Mineral Sands Process Development
Metallurgical Testing Capabilities
Without **ilmenite** and **rutile** there would be no snow-white paints and airplanes; without **zircon** no control rods for nuclear reactors; without **tantalite** no transistors; and without **cassiterite** no tin cans. Some heavy minerals are **not easily substituted** and only available in a few countries. Many of them are thus very **valuable and rare** – wars have been and are still being waged because of them.

- HARALD ELSNER
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.
Introduction to Heavy Minerals

Heavy minerals are defined as minerals having a higher density than quartz (density above 2.65 g/cm³). The most commonly occurring Heavy Minerals are: Ilmenite (FeTiO₃), Leucoxene (pseudorutile), Rutile (TiO₂), Zircon (ZrSiO₄), Monazite [(Ce,La,Nd,Th)PO₄], Xenotime (YPO₄), Kyanite (Al₂SiO₅), Sillimanite (Al₂SiO₅), Andalusite (Al₂SiO₅), Staurolite [(Fe,Mg,Zn)₂Al₉(Si,Al)₄O₂(OH)₂], Garnet [(Ca,Mg,Fe,Mn)₃(Al,Fe,Cr)₂(SiO₄)₃], Chromite (FeCr₂O₄), Magnetite (Fe₃O₄), Cassiterite (SnO₂), Columbite-Tantalite (Coltan, Fe⁺⁺Ta₂O₆), Wolframite [(Fe,Mn)WO₄] and Scheelite (CaWO₄).

They are used in the manufacture of very important construction and industrial products.

ALS Metallurgy has a fully integrated mineral processing laboratory. Our facilities are located in Balcatta and Wangara with over 300 technical staff. ALS has established a reputation as the leaders in Iron Ore, Gold and Flotation optimisation and process development.

Every deposit is unique and processing of the orebody would require high recovery equipment necessary to achieve maximum efficiency. This of course, requires an optimum amount of metallurgical and engineering data before the process concept is finalised.

ORE CHARACTERISATION

Mineralogy
* QEMSCAN and XRD

Wet Liquid Separation (HLS)

XRF

Sizing (PSD)

Specific Gravity (SG)

MINING UNIT PLANT

Wet Scrubbing (clay balls and indurated HM)

Wet and Dry Screening

De-slimming

Hydro-cyclones

WET CONCENTRATOR

Gravity Separation
* Willey (Wet) Table

Wet Magnetic Separation
* LIMS

Thickening

Flocculant selection

Cylinder settling tests

MINERAL SEPARATION PLANT

Magnetic Separators
* PERMROLL Mag Separator

* READING Mag Separator

* CARPCO Mag Separator

* FRANTZ Mag Separator

* Electrostatic Separators

* CoronaStat HTR

* UltraStat HTP

* Froth Flotation

* pyrite extraction

Figure 1. Typical Flowsheet for Mineral Sands test-work program.

Liberation and Comminution

ALS Metallurgy offers a comprehensive range of equipment to liberate the valuable minerals.

Depending on the degree of liberation, the lab scale and pilot scale scrubbers (including ISO Style) could be used to process samples from a few kilograms to many tonnes.

Jaw and Cone crushers are used for sample preparation (i.e. size reduction) work. Ore hardness testwork is also carried out in comprehensive state of the art comminution testwork facility.

Screening is carried out on vibratory and gyratory screens as well as on revolving screens (Trommel).

Mechanical classifiers (i.e. spiral and rake classifiers) are used when the particle sizes are considered to be too fine for screening.

Hydro-cyclones (Cyclones) are used for de-slimming, de-gritting and thickening to separate at finer sizes than most screening and classification equipment.

Separation and Concentration

ALS Metallurgy employs a number of different techniques to separate and concentrate the valuable mineral. These techniques utilise differences in physical or chemical properties of the valuable and gangue (waste) minerals.

i. Gravity Separation - based on the difference in specific gravity (SG) of the valuable mineral to gangue and the carrying medium such as water.

ii. Magnetic and Electrostatic Separation – based on natural or induced differences in magnetic susceptibility or conductivity of the minerals.

iii. Froth Flotation – based on the surface chemistry properties of a mineral. The natural or modified surface property of the mineral determines its ability to attach to an air bubble and float to the surface.

Depending on the volume of samples (from a few kilograms to 1-2 tonnes) high or low capacity gravity equipment can be used.
**Spiral Concentrator**

ALS Metallurgy offers a spiral pilot plant which includes a scrubbing, screening and slurry preparation circuit. The pilot plant has been designed to meet a wide range of operating conditions (i.e. different size of feed particles, pulp density and flux rate).

ALS Metallurgy stocks a range of spirals that could predominantly be used as a Rougher, Cleaner or Scavenger. The selection of the spirals could be based on the feed grade, particle size distribution and specific gravity. The development data for a new Wet Concentrator Plant or optimizing data for the existing plant could be obtained by simulating its performance. The quality and accuracy in carrying out the spiral pilot test work will provide our clients with reliable results.

![Figure 2. Process Flow Diagram for the Spiral Pilot Plant - ALS Metallurgy.](image)

**Wilfley Shaking Table**

The Wet Shaking Table separator is the oldest mineral processing method used to determine the maximum gravity recovery and it is used to separate the samples into light and heavy-mineral fractions provided that there is a marked difference in the density of the minerals. Due to its low capacity (a few kilograms), the shaking table is typically used as a Cleaner for final upgrading of gravity concentrate produced from centrifugal concentrators, jigs and spirals.

The shaking action causes the grains to be arranged according to their density; the heaviest and coarsest particles move to one end of the table while the lightest and finest particles tend to wash over the riffles and to the bottom edge of the table.

![Figure 3. Principal of operation of the Wilfley shaking table.](image)
Heavy Liquid Separation

This type of gravity separation is also known as “sink-float” separation. The heavier particles will sink and effect sharp separation of the heavy and light particles. In practice, the dense media (i.e. bromoform at 2.84-2.89, tetrabromomethane at 2.94, or lithium heteropolytungstates at 2.85) are used in the laboratory to sink those minerals and separate them from the lower density group minerals e.g. most mica minerals, dolomite, aragonite, anhydrite, magnesite and quartz, called light minerals.

ALS Metallurgy can further separate the heavy minerals by using diiodomethane at 3.32 or thallium malonate formate (aka Clerici’s solution) at densities up to 4.4, or on a larger scale utilising gravity separation methods such as spiral, jigs, wet tables, or air tables or by exploiting their magnetic and electrical properties to separate at varying magnetic field strengths or using electrostatic separators produce more or less pure products.

Products can be analysed using X-ray Fluorescence to determine chemical makeup and the mineralogy can be determined using techniques such as X-ray Diffraction and QEMSCAN.

ALS Metallurgy can utilise all of the techniques to assist at all stages of the project from initial exploration through to process design and plant optimisation.

Hydro-cyclone preconcentration

ALS Metallurgy uses hydrocyclones for both classification of material into separate sizes and to enrich heavy mineral. This is a typical gravity or centrifugal concentrating process where ores are in the fine size range.

Magnetic and Electrostatic Separators

The above-mentioned separation methods could remove more than 90% of the original sample volume. ALS Metallurgy operates several Magnetic and Electrostatic Separators (including: PERMROL, CARPCO, HTR and HTP CORONA STAT separators). They are used to distinguish and extract magnetic, slightly magnetic and non-magnetic components present in the heavy fraction (Rutile, Ilmenite, Magnetite, Garnets, Zircon and Monazite) and to separate conducting (Rutile) from non-conducting (Zircon) minerals. The service of Western Process Equipment (WPE) could be used to secure additional RE Roll and RE Drum magnetic separators for small scale and pilot separations at medium to high magnetic field strengths.

All minerals have one of three magnetic properties: ferromagnetic, paramagnetic and diamagnetic. Ferromagnetic minerals (i.e. Magnetite and Ilmenite) are magnetic and easily attracted to the poles of magnet. Paramagnetic and diamagnetic minerals are not magnetic, but if the mixture of paramagnetic and diamagnetic minerals is passed through a magnetic field: the paramagnetic minerals will be pulled into the field and diamagnetic minerals will be separated from the field. By varying the intensity of the magnetic field it is also possible to separate different paramagnetic minerals from each other.
Froth Flotation

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

Flotation testwork is carried out using Agitair and Denver cells and is performed by trained, experienced metallurgical technicians to ensure consistent, reliable results.

Today froth flotation remains the separation process of choice for most sulphide deposits (e.g. Pyrite FeS₂), and an increasing number of other minerals.

Bench flotation test programmes are commonly designed to consider the following parameters: flotation kinetics, grind size, reagent selection and optimisation, selective flotation (complex sulphides), pulp potential and flowsheet design.

Flotation is a physical-chemical process carried out in agitated tanks (cells). The surface properties of the slurry are chemically modified by adding reagents (collectors, frothers, modifiers) to generate air bubbles.

Mineralogical Services

A thorough understanding of the mineralogy of the ore is crucial to the success of any beneficiation test work programme. The leading edge mineralogy services include QEMSCAN, X-ray diffraction (XRD) and optical microscopy. The highly experienced team of mineralogists and technicians work closely with the metallurgists to provide an integrated solution for the client. When performed during 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.

Assay Laboratory

With a state-of-the-art analytical laboratory on-site at our metallurgical facilities ALS Metallurgy can perform an extensive range of analysis techniques. Results are continually monitored by a system of QA/QC standards and external “Round Robin” checks. The Analytical Facility at ALS Metallurgy in Balcatta has recently added a Minerals Sands Program to the XRF suits available.
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