

# GOLD ORE PROCESSING

## SGS MINERALS SERVICES (MINERALS METALLURGY)

SGS Lakefield Orestest Pty Ltd (SGS) was originally founded in 1993 as Orestest Pty Ltd. SGS has since developed into a major metallurgical services organisation located in a purpose-built laboratory in Perth, Western Australia.

The laboratory is dedicated to providing high quality metallurgical testing across the broad spectrum of the minerals industry including:

- Gold ores
- Nickel laterites
- Base metal ores
- Iron ore
- Mineral sands
- PGM ores
- Rare-earths and other exotics
- Diamond ores
- Environmental services



SGS provides a comprehensive range of test work capabilities including bacterial leaching, crushing, screening, grinding, ultra fine grinding, gravity, magnetic & electrostatic separation, solvent extraction, electrowinning, flotation, pressure leaching, pressure oxidation, pressure acid leach and cyanide speciation. Pre-feasibility studies, on-site diagnostic metallurgical services, environmental testing and analytical services are also included in our range of capabilities.

### INTRODUCTION

For the past 100 years the backbone of gold extraction has been the cyanidation process. Over the years steady improvements have occurred in equipment design; milling has evolved from stamp mills, through tube mills and ball mills to the large SAG and FAG circuits we see today. Gravity concentration has also waxed and waned over the years but with the development of modern centrifugal machines, this technique has become ever more popular. The advent of carbon-in-pulp in the early 1980s was probably the single most important technological development over the past 100 years. The recovery of gold from refractory ores has also steadily increased over the past 10 years. Hydrometallurgical processes, like pressure oxidative and bacterial leaching, have in many cases superseded traditional roasting practice.

Processing of gold ores has become a site-specific choice of techniques and processes, depending upon mineralogical, chemical and metallurgical factors. Knowledge of these is important in testwork for any gold operation.

## FACILITIES AT SGS FOR GOLD ORE PROCESSING

Accurate analysis and assaying is critical in any gold test work programme. SGS conducts all solution analyses for gold and silver in-house, as well as carbon assays and gold by aqua-regia digest. Fire assay is conducted by SGS' assay facility in Perth. If required commercial laboratories in Perth can carry out fire assays under a special priority arrangement. Accuracy of all results is continually monitored by a system of standards and external checks.

The main facilities at SGS for evaluating the treatment of gold ores are:

### Mineralogical Analysis

SGS is capable of providing a detailed mineralogical and analytical characterisation of a wide variety of mineral and process samples.

X-Ray diffraction analysis (XRD) is a very useful tool commonly used in determining bulk mineralogical/phase composition of the materials.

QEMSCAN is the latest, most powerful quantitative mineralogical analysis instrument. Consisting of a base scanning electron microscope, equipped with four light element energy dispersive X-ray detectors, a microanalyser and an electronic processing unit designed by Intellection, it is a powerful automated system that can acquire and process vast amounts of chemical, textural and liberation data.

QEMSCAN technology can provide significant input into strategic decisions at the acquisition, exploration, feasibility and operational levels:

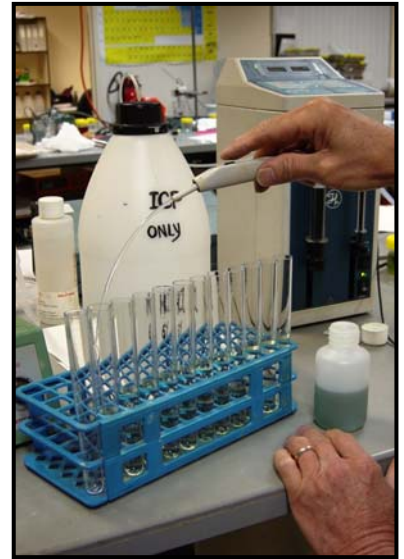
- Mineral Exploration and Resource Delineation - QEMSCAN can map the bulk mineralogy and ore textures throughout a deposit and export this data to 3D imaging software. It can also perform automated trace mineral searches to identify precious or rare minerals like gold. As well, it can provide liberation and grain size data to a geometallurgical mapping database.
- Metallurgical Testing, Operations and Plant Level - QEMSCAN data can provide a detailed snapshot of metallurgical recovery. Through routine auditing, a performance baseline can be established to monitor plant efficiency and enhance life-of-mine economics.
- Closure and Environmental Monitoring - QEMSCAN can assess the composition of waste rock, tailings and soils, and can be used to detect deleterious minerals containing As, Pb, Se etc.

SGS has five QEMSCAN instruments at its state of the art mineralogical laboratory in Brisbane, Queensland.

### Ore Preparation

A range of tests is available for assessing the following parameters:

- Abrasion Index
- Crushing Work Index
- Unconfined Compressive Strength
- Bond Rod Mill Work Index
- Bond Ball Mill Work Index
- JK Drop-weight Test
- SMC Test
- SAG Performance Index (SPI)
- High Pressure Grinding Rolls (HPGR)



High pressure grinding rolls are emerging as an energy-efficient alternative to conventional comminution circuits. SGS provides testing on the Polysius SMALWALL HPGR and also has various crushers and mills, including pilot equipment, available.

### Gravity Concentration

This can be carried out using a range of equipment including jigs (includes Kelsey jig), spirals, tables, Knelson concentrator, Falcon Superbowl, etc. The In-Line Pressure Jig (IPJ) can also be tested by arrangement.

### Cyanide Leaching

- Standard rolling bottle leaching is carried out using 0.25 to 25 kg charges. Larger leaches can also be conducted as required.
- Agitated batch leaching is done using small-scale Lightning mixers. Tanks can be covered to minimise loss of cyanide during sparging with air or oxygen.
- Monitoring is usually carried out at regular time intervals to control pH, cyanide concentration and dissolved oxygen. Samples of solution, solids and carbon can also be taken to measure leach rates.
- Large-scale batch or continuous cyanide leaching (piloting) can be conducted using the wide range of hydrometallurgical pilot equipment available.



### Column / Heap Leaching

The recovery of gold from heaps or dumps, is often seen as a specialty area of gold metallurgy. SGS has built up a solid track record, with well-developed in-house procedures and techniques, and works closely with industry consultants.

Facilities include a large number of column sizes and types including:

- 0.1 m x 1 m columns for preliminary sighter testwork
- 0.15 m x 2 m columns
- 0.15 m x 3 m columns (jacketed for temperature control)
- 0.15 m x 6 m columns (sectional columns in 2 m lengths; temp controlled)
- 0.145 m x 6 m columns (single length columns with provision for sampling at height)
- 0.3 m x 4 m column
- 1.8 m x 8 m column



Column leaching (to assess heap-leaching potential) is conducted using columns ranging from 100 mm diameter x 3 metres high to 1,800 mm diameter x 8 metres high.

Agglomeration is performed to bind fine particles in order to improve the percolation characteristics of that sample. The procedure involves rolling a known quantity of ore and reagents in a drum, adding water as required. The agglomerated material is then allowed to cure in air for 24 to 48 hours.

Column leaching involves barren cyanide solution being pumped onto the ore at the desired flowrate. The solution is monitored for Au, mass, NaCN and pH. The column is monitored on a daily basis. On completion of leaching, the ore is washed and maximum percolation and slump determined. Percolation determines the flow rate of a lixiviant through a sample, and is used to decide whether and to what extent agglomeration is required prior to column leaching.

Recently completed and current projects include:

- Bacterially assisted column leach tests on:
  - Refractory gold ore
  - Refractory gold concentrates
  - Nickel sulphide concentrates
  - Copper sulphide ores
  - Sulphide containing ilmenite
- Acid column leach tests on:
  - Oxide nickel ore
  - Oxide copper ore
- Cyanide column leach tests on:
  - Low grade gold ores
  - High grade silver ores

### Recovery From Solution

Most work carried out involves the use of carbon in leach (CIL) or carbon in pulp (CIP).

- The sequential CIP test is done to assess the rates and extent of gold leaching and loading for new ore types, generating Fleming kinetic parameters "k" and "n".
- The full range of ASTM tests is carried out to keep a check on the quality of new and regenerated carbons, maximising gold adsorption and elution, i.e.:
  - Activity (kinetic parameters "k" and "n")
  - Ball pan hardness
  - Apparent Density
  - Moisture Determination
  - Elution Profile
  - Chemical analysis
  - Attrition
  - Ash content
  - Iodine number

Zinc precipitation tests are also conducted for operations using Merrill-Crowe circuits.

Some new types of resins have been tested as alternatives to carbon in special applications.

### Flotation

Certain gold ores, mainly those containing sulphides, arsenides or tellurides, are best treated by producing a flotation concentrate.

SGS provides comprehensive flotation testing services, from batch through to continuous pilot plant. The dedicated batch flotation laboratory has four fully instrumented bench machines with stabilised voltage supply. A range of fresh reagents is kept in stock, whilst others can be obtained at relatively short notice.



## Filtration/Settling

Many ores, particularly those with significant clay content, may exhibit poor filtration and/or settling characteristics. SGS conducts batch tests to assess these unit operations. A pilot counter current decantation (CCD) circuit is also available. Test programmes are often carried out in conjunction with suppliers of equipment or chemical additives.

## Detoxification

SGS offers testing and consulting services in the area of cyanide detoxification covering all common technologies from alkaline chlorination to hydrogen peroxide, Caro's Acid, sulphur dioxide/Air, DTOX and ferrous sulphate to bacterially assisted detoxification. Cyanide recovery technologies such as AVR and resin and carbon adsorption can also be assessed. SGS Lakefield SGS has an agreement in place to test Inco technology in the Asia-Pacific region.

SGS can assist in the correct choice of detoxification technology by using the extensive experience of its staff in this field.

## General Tests

These include amalgamation, rheological measurements (Bohlin viscometer), thiourea and thiosulphate leaching.

## Refractory Gold Ores

A range of treatment options can be assessed by SGS:

- *Pressure oxidation*: from batch to continuous pilot testing, including the PLATSOL process.
- *Activox<sup>®</sup> oxidation*: a low temperature, low cost version of pressure oxidation, which can also be tested from batch to continuous piloting. In 1997 SGS installed a comprehensive pressure leaching pilot plant.
- *Bacterial oxidation*: both batch and pilot scale tank leach facilities are available using a range of bacteria. An agglomerated heap leach test has also been developed.
- *Bacterial leaching*: an independent assessment of the potential of bacterial oxidation can be carried out using tank leaching and agglomerated column leaching. SGS has developed a novel agglomeration technique for low-grade concentrates or ores.
- *Roasting*: small scale testing in a muffle furnace or rotary kiln is carried out.
- *Ultra-fine milling (UFM)*: some pyritic ores contain fine particulate gold that is liberated by UFM below 20 µm. UFM is carried out using stirred mills and accurate power requirements can be measured.
- *Copper-rich ores*: testwork are performed on all aspects of the processing of copper-rich ores, from flotation to selective leaching, CIP, elution and electrowinning (EW). SGS Lakefield Orestest has particular expertise in cyanide recovery and detoxification by Caro's acid, SO<sub>2</sub>/O<sub>2</sub>, SART, AVR, EW and others.



## Gold Processing Testwork

- Cyanidation leaching of free-milling ores has been carried out for most major operations in Australia.
- Treatment of various types of refractory ore have been assessed, e.g.,
  - Arsenopyrite
  - Pyrite
  - Copper sulphide and oxide
  - Telluride
- Pre-treatment testing has included:
  - Roasting
  - Pressure oxidation
  - Activox
  - Bacterial oxidation
  - Ultra-fine milling
  - Ammoniacal cyanidation, etc.
- Column leaching (heap leaching) tests have been conducted including pre-oxidation with bacteria.
- Gravity concentration programmes have included the use of tables, jigs, centrifugal bowl (Knelson and Superbowl), spirals, hand panning and amalgamation.
- Flotation tests, both batch and continuous piloting, have been conducted to recover sulphide –associated gold.
- Consulting on gold processing.

SGS staff have been involved in a broad spectrum of consulting work in the field of gold processing, including;

- Technical audits.
- Cyanide consumption and deportment studies.
- Diagnostic leaching as a tool to identify sources of possible gold losses.
- Enhancing gold recovery from preg-robbing ores.
- Testwork program development and interpretation.
- Feasibility studies.
- Plant design.
- Plant commissioning.
- Process plant management.

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