

METALLURGICAL COAL AND COKE TESTING

RHEOLOGY, CARBONIZATION, REACTIVITY, PETROGRAPHY

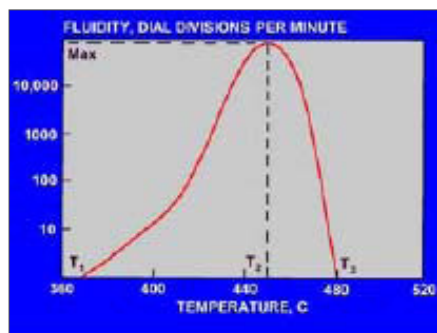
SGS is a global leader in coal and coke laboratory analysis. Our experienced staff can provide complete and impartial rheological property tests on your coking coals to ensure their quality and suitability for your operation. Partner with SGS and leverage our technical capabilities to guarantee your coal analysis meets the global standards for quality and excellence.

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. In addition, the Sapozhnikov and G Caking Index tests are used in certain areas of the world as rheological evaluation tools.

GIESELER PLASTOMETER TEST

For this analysis, 5 grams of minus 40 mesh prepared coal are packed into a retort barrel assembly 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



Gieseler Plastometer Curve

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.

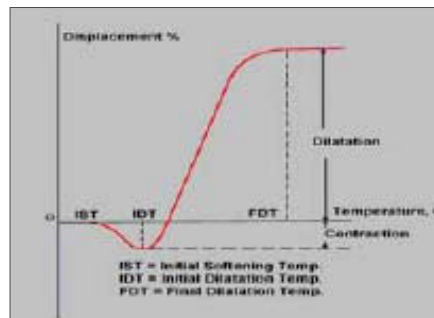
The Gieseler Plastometer test is useful in determining the plastic range of coals, which is the difference between the initial softening and resolidification temperatures. Plastic range in °C and maximum fluidity in DDPM are key factors in determining which blends of coals will be optimal for coking.

ARNU DILATOMETER TEST

The Arnu Dilatometer test is used to determine the swelling properties of coal when heated under standard conditions. A 60 mm coal pencil, 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 pencil 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%.



Arnu Dilatometer Curve

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

SAPOZHNIKOV TEST

This test was developed in Russia in 1931 and is performed in accordance with GOST 1186. The Chinese have adopted the test (GB/T 479) with some minor differences. A 100g sample of minus 1.5/1.6mm coal is placed into a steel capsule and pressed with the help of a piston and a prescribed weight forming a briquette. Heating is performed in a furnace with a temperature rise of 3°C/minute. Between 350 and 650°C, the upper and lower levels of the plastic layer are measured at regular intervals using a needle and millimeter scale. The Y value is the maximum difference between the upper and lower plastic layer levels expressed in mm. Y values will typically range from 5-35mm. The X value equals the percent contraction, or shrinkage, of the coal brickette during the test. X values generally range from 0-35%.

SGS currently performs this test in Russia and China, with new testing facilities coming on line in Australia and the US.

G CAKING INDEX TEST

This test was developed in China and is performed in accordance with GB/T 5447 and ISO 15585 standards. It is used as a primary met coal evaluation tool by Chinese coke producers. In this test, 1g of minus 0.2mm coal is mixed with 5g anthracite and placed in a crucible. A 100-115g steel weight is placed on top of the coal sample and then the sample is pressed for 30 seconds under a 6lk mass. The sample is rapidly coked in an electric furnace to 850°C in 15 minutes. The coked is weighed (M), placed in a small drum and rotated for 5 minutes at 50 +/- 2 rpm. The coke residue is screened at 1mm and the weight of the +1mm coke (M1) is determined. The +1mm coke is then tumbled a second time, with the residue screened at 1mm and the weight of the +1mm coke (M2) is determined.

G Caking Index = $10 + ((30M1 + 70M2) / M)$
Values typically range from 20 to >100, with >85 desired.

SGS currently has the capability to perform this test in China, with facilities being set up in Australia and the US.

CARBONIZATION TESTING

Pilot scale carbonization tests are used to evaluate coking coals and 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 the sole heated oven 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 by-product oven.

SGS operates sole heated ovens in the US to meet your coal testing requirements.



Sole Heated Oven

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 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.



Pressure Test Oven

MOVEABLE WALL OVEN TEST

SGS uses a moveable wall oven to accommodate your coal carbonization testing. Our 18' oven 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.



Moveable Wall Oven

COKE PHYSICAL TESTING

Several tests are used to measure the physical properties of blast furnace coke however the ASTM, ISO Micum/IRSID and JIS tumbler tests, 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 CO₂ 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 3/4" x 7/8" (19 x 22 mm) sized coke is reacted in a vessel with CO₂ 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 + 3/8" coke equals the CSR. Most blast furnaces will require a coke with a CSR greater than 60 and CRI less than 25.

ASTM STABILITY AND HARDNESS, ISO MICUM/IRSID AND JIS JAPANESE TUMBLER TESTS



CRI / CSR Furnace and Controller

These coke tumbler tests measure 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. The ASTM, ISO and JIS tumbler tests differ in the coke sample size consist and weight, as well as the coke tumbler drum dimensions. ASTM stability



ASTM Coke Tumbler

and hardness determinations are used primarily in the US. ISO Micum and IRSID tumbler results are used mainly in Europe, while the JIS tumbler data is mainly used in Japan, South Korea and Brazil.

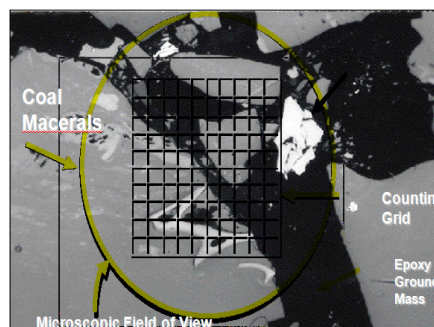
PETROGRAPHIC ANALYSIS

COAL PETROGRAPHY

Coal petrography is a microscopic technique used to determine a coal's rank (degree of coalification) and type (amount and category of macerals) on polished specimens of minus 20 mesh prepared coal. Petrography is primarily used as a tool to evaluate bituminous coals and coal blends in terms of their ability to produce blast furnace coke. Rank is determined by measuring the percent light reflectance of 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)



Coal Petrography

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 reflectance 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

COKE AND BY-PRODUCT PETROGRAPHY



Digital Imaging System

SGS provides coke petrography services that will help you determine the percentage of each rank of coal in your blend, troubleshoot quality problems, and evaluate how coking operations impact your final product. In addition, we can evaluate by-product quinoline insoluble (QI) residues to determine coal tar quality.

CONTACT INFORMATION

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WHEN YOU NEED TO BE SURE