

# HIGH DEFINITION MINERALOGY ANALYSIS

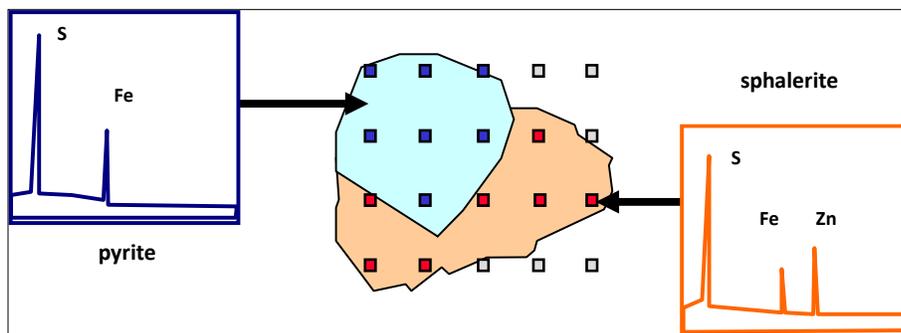
## QUANTITATIVE EVALUATION OF MATERIALS

High-definition mineralogy is the quantitative study of minerals, using technologies such as QEMSCAN, X-ray diffraction analysis (XRD), image analysis and other techniques which are automated. High-definition mineralogy provides the user with the ability to truly balance the minerals in an ore or a process, in the same way that assay data is used to balance the elements in an ore or process. Thus high definition mineralogy is therefore the only quantitative way to truly assess mineralogically how a process is working.

The QEMSCAN™ instrument is the newest, most powerful process mineralogical instrument currently available to the minerals industry. The QEMSCAN™ instrument is a proven and powerful automated system that can acquire and process vast amounts of chemical, textural and liberation data.

SGS' High Definition Mineralogy can provide significant input into strategic decisions at the acquisition, exploration, prefeasibility, feasibility and operational levels:

- Mineral Exploration and Resource Delineation High Definition Mineralogy 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 High Definition Mineralogy 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. High Definition Mineralogy assesses the composition of waste rock, tailings and soils, and can be used to detect deleterious minerals containing As, Pb, Se etc.

The instrument also calculates the weight distribution of each mineral, based on the acquired spectral data and published mineral densities.

## DATA OUTPUT

Particle maps (below top) graphically illustrate mineral liberation and intergrowth textures. Mineral abundance (below right) or liberation by size fraction is plotted to reveal metallurgical recovery trends. Calculated sample compositions (bottom) compare favourably with independent chemical analyses.

## RHEOLOGICAL PROPERTIES

Coking coals possess the ability, when heated in the absence of air, to soften, swell and then re-solidify to form a coherent, porous, hard coke structure. The Gieseler Plastometer and Arnu Dilatometer tests are used to evaluate the rheological or plastic properties of a coal or coal blend.

### GIESELER PLASTOMETER TEST

For this analysis, 5 grams of minus 40 mesh prepared coal are packed into a retort barrel along with a stirrer. A constant torque is applied to the stirrer and the coal is heated at 3°C/minute. As the coal softens, the stirrer begins to turn. The maximum fluidity value is expressed in dial divisions per minute (DDPM) of the stirrer rotation.

- High volatiles: 5,000 to >30,000 DDPM.
- Medium volatiles: <200 to 20,000 DDPM.
- Low volatiles: 20 to 1,000 DDPM.

The Gieseler Plastometer test is useful in determining the plasticity range of coals including the temperature at which: initial softening, maximum fluidity, and resolidification occurs. Plasticity range in OC and maximum fluidity in DDPM are key factors in determining which blends of coals will be optimal for coking.

### ARNU DILATOMETER TEST

The Arnu Dilatometer test is used to determine the swelling properties of coal when heated under standard conditions in a dilatometer. A thin 60 mm cylinder of coal formed under pressure from minus 60 mesh coal is inserted into a precisely calibrated retort tube with a graduated piston on top. The sample is then placed in a furnace. The apparatus is heated at 3°C/minute and the movement of the piston as the coal cylinder shrinks and expands is recorded.

The maximum dilatation value is the key parameter and for individual coals, the highest value possible is considered optimal:

- High volatiles: +50 to >300%.
- Medium volatiles: +100 to 250%.
- Low volatiles: <0 to 200%.

Characteristic Arnu Dilatometer curves are generated when the piston movements (taken as a percentage of the total original coal cylinder length) are plotted against the corresponding temperatures. These charts provide valuable information regarding the suitability of your samples for use as coking coals.

### SAPOZHNIKOV TEST

This test is performed in accordance with GOST 1186. It is the main test in Russian and Ukraine for determination of the coking properties of the coal. 100 g of 1.6 mm sample is placed into the steel cylinder. Sample is pressed with the help of the piston and a prescribed weight. Heating is performed from the bottom (3 0C per min.). Temperature is measured on the bottom with thermocouple. Over the temperature range 350 – 650 0C the lower and higher level of the plastic layer are detected with a needle and measured with a ruler. Y value (in mm) is determined as maximum thickness of the plastic layer.

Thickness of the coal briquette is measured during analyses. Correlation of the briquette thickness via temperature is plotted as a plastometer curve.

### CARBONIZATION TESTING

Pilot scale carbonization tests are used to evaluate coking coals and coking coal blends prior to testing in commercial coke ovens. These tests are used to evaluate how coals and coal blends will perform in by-product coke ovens in terms of ease of pushing of the coke mass from the oven, coking pressure, and resultant coke quality.

### SOLE HEATED OVEN (SHO)

Tests done in sole heated ovens evaluate the contraction or expansion tendencies of coals or coal blends when heated under controlled conditions. High volatile coals generally contract and low volatile coals generally expand. The final coke mass must contract 8-12% for ease of pushing from the byproduct oven. SGS operates several sole heated ovens to meet your coal testing requirements. We will generate data that will help you formulate the specific coal blends required to produce high-quality coke.

### 30 LB PRESSURE TEST OVEN (PTO)

SGS operates a 30lb pressure test oven with 2 computer-controlled heating programs. There is a 3-hour program to determine maximum wall pressure generated by the expanding coal sample, and a 7-hour program used to generate coke for reactivity and after reaction strength testing. High coking pressure can damage the walls in by-product coke ovens. SGS will use the PTO as an effective screening and comparison tool for evaluating medium and low volatile coking coals for your facility.

### MOVEABLE WALL OVEN TEST

SGS has an 18' wide movable wall oven that holds a charge of 650-750 lbs of coal to test new or modified coal blends. This oven produces coke of suitable size and quantity for coke physical tests such as stability, hardness, and CRI/CSR. Wall and internal gas pressures generated during the test are also measured. The movable wall prevents oven damage due to excess expansion and/or pressure.

SGS has a network of accredited, independent laboratories around the world to accommodate your coal carbonization testing. SGS provides complete assessment services on your coal and coal blends to determine suitability and performance in accordance with ASTM, ISO and other international standards. Partner with SGS and leverage our technical capabilities to minimize your risks and enhance the efficiency of your operations.

## COKE PHYSICAL TESTING

Several tests are used to measure the physical properties of blast furnace coke however the ASTM stability and hardness test and the coke reactivity/coke strength after reaction test are the most commonly performed.

### COKE REACTIVITY INDEX (CRI) AND COKE STRENGTH AFTER REACTION (CSR)

When coke descends in the blast furnace, it is subjected to reaction with countercurrent CO<sub>2</sub> and abrasion. These concurrent processes weaken the coke and chemically react with it to produce excess fines that can decrease the permeability of the blast furnace burden.

The CRI/CSR test measures coke reactivity in carbon dioxide at elevated temperatures and its strength after reaction by tumbling. In the test, 200g of  $\frac{1}{2}$  x  $\frac{3}{4}$ " (19 x 22 mm) sized coke is reacted in a vessel with CO<sub>2</sub> gas for 2 hours at 1100°C. The weight loss after the reaction equals the CRI. The reacted coke is then tumbled in an I-shaped tumbler for 600 revolutions at 20 rpm and is then weighed. The weight percent of the  $\frac{1}{2}$  x  $\frac{3}{4}$ " coke equals the CSR. Most blast furnaces will require a coke with a CSR greater than 60 and CRI less than 25. SGS is committed to providing accurate, cost effective blast furnace coke analysis for your operation.

### ASTM STABILITY AND HARDNESS TUMBLER TEST

This test measures the resistance of coke to impact and abrasion during removal from the coke oven and transportation and the abrasion that occurs during its descent in the blast furnace. Twenty-two pounds of 3" by 2" sized coke is tumbled in a drum of specific dimensions for 1400 revolutions at 24 rpm. The coke is then screened and the percent + 1" equal its stability and the cumulative percent +  $\frac{1}{4}$ " determines the hardness. Most blast furnace operators require +60 stability coke.

## PETROGRAPHIC ANALYSIS

### COAL PETROGRAPHY

Coal petrography is a microscopic technique used to determine a coal's rank (degree of coalification) and type (amount and class of macerals). Macerals in coal are analogous to minerals in igneous rocks and are determined by examining polished specimens of minus 20 mesh prepared coal. Petrography is primarily used as a tool to evaluate bituminous coals and coal blends and their ability to produce blast furnace coke. Rank is determined by measuring the percent light reflected by the maceral vitrinite. Type is determined using a point count procedure to obtain the volume percent of the various coal macerals, or fossilized plant remains. Coal petrography can also be used to determine whether contaminants are present in the coal and to detect oxidized coal in the sample.

### DIGITAL IMAGING SYSTEM (DIS)

SGS uses a digital imaging system (DIS) to determine the percentage of each coal in a blend or to compare changes in quality of individual coals or blends over time. This system consists of a Zeiss microscope and digital camera, a computer controlled motorized stage, and software to compile and analyze the data. The DIS gathers over 5 million reflective values for a single coal and over 9 million for multi-seam coals or coal blends to generate a unique reflectogram for each sample. Cursors can be set to isolate the various ranks of coal in a blend and determine their corresponding percentages.

### QEMSCAN

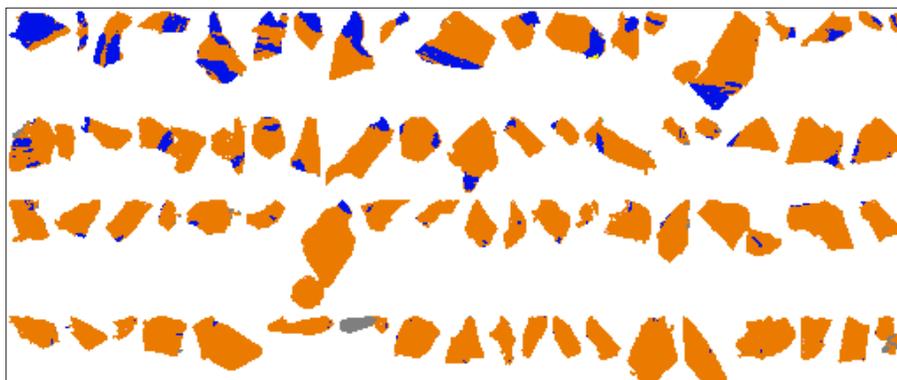
QEMSCAN® is a non-destructive, microanalysis instrument that provides rapid, automated, robust mineralogical and petrography data. SGS is has a number of QEMSCANs and these can be used in the analysis of coal, pulverized fuel and coal combustion products, to help understand combustion parameters and blending efficiencies.

## COKE AND BY-PRODUCT PETROGRAPHY

SGS provides coke and petrography services that will help you determine the percentage of each coal in your blend, troubleshoot quality problems, and to evaluate how coking operations impact your final product. In addition, we can evaluate by-product quinoline insoluble (QI) residues to determine coal tar quality. Quinoline insoluble residues are solid carbon particles created in coal tars during carbonization that strongly affect the characteristics of products that are produced later.

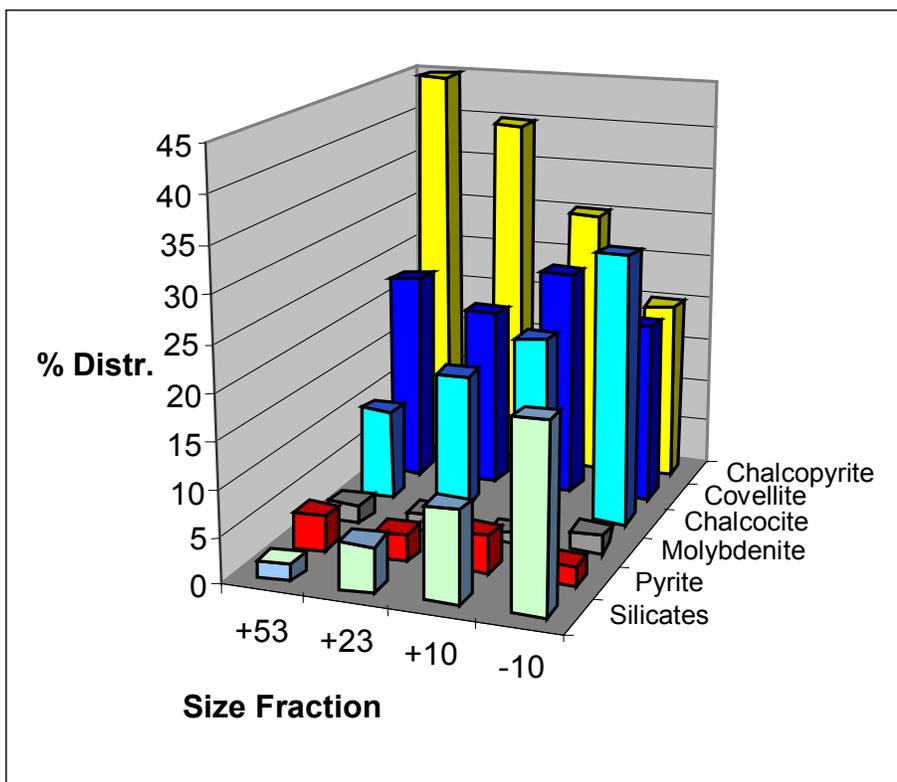
## SUMMARY

SGS provides a comprehensive range of coal, coke and by-product petrographic services in accordance with recognized global standards. Our experienced staff will provide you with expert rank and type determination, as well as complete coke and by-product analysis using computer controlled DIS. Leverage our extensive technical capabilities and allow SGS to help you minimize your operational and financial risk.



- Pentlandite
- Pyrite
- Pyrrhotite
- Chalcopyrite
- Other\_Sulfide
- Gangue

Cleaner Tail: Pentlandite Losses in +25 µm Size Fraction



ELEMENT	QS Assay wt. %	XRF wt. %
Ca	25.2	26.0
P	12.1	12.0
Fe	10.9	10.2
Si	4.4	4.8
Al	0.7	

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