

SGS STATEMENT OF CAPABILITIES FOR IRON ORE

SGS MINERALS SERVICES' METALLURGICAL EXPERTISE IN THE IRON ORE INDUSTRY

SGS is an international testing, inspection and certification company. We deliver cost effective, practical processing solutions to the global mineral industry. We have earned our reputation for market leading mineral processing services. For the iron ore exploration and mining industries, SGS Minerals Services provides a comprehensive range of testwork services. Our extensive global network of laboratory and metallurgical testing facilities support most of the processes that are used in the exploration and treatment of iron ore.

Here, we describe in detail the metallurgical services SGS routinely provides to the iron ore mining market. At the broadest level, these include:

- Metallurgical testing at the bench or pilot scale:
 - Geometallurgy highlighting ore variability.
 - Comminution testing, modeling and circuit specification.
 - Physical mineral separation/beneficiation including gravity, magnetic and electrostatic separation and flotation.
 - Hydrometallurgical (chemical) separation including leaching (atmospheric and pressure leaching using autoclave), S/L separation, ion-exchange, solvent extraction and electrowinning.
- Flowsheet development and pilot plant testing.
- High definition mineralogy by QEMSCAN, electron probe, image analysis and XRD.
- In-plant support including audits, plant benchmarking, optimization and metallurgical accounting.
- Production forecasting using geometallurgical principles

METALLURGICAL TESTING

GEOMETALLURGY: UNDERSTANDING ORE VARIABILITY

Ore variability impacts on plant performance and therefore has direct financial implications. Geometallurgy significantly reduces the impact of spatial uncertainty in mine planning because it documents the variability in a deposit. The geometallurgical approach uses a six stage "Geometallurgical Framework" to group activities. These stages are:

- Stage 1 – Multivariate Spatial Domain Definition
- Stage 2 – Sample Selection
- Stage 3 – Parameter Determination (Testing)
- Stage 4 – Multivariate Model Definition
- Stage 5 – Multivariate Spatial Model Generation using the Block Model or Mine Plan
- Stage 6 – Joint Mining and Mineral Processing Optimization

In Stage 1, regions (domains) of like characteristics are defined. Then, in Stage 2, a number of test samples are chosen, based on geological data. The metallurgical parameters or data are collected in Stage 3. These parameters are then distributed through an orebody using accepted geostatistical techniques in Stage 4. The geometallurgically-enabled mathematical models are used to generate economic parameters such as throughput, grind size, grade and recovery. The data can then be modeled with respect to cash flow and future mining strategies in Stages 5 and 6.

A geometallurgical approach lowers project risk by enabling:

- Rigorous documentation of geological and mineralogical factors that impact on metallurgical performance and grindability
- Plant design that recognizes the inherent variability of the deposit

- Forecasting of production parameters such as plant throughput, grade, recovery, P80 and concentrate grade on a quarterly or yearly basis, with a statistical confidence interval
- Optimization of plant performance with respect to ore variability
- Effective mining of the ore over the entire mine life
- Optimized mine resource and plant performance
- Maximize the Net Present Value whilst minimizing risk.

SELECTED GEOMETALLURGICAL EXPERIENCE IN IRON ORE

COMMINUTION

SGS Minerals Services supports the minerals and chemical industries in the design and operation of efficient crushing and grinding circuits using both power and model-based methods. We design circuits and provide operating advice to maximize milling efficiency, considering both steel and power consumption. Our practical experience also ensures that we recommend circuit configurations that offer ease of operation and maximum flexibility.

SGS Minerals Services' metallurgists have experience in operating SAG mill plants and have operated over 500 pilot-plant SAG circuits. This hands-on experience fosters a practical view of the design and operation of grinding circuits.

We have experience in many modeling techniques, including the model-based approach and the empirical power-based approach, using the Bond and autogenous grindability tests. All data is analyzed and related to previous testing

results. We compliment the JKTech models with mass-balancing, using the Bilmat program. We suggest that the most robust results are obtained when more than one approach to grinding circuit testing and design is used.

SGS Minerals Services can complete the following grindability tests:

- SPI (Sag Pressure Index) Test
- Bond Ball Mill Grindability Test
- Bond Impact Test
- Abrasion Test
- SPT (Static Pressure) Test
- JK Drop-Weight Test
- MacPherson Autogenous Grindability Test
- MacPherson 18" Mill Test

Well-instrumented pilot-scale autogenous grinding circuits, ball and rod mill circuits, and crushing circuits are also available for testing and design purposes. In-plant audits allow modeling and simulation of existing plants to assist in optimization. Rotary scrubbers and attrition scrubbers are available to test lateritic iron ores.

PHYSICAL MINERAL SEPARATION / BENEFICIATION

Separation of certain minerals can be efficiently achieved by taking advantage of their physical, electrical and magnetic properties. For example, iron ore, mineral sands, coal, and diamonds are some minerals that use at least one of these extraction processes. The product can then be further upgraded by chemical (hydrometallurgy) or high-temperature techniques (pyrometallurgy).

All physical separation techniques can be tested at SGS, both on laboratory scale and pilot plant scale. The commonly used beneficiation techniques follow:

- **Gravity Separation**
Spirals are the most practical equipment to use for gravity separation of iron ores because of the high throughputs needed. SGS has a variety of spiral test rigs, including the spiral designs typically used in iron-ore plants. Our accessory equipment allows sizing of feeds, multiple spiral stages, and recycling of products. Other gravity separation equipment,

CLIENT	DEPOSIT	LOCATION	COMMODITY	ACTIVITY
Crosslands Resources	Jack Hills Expansion Project	Australia	Fe (magnetite)	Geometallurgy.
CVRD / Vale Inco	Cauê	Brazil	Fe	FLEET benchmarking sites and circuit optimization projects.
Northland Resources Inc.	Hannukainen	Finland	IOCG – Fe, Cu, Au	Geometallurgy and EXPLOMIN.
Northland Resources Inc.	Stora Sahavaara	Sweden	IOCG –	Geometallurgy and EXPLOMIN.
Australian Bulk Minerals	Savage River Mine	Tasmania	Fe	Grinding circuit benchmarking study, CEET productions forecast runs and optimization study.
BHP / CVRD	Samarco	Brazil	Fe	FLEET benchmarking sites and circuit optimization projects.
Cleveland Cliffs	Tilden	USA	Fe	FLEET design, FLEET benchmarking sites and circuit optimization projects.
Iron Ore Company of Canada	Carol Lake	Canada	Fe	Geostatistics study.

Selected Geometallurgical Experience from over 120 projects

such as shaking tables, Falcon and Knelson centrifugal separators, Mozley MGS units, and hydrosizers, are also available.

- **Magnetic and Electrostatic Separation**
A full range of magnetic separators is available for iron ore testing, from low intensity drum separators to high gradient/high intensity separators, and for either wet or dry feeds.
- **Flotation**
Reverse flotation is commonly used to remove silica and/or phosphate from hematite-magnetite ores. SGS Minerals Services has strengths in both conventional cell and column flotation methods.
- **Selective Flocculation**
Although not commonly used, selective flocculation has been successfully piloted at SGS Minerals Services to remove silicate minerals from iron ores.

HYDROMETALLURGY

Hydrometallurgy is concerned with the principles and practice of the aqueous extraction of metals from natural or recycled resources and their subsequent recovery into useable products by means of environmentally sound and cost effective processes. Leaching rates, reagent consumption, temperature requirements and gas/pressure requirements can be determined through hydrometallurgical leaching test work including bench-scale autoclave work.

Conducting metallurgical leach testing can provide an indication of reagent costs, equipment requirements, indication of metallurgical amenability to leaching and also provide environmental considerations due to deleterious elements or even ARD. While hydrometallurgy is not regularly used in iron ore processing, SGS' expertise can be used perform this work on a laboratory and pilot scale.

FLWSHEET DEVELOPMENT AND PILOT PLANT TESTING

FLWSHEET DEVELOPMENT

SGS Minerals Services' experienced team of metallurgical professionals develop and demonstrate bankable flowsheets and processes for environmentally sustainable metal and mineral extraction processing. These flowsheets are confirmed on-site through bench and pilot plant testing programs that are internationally recognized by the mining, engineering and financial communities.

Developing the most effective processing flowsheet reduces the technical risk. Alternative options can be assessed and a conceptual flowsheet developed which is then tested and optimized. Changes in ore-type, technology or environmental regulations can mean that existing plants must adapt their flowsheet strategies.

PILOT PLANT TESTING

Pilot testing is the best way to reduce risk associated with a new flowsheet or flowsheet changes. It will generate the data needed to design the full scale plant. As well, existing operations can be simulated at the pilot scale to evaluate new technologies or address problems without interrupting production. In a pilot plant, the actual process is constructed from appropriately sized equipment and the testing involves virtually all of the issues that a full processing plant will have to deal with.

SGS employs engineers having a combination of operating plant experience and laboratory/piloting experience. This is a rare combination in the industry and provides a much broader experience base than those that have exclusive exposure to either operating plants or laboratory/piloting testing.

CLIENT	DEPOSIT	LOCATION	COMMODITY	ACTIVITY
Wiluna Gold Mines	Wiluna	Australia	Au	BIO, lab., PP, CPC, PGR
Barrick Gold Corp.	Pascua	Chile	Cu / Au	BIO, lab.,
Kinross Gold Ltd.	Hoyle Pond	Canada	Au	BIO, lab., FLT, POX, CND
Cogema Resources	Hudson Bay Mining	Canada	FeS	BIO, lab.
Western Mining	Mt Keith	Australia	Ni	BIO, lab., COL, GCL
Barrick Gold Corp.	Golden Ridge	Tanzania	Au	BIO heap, lab., FLT, POX, CND
Riddarhyttan (GFL)	Suurikuusikko	Sweden	Au	BIO, lab., PP
ISCOR	Rosh Pinah	Namibia	Zn	BIO, GCL, CIL

Selected Hydrometallurgical Experience from over 45 projects.

Typical activities that can be undertaken during pilot testing include:

- Establish flowsheet viability. This is especially important for complex deposits, those utilizing new or unusual technologies or projects that are located in high risk areas
- Fine-tune flowsheet parameters
- Demonstrate continuous integrated operation
- Evaluate the impact of local water supply
- Develop a water balance
- Quantify the impact of ore variability
- Produce byproducts for specialized testing (e.g. environmental assessments)
- Generate bulk samples for market evaluation
- Train critical mill staff

SGS Minerals Services has run over 20 semiautogenous grinding (SAG) and metallurgical pilot plants on iron ores, including extremely large plants treating up to 1,000 tonnes of ore and lasting for 6 months. Many complex circuits using autogenous grinding, de-sliming,

magnetic separation, gravity separation, selective flocculation, and flotation have been run in our laboratories. Smaller pilot plant operations have been set-up on-site in major operating plants to test specific operations such as flotation, gravity separation, and thickening.

HIGH DEFINITION MINERALOGY

Most beneficiation plants separate the valuable minerals from the waste minerals by physical means. Understanding the mineralogy is paramount for this activity. Understanding how the ore and gangue minerals behave in the metallurgical processing requires qualitative and quantitative knowledge of ore and waste minerals present and their textures and associations.

SGS Minerals has X-Ray diffraction, electron microprobe microscopy, QEMSCAN, image analysis and optical microscopy available to provide objective data. Automated QEMSCAN mineralogy can be used for iron ore as it can examine a large amount of particles and can therefore provide statistically meaningful

quantitative data. In addition, it produces digital data, which can be sorted using a computer program. For instance, it is possible to sort the particles by their specific gravity, based on the specific gravity of the minerals making up the grains. The advanced characterization available from the SGS network facilities provides the following advantages:

- Characterisation of raw materials
- Selection of suitable raw materials
- Comparison of different ore types
- Quality control of raw materials
- Identification of deleterious elements
- Monitoring of product consistency and quality

In addition to basic compositional analysis, SGS can provide comprehensive analytical overviews of mineralogical characteristics and their influence on metallurgical properties including:

- Reduction Disintegration Index (RDI)
- Tumble Index (TI)
- Reducibility Index (RI)
- Cold Strength

IN-PLANT SUPPORT

Operational improvements can improve grade, recovery or create maintenance or other time efficiencies. SGS Minerals Services can work with you to:

- Thoroughly evaluate your on-site operations without bias or special interest so you can access the best available technology
- Give you innovative workable alternatives to bottlenecks in your plant
- Provide short-term metallurgical commissioning assistance during start-up
- Assist with training or provide resources to assist with transitions.

From periodic technical auditing to troubleshooting to complete on-site daily metallurgical management, SGS Minerals Services can support on-site operations. Whether it's initiating a new project, re-starting an old mill or maximizing your performance from an existing mill, we are able to provide world-class technical support to ensure constant optimal mill throughput and metallurgy. SGS Minerals

CLIENT	DEPOSIT	LOCATION	COMMODITY	ACTIVITY
British Steel	Wadi Sawawin	Saudi Arabia	Fe	SAG Power Index testing
New Millenium Capital Corp.	LabMag	Canada	Fe	Pilot Plant testing of grinding, magnetic separation and flotation
Northland Exploration	Stora Sahavaara	Finland	Fe	SAG, Pilot Plant testing of magnetic separation and flotation
Iron Ore Company of Canada	Labrador	Canada	Fe	Flotation test work and training to IOC operators
Rio Tinto	Simandou	Guinea	Fe	Screening, desliming, settling and filtration

Selected Iron Ore Pilot Plant Experience from over 20 projects.

Services can support your operation in a way that best suits your needs and budget.

SELECTED ON-SITE IRON ORE PILOT PLANT PROJECT EXPERIENCE

AUDITS & OPTIMIZATION

SGS routinely provides audit and optimization programs for existing grinding circuits to ensure maximum efficiency. Working directly with your plant staff to understand the practical aspects of your operation, we will review of your mine plan and historical data analysis and perform on-site testing and evaluation.

The scope of each project is different and tailored to the owner's request. Some of the many in-plant testing projects SGS has performed include:

- Start-up of the Caribou Pb-Zn concentrator
- 3-month optimization program at the Impala PGM beneficiation plant

- Full plant audit of the KGHM copper beneficiation plant
- Flotation sampling campaign at the Tilden iron ore concentrator.

SGS can support:

- **Materials Handling and Product Testing**
Treatment of many iron ores is straightforward - crush and screen. Sometimes this is extended to include scrubbing, grinding and pelletising. Quality control is the main concern in most plants, and SGS can assist with sampling, size analyses, chemical analysis, and other standard tests. When slurry or material flow is critical, thickening and filtration studies and rheology assessments can be performed, on in-plant streams or samples shipped to our facilities.
- **Audit to Improve Metallurgical Performance**
In more complex plants, a metallurgical audit can often indicate where improvements in plant performance can be achieved. For instance, a mineralogical study

of various plant streams using techniques such as QEMSCAN or image analysis can highlight liberation problems, or areas with poor recovery. Improvement studies can then be focused in these areas. If necessary, samples can be taken and metallurgical studies performed on-site and at our facilities. We use the equipment and reagents in the plant, or assess alternative reagents or techniques. If necessary, we can make improvements in an on-site pilot plant using a small feed stream taken from the critical part of the operation.

- Audit to Increase Plant Throughput**
Increasing plant throughput often improves profitability. Audits of the grinding and flotation areas can help address this. Throughputs in the flotation area can be improved by reducing recycle loads, flotation rates or magnetic or gravity separation performance. This may be achieved by changing reagent regimes, improvement of feed particle size, and better control of pulp densities.
- Grinding Studies**
Grinding is usually one of the more prominent bottlenecks in plant activities. SGS Minerals Services can perform detailed grinding studies, using both power-based methods, and simulation-based methods to help yield increased throughput, and/or improve fineness-of-grind.
- Pelletizing**
A one-meter disc pelletizer is available for pelletizing testwork of fine iron ore products.

METALLURGICAL ACCOUNTING

Metallurgical accounting is an ongoing process that involves sampling, analyzing and accounting for the metal that enters and exits your metallurgical plant. Just as monetary accounting provides the necessary framework for financial decisions, met accounting provides the diagnostic information required for effective metallurgical decisions, and informed marketing, sales and corporate planning.

CLIENT	COUNTRY	ACTIVITY
USS Minntac	USA	Flotation audit, Circuit redesign and engineering, Commissioning and pilot plant
Warbush Mines	Canada	3-week on-site column pilot project
Samarco	Brazil	2-week on-site pilot plant project, MET Advanced control needs analysis, FLEET® Benchmarking
CVRD – Conceicao	Brazil	Flotation audit and detailed column scale-up, 2-week on-site pilot plant project
Sydvaranger	Norway	On-site column pilot plant project, Two stage circuit commissioning, Spargers and control system for flotation circuit

Selected On-Site Iron Ore Pilot Plant Project from over 20 projects.

Properly designed met accounting procedures are a powerful tool that can provide insight and remedial measures for:

- Production variability
- Unexplained material losses and gains
- Process inefficiencies
- Production forecasting problems.

Our staff are independent process experts with extensive testing and plant expertise. They have the ability to establish and optimize your met accounting process to ensure your metal throughputs meet corporate requirements.

CASE HISTORY – TILDEN MINE, CLIFFS NATURAL RESOURCES INC.

The staff at the Tilden iron ore concentrator wished to reduce the silica content of their iron ore product. A high silica content in the ore reduces saleability of the iron ore product. Reducing the silica content can significantly improve the economic viability of a project. To achieve this, the company asked SGS to explore the benefit of installing flotation columns in Tilden’s silica flotation circuit.

SGS visited the plant to determine the sampling requirements and perform the sampling. During the plant visit, SGS performed flotation tests and with the resulting data, developed a computer simulation of the flotation process. At the same time, QEMSCAN mineralogy was performed on the samples to provide a better understanding of the mineralogy

of the ore. SGS then combined the computer flotation simulation and QEMSCAN data to show that there would be little benefit to using column flotation in the Tilden plant.

SGS’ expertise allows us to provide comprehensive audit, troubleshooting and coordinated retrofit or redesign of plant operations. You can depend on us to ensure effective solutions to your development and production challenges. Our combination of plant and laboratory expertise, process understanding, modeling capabilities and mineralogical abilities result in significant operational and financial benefits to the client.

PRODUCTION FORECASTING USING INTEGRATED GEOMETALLURGICAL SIMULATOR (IGS)

SGS Minerals Services has extensive experience using geometallurgical technology for production forecasting applications. The application of geometallurgical technology to production forecasting results in a more rigorous and reliable forecast. Geometallurgical production forecasts consider geological, metallurgical, mineralogical and chemical influences on recovery, instead of simply relying on chemical assays.

IGS simulates comminution and flotation circuits either separately or as a combined process. Using previously determined results from bankable SGS comminution and metallurgical testwork, IGS enables you to easily see how changes made to any part of your grinding or flotation circuit

will affect your overall performance. The data highlights times of smooth operation and periods when production will experience challenges, giving operational staff time to address these challenges and minimize the effects on productivity and profitability.

SGS enables a geostatistically sound mill and flotation circuit design with optimized equipment selection and an accurate prediction of power consumption. Capital investment and production planning decisions can thus be based on well-defined representative data sets representing the block model. IGS links the grinding and flotation circuit design models with the mine resource block model to:

- Ensure throughput tonnage targets are consistently achieved
- Determine best circuit design for the ore body and mine plan
- Improve revenue-stream predictions for both budgeting and metal sales
- Optimize the mine plan for throughput and grind and flotation quality
- Minimize capital investment & operating costs for desired production rates
- Trade off capital investment with variance in throughput
- Quantify uncertainty arising from throughput predictions

Upon downloading the IGS software, you can draw and configure your circuits based on two data types:

- Operational data: This is day-to-day information that you gather from your plant.
- Ore characterization: These are the input parameters determined from your samples using SGS testwork.

Required tests vary according to your specific requirements. SGS provides training workshops to teach you how to use IGS software. These include interpretation and validation of the results.

CASE HISTORY – CAROL LAKE, IRON ORE COMPANY OF CANADA

Recently, SGS Minerals Services completed a successful seven year program of forecasting throughput of the autogenous milling circuit at Iron Ore Company of Canada's (IOC) Carol Lake iron ore concentrator. Work started with audits of the grinding circuit in 2001 and benchmarking of the data collected from samples of mill feed and plant operation to the CEET mill design and throughput forecasting model. The obvious benefits to the mine and plant operators include:

- Improved ore body definition
- Optimized mine planning
- Consistency of ore hardness delivered to the plant
- Better stockpile utilization
- Reduced downtime loss
- Improved seasonal operation
- Reduced shipping costs
- Improved inter-departmental relationships

REFERENCE

Bulled. D., Leriche. T., Blake. M., Thompson. J., Wilkie. T. – 2009- Improved Production Forecasting through Geometallurgical Modeling at Iron Ore Company of Canada - 41st Annual Meeting of the Canadian Mineral Processors- SGS 2009- , pages 279-295- Proceedings of the CMP Annual Meeting, Ottawa , Canada

SUMMARY & CONCLUSIONS

SGS Minerals Services uses a step-by-step approaches to iron ore production to turning our expertise into profitable plant performance. Our areas of expertise in iron ore include extensive understanding of:

- Ore variability
- Mineralogy
- Metallurgical testing
- Chemical analysis
- Flowsheet development
- Piloting (either on-site or at our facilities)
- Product testing
- Plant improvements in materials handling or operations

SGS offers you the unique advantage of combined skill sets and industry expertise that you won't find anywhere else. The wide range of services we offer to the iron ore industry help to maximize the economics of the operation, ensuring higher product quality, improved recovery, reduced costs and greater revenue.

SGS Minerals Services can help to:

- Improve production throughput
- Optimize safe operations
- Reduce costs
- Enhance product quality
- Increased revenues.

CONTACT INFORMATION

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