in vats. Cyanidation leaching of free-milling ores including batch leaching tests to determine the effect of grind size, pH, cyanide solution strength, influence of dissolved oxygen concentration, influence of leach accelerants (such as lead nitrate and other chemicals) and leach time can be performed. Tests can be on samples from 0.50kg up to 2000kg. Plant design data generation such as slurry rheology measurements, oxygen uptake rate determinations, slurry flocculation/settling and filtration test work can also be conducted.
Carbon-In-Pulp (CIP) and Carbon-In-Leach (CIL)

The loading of gold onto activated carbon can be described by the Fleming equation. ALS Metallurgy can carry out sequential batch carbon loading tests to determine the Fleming constants k and n. The Fleming constants are used by consulting engineers to size CIP contactors. Pilot scale CIP facilities are available to confirm laboratory test results.

Some gold bearing ores also contain active constituents which adsorb the leached gold and thus reduce gold recovery. The use of CIL can reduce or eliminate the loss of gold by the process of competitive adsorption. ALS Metallurgy can perform laboratory scale CIL tests and compare the results with conventional cyanidation. Pilot scale CIL test programmes can also be performed.

Cyanidation – Heap Leach

Column leaching using cyanide solution to assess heap-leaching potential of gold bearing ores can be conducted using columns ranging from 100mm diameter x 1m high to 1.8m diameter x 10m high. All columns are made in-house according to the client/project specifications (for example, sectional columns, one piece units, jacketed for temperature control).

We have expertise with agglomeration tests involving a range of selected additives to bind fine particles in order to improve the percolation characteristics of that sample. Standard percolation tests to optimise the ability of a sample to allow solution through the bed and provide a means of measuring the effectiveness of the agglomeration process can be performed.

Typically, the majority of these tests involve 1.5 – 2.0m high columns of 190mm diameter and can be run in either open or closed circuit configuration. For both circuit configurations, metal can be recovered from the leach solution using an appropriate method (e.g. carbon adsorption, precipitation, solvent extraction, etc.). For re-circulated solutions, reagents are adjusted as necessary.

Larger scale tests using 4m, 6m, 7m, 8m and 10m high columns at the same 190mm diameter can be run. Larger diameter columns up to 1.8m have been tested, although often limitations on the amount of available ore see most clients revert back to the nominal 190mm diameter columns. ALS Metallurgy has also conducted sequential column tests whereby leach solution from one column is used to irrigate a second column in series. Pregnant leach solutions can be passed through activated carbon columns and the regenerated cyanide solution recycled.

Other design data such as heap slumpage and actual percolation rates can be evaluated during the column leach cyanidation testwork.

Flotation

Batch testing can be conducted on refractory ores to optimise flotation performance.

Pilot scale continuous flotation testing can then be conducted to confirm the batch test data and to produce sufficient gold concentrate for refractory testing.

Flotation tests, both batch and continuous piloting, have been conducted to recover sulphide associated gold.
Ref refractory ores

Treatments of various types of refractory ores have been assessed including arsenopyrite, pyrite, and copper sulphide ore.

Roasting

Refractory sulphide ores can be roasted to produce a calcine amenable to cyanidation. A Dorr-Oliver pilot roasting unit is available to study the roasting of sulphide concentrates. Batch muffle tests and batch rotary kiln reactor tests can precede pilot scale testing in a continuous 4 inch continuous fluid bed roaster to establish the influence of gas composition, temperature and the roasting scheme to be used. The calcine products from the roasting oxidation are cyanide leached using conventional methods. Feed material for roasting studies are usually produced by laboratory or pilot scale flotation tests.

Ultra Fine Grinding

Some refractory ores such as those containing pyritic gold can benefit from very fine grinding prior to cyanidation. Several technologies including IsaMill, Metso Verti-mill and Stirred Media Detritor (SMD), Deswik, and Metprotech are available to grind ores or concentrates to as fine as 2-3µm to liberate fine particulate gold.

Gold bearing, Copper-rich sulphide ores

Ores containing soluble copper can have very high cyanide consumption. Ammoniacal cyanidation can dramatically reduce the overall level of cyanide consumption and we can carry out leach tests to optimise reagent conditions. Our expertise covers all aspects of processing copper-rich sulphide ores, from flotation to selective leaching, CIP, elution and fully integrated electrowinning circuits.

BIOX® Oxidation

Our gold laboratory is BIOX® equipped to pre-treat refractory sulphide gold ores such as pyrite, arsenopyrite and pyrrhotite.

Bacterial Oxidation

Several strains of bugs are available for these tests or the bugs inherent to the ore can be cultured for the tests. Batch and pilot scale facilities are available.

Activox® Oxidation

Low temperature pressure oxidation is available for batch to continuous piloting tests.

Cyanide Detoxification

Expertise covering all common technologies including hydrogen peroxide, Caro’s Acid, sulphur dioxide/air, ferrous sulphate to bacterially assisted detoxification.

Carbon Characterisation

All the industry standard carbon tests can be conducted to assist in carbon selection and optimisation, including ASTM ball pan hardness, attrition testing in a rotary tumbler for 24 hours and adsorption testing using gold solutions or slurries with the calculation of kinetic rate constants.

Recovery from solution

Cyanide leach solutions can be treated via carbon adsorption, the Merrill-Crowe zinc precipitation process and electrowinning.

Filtration/Settling

Many ores, particularly those with significant clay content, may exhibit poor filtration and/or settling characteristics. ALS Metallurgy works closely with suppliers of equipment and reagents to conduct batch tests to assess these unit operations in our laboratories.
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