R&D Carbon

OUR TEST EQUIPMENT USED IN THE CARBON ELECTRODE INDUSTRY

SUMMARY

The characterization of carbon materials is essential to check their suitability for a given application, to ensure that the specifications are met, as well as to systematically quantify and improve their quality. Testing their relevant properties and performance through bench or pilot scale evaluations is the best method to anticipate any quality drift or select new material sources. Additionally, having a well-defined routine quality control is the only efficient way to find the root causes of potential issues allowing to solve them.

For this reason, R&D Carbon has developed specific instruments for testing different carbon material types, from raw materials to final products, conforming with international standardized methods. In order to facilitate the understanding, each equipment is assigned to "material type" and "utilization" categories. The descriptions of the categories shown below are non-exhaustive and additional carbon products may be measured. R&D Carbon experts would be pleased to give any assistance upon request.

Material Type	GRANULAR	Petroleum and pitch coke, crushed anode butts, anthracite, natural and artificial graphite, recarburizer, coal, chars, etc.
	PITCH	Petroleum and coal tar pitches used as binder or as impregnation pitch, PAH free binder, etc.
	ELECTRODES	Green and baked prebaked anodes, anode butts, Söderberg paste for the Aluminium or Ferro-alloys industries, graphite electrodes, carbon electrodes, etc.
	LINING	Amorphous, graphitic or graphitized cathodes, sidewall blocks, ramming pastes, etc.
Utilization	R&D	Instruments used principally for Research & Development purposes, such as the evaluation of new material sources, optimization of process parameters, etc.
	IN-PLANT	Instruments placed directly in the plant, in order to help the operators adapt the production process or for sampling purpose.
	LAB	Instruments used in the laboratory for routine quality control or for specifications checks.

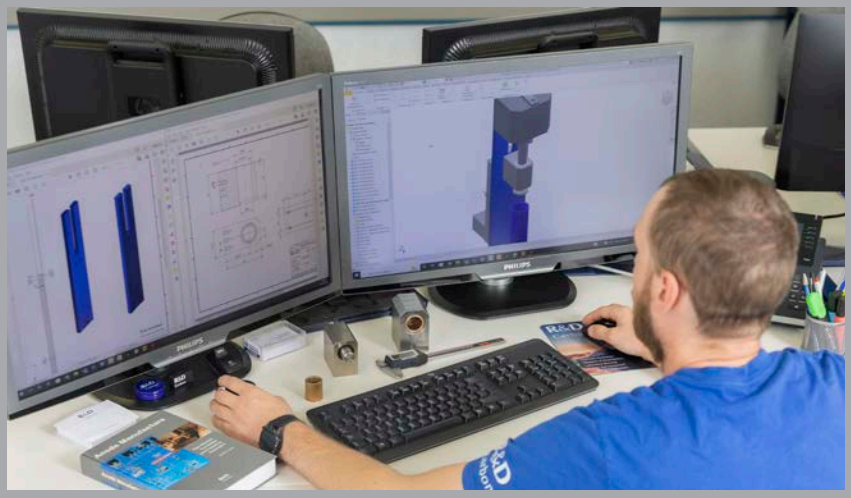
EQUIPMENT, CERTIFIED REFERENCE MATERIAL & GAUGE LIST

Number	Description	Certified Reference Material & Gauges	Granular	Pitch	Electrodes	Lining	R&D	In-plant	Lab	Page
RDC-117	VIBRATED BULK DENSITY COKE	RDC 1117	x					x	x	5
RDC-135	ARCHIMEDES BALANCE				x	x			x	6
RDC-140	ANODE CORE SAW				x				x	7
RDC-141	CO_2 REACTIVITY COKE	RDC 1141	x						x	8
RDC-142	AIR REACTIVITY COKE	RDC 1142	x						x	9
RDC-143	THERMAL CONDUCTIVITY	RDC 1143			x	x			x	10
RDC-144	COMPRESSIVE STRENGTH AND YOUNG'S MODULUS				x	x			x	11
RDC-145	AIR PERMEABILITY	RDC 1145			x	x			x	12
RDC-146	CO_2 REACTIVITY ANODE	RDC 1146			x				x	13
RDC-147	RESIFLEX	RDC 1147	x					x	x	14
RDC-148	DIAMOND WHEEL SAW				x	x			x	15
RDC-149	GRINDING MACHINE				x	x			x	16
RDC-150	SPECIFIC ELECTRICAL RESISTANCE ANODE	RDC 1150			x	x			x	17
RDC-151	AIR REACTIVITY	RDC 1151			x	x			x	18
RDC-152	REAL DENSITY	RDC 1152-C	x	x	x	x			x	19
RDC-153	BULK DENSITY COKE	RDC 1153	x					x	x	20
RDC-154	BULK DENSITY RECIPE		x				x		x	21
RDC-155	DUST FINENESS BLAINE	RDC 1155A	x					x		22
RDC-156	VIBRATORY BALL MILL FOR GRAIN STABILITY	RDC 1156	x						x	23
RDC-157	CORE DRILLING MACHINE				x	x		x		24
RDC-158	THERMAL EXPANSION	RDC 1158			x	x			x	25

OUR SPECIALIZATION

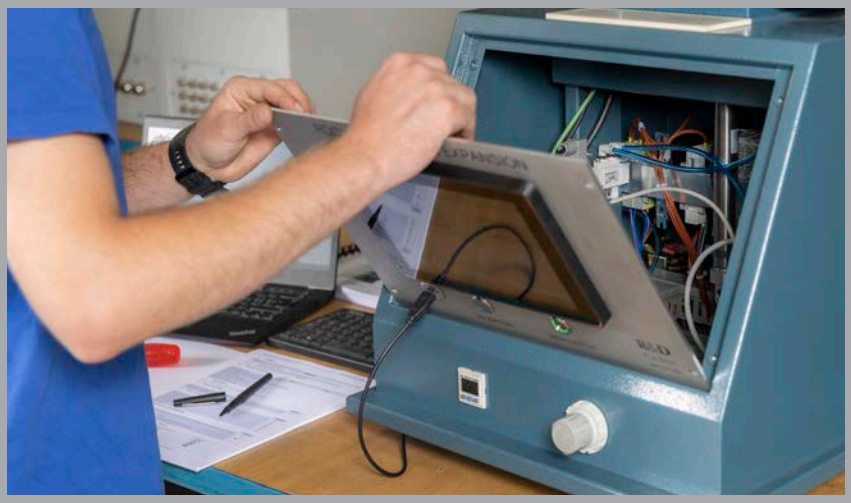
Our easily-operated and reliable test instruments have set standards worldwide for testing carbon products. These instruments can measure all key properties of carbon materials based on methods approved by DIN, ISO and ASTM standards. 75% of the world's anode production is monitored with R&D Carbon's test equipment. In our modern workshop, we produce over 50 different test instruments. Before shipping, each equipment undergoes extensive testing and calibration to ensure equipment is accurate and reliable.

OUR TEAM IS SPECIALIZED IN THE FOLLOWING SERVICES:



Development

ENGINEERING
DESIGNING
PROTOTYPING



Production

PROCUREMENT
ASSEMBLY
ACCEPTANCE TEST
PACKING

Services

SUPPORT
COMMISSIONING
MAINTENANCE
UPGRADE
REPAIR
TRAINING

RDC-117

Name **VIBRATED BULK DENSITY COKE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The porosity of the different raw materials used for the production of electrodes has a very big impact on the electrode performance, not only for its quality but also in terms of process parameters to be optimized accordingly, such as the binder content. This porosity level can be estimated by measuring the Bulk Density of the materials.

The measurement is conducted with the RDC-117 apparatus, where a given quantity of one coke fraction, prepared according to the ASTM D4292 standard method, is filled under controlled conditions into a graduated cylinder. This cylinder is then vibrated for a given time and the volume of the sample is measured after the test. The bulk density is calculated and reported in kg/dm³, as the ratio of the sample's mass to its volume.

Alternatively, this measurement can be performed by using the RDC-153 apparatus according to the ISO 10236 standard method, which allows to reach better precision figures and to gather additional information, as several natural fractions are measured.

Technical information

Standard Method:	ASTM D4292
Property: Vibrated Bulk Density	[kg/dm³]
Sample:	100 g of one specific prepared fraction
Process time:	~ 7 minutes
Installation:	Workbench
Dimensions (LxWxH):	40 x 48 x 82 cm
Weight:	46 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.14 kW, 0.6 A
Certified Reference Material:	RDC 1117
Database Connection:	No

Additional Recommended Equipment:
Drying oven (min. temperature 110°C)
Sieving machine with defined sieve sizes
Jaw Crusher
Roller Crusher
Weighing scale with an accuracy of 0.1 g

RDC 1117

Technical information

Weight per unit:	400 g
Number of tests:	N/A

RDC-135 Name ARCHIMEDES BALANCE

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The Archimedes balance allows for determining the apparent density and open porosity of electrode core samples, which are two important properties.
The apparent density of a sample corresponds to the ratio of its mass to its volume in kg/dm³. The mass is obtained by weighing the core sample, while its volume is determined according to the Archimedes principle by immerging the sample in water and measuring the resulting force applied to it. This method has the advantage of allowing the determination of the volume of a sample with complex geometry.
The open porosity, in percent, is calculated by measuring the mass of water that has penetrated the open pores of the sample.
The RDC-135 apparatus is compatible with the international standard method ISO 12985-2 and allows the measurement of samples with a size of up to 50 mm.

Technical information

Standard Method:	ISO 12985–2
Property:	
Apparent Density	[kg/dm³]
Open Porosity	[%]
Sample:	Core Ø50 x 50 mm
Process Time:	~ 2 hours
Installation:	Workbench
Dimensions (LxWxH):	35 x 26 x 37 cm
Weight:	7 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 70 W, 0.3 A
Fluid Property:	Distilled water
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)
Heating plate (for boiling)

RDC-140

Name **ANODE CORE SAW**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The RDC-140 Anode Core Saw was specifically designed for the preparation of baked anode cores to perform typical routine analysis. In a single step, it allows the cutting of a core into pieces of the required lengths. These cores are typically used for the testing of the following properties:

- **20 mm:** RDC-145 Air Permeability and RDC-143 Thermal Conductivity.
- **60 mm:** RDC-151 Air Reactivity Anode (or RDC-146 CO2 Reactivity Anode).
- **130 mm:** Apparent Density, RDC-150 Specific Electrical Resistance, EXT-110 Dynamic Elasticity Modulus, RDC-187 Flexural Strength.

In a second step, a supplied stop plate can be inserted into the sample holder to cut a 130 mm core sample following the flexural strength test for the determination of the following properties:

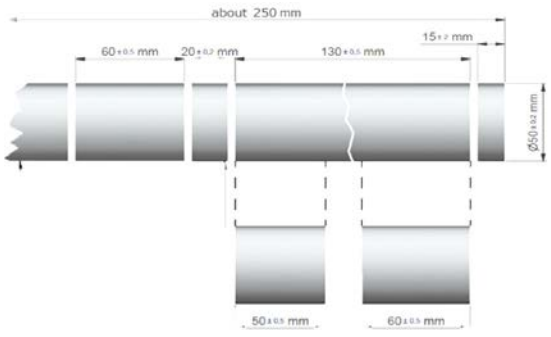
- **50 mm**: RDC-158 Thermal Expansion and RDC-144 Compressive Strength & Young's Modulus.
- **60 mm:** RDC-146 CO2 Reactivity Anode (or RDC-151 Air Reactivity Anode).

Samples with a diameter of 30 mm or 50 mm and a length of up to 280 mm can be cut with the RDC-140 apparatus. Water is sprayed onto the blades during the cutting operation, a drying step is then required prior to performing any subsequent testing.

Technical information

Sample:	Core Ø30 mm or Ø50 mm with length up to 280 mm
Process Time:	~ 90 seconds
Installation:	Workbench
Dimensions (LxWxH):	90 x 60 x 61 cm
Weight:	186 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 1.10 kW, 3 A
Fluid Property:	Water 3-7 bar, 150 l/h
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Drying oven (min. temperature 180° C)



RDC-141

Name CO_2 REACTIVITY COKE

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

To minimize the net anode consumption in the electrolysis cells, it is important to use anodes with low reactivity to CO_2 gas, which can be measured by the RDC-146 apparatus. This allows increasing the quantity of carbon available for the production of aluminium and decreasing the excess carbon consumption, which reduces the aluminium production cost.
As the CO_2 reactivity of the baked anodes is strongly impacted by the reactivity of the calcined cokes, it is worthwhile to measure it on a routine basis to predict and anticipate any anode quality variations.
The measurement is conducted with the RDC-141 apparatus, where a calcined coke sample is heated at 1000°C during a given period of time while it is exposed to a saturated CO_2 atmosphere. At the end of the heating cycle, the sample is weighed and the mass loss, in percent, is used to express the CO_2 reactivity of the sample.

Technical information

Standard Method:	ISO 12981–1
Property: CO_2 Reactivity Coke	[%]
Sample:	5 g of coke (1.4–1 mm)
Process Time:	~ 3 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	60 x 40 x 68 cm
Weight:	53 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.90 kW, 4 A
Fluid Property:	CO_2, 50 l/h, 3-7 bar
Certified Reference Material:	RDC 1141
Database Connection:	Yes

Additional Recommended Equipment:
Oil content (RDC–176 or RDC–208)
Drying oven (min. temperature 110°C)
Weighing scale with an accuracy of 0.001 g
Crusher (< 1.5 mm)
Sieving machine (1.4 mm and 1 mm sieves)

RDC 1141

Technical information

Weight per unit:	180 g
Number of tests:	36

RDC-142 Name AIR REACTIVITY COKE

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

To minimize the net anode consumption in the electrolysis cells, it is important to use anodes with low reactivity to air, which can be measured by the RDC-151 apparatus. This allows increasing the quantity of carbon available for the production of aluminium and decreasing the excess carbon consumption, which reduces the aluminium production cost.
As the air reactivity of the baked anodes is strongly impacted by the reactivity of the raw materials used for its production, it is worthwhile to measure them on a routine basis to predict and anticipate any anode quality variations.
The measurement is conducted with the RDC-142 apparatus, where a sample will be heated with a constant heat-up rate under an air atmosphere until its ignition temperature is detected. Two different heat-up rates are available: a slow one of 0.5°C/min to be used for calcined coke testing and a faster one with 10°C/min to be used for checking the recycled anode butts material.
As indicated in the international method ISO 12982-1, the air reactivity of the sample is calculated in %/min from its ignition temperature according to specific equations.

Technical information

Standard Method:	ISO 12982–1
Property:	
Ignition Temperature	[°C]
Air Reactivity Coke	[%/min]
Maximum Temperature:	700° C
Sample:	5 g of coke (1.4-1 mm)
Process Time:	~ 4 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	60 x 40 x 68 cm
Weight:	42 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.90 kW, 4 A
Fluid Property:	Air, 50 l/h, 3-7 bar
Certified Reference Material:	RDC 1142
Database Connection:	Yes

Additional Recommended Equipment:
Oil content (RDC–176 or RDC–208)
Drying oven (min. temperature 110°C)
Weighing scale with an accuracy of 0.01 g
Crusher (< 1.5 mm)
Sieving machine (1.4 mm and 1 mm sieves)

RDC 1142

Technical information

Weight per unit:	180 g
Number of tests:	36

RDC-143

Name **THERMAL CONDUCTIVITY**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The thermal conductivity of an electrode is an important property in predicting its thermal shock behavior. A low thermal conductivity leads to a large temperature difference within the carbon block, which can trigger cracking. For anodes and cathodes used in the aluminium industry, thermal conductivity is also an important property for the thermal balance of the cell. A high anode thermal conductivity increases the temperature of the anode head and potentially the air burning.

The measurement is conducted with the RDC-143 apparatus, where a sample with a height of 20 mm is clamped between two heads, one heated at 60°C and the other cooled to 20°C. The method is based on a comparative measurement: once the thermal equilibrium is reached, the obtained temperature is measured and compared to the one obtained on a reference material with a known conductivity to determine the electrode thermal conductivity.

Levels from approximately 2 W/mK up to more than 180 W/mK can be measured with this equipment if correct reference materials are used and if the sample's diameter is adapted (30 mm or 50 mm). The sample preparation must be made with the RDC-140 or the RDC-149 apparatus to ensure adequate parallelism of the sample's surfaces.

Technical information

Standard Method:	ISO 12987
Property:	
Thermal Conductivity	[W/mK]
Sample:	Core Ø50 mm or Ø30 mm x 20 mm
Process Time:	~ 10 minutes
Installation:	Draft-free workbench
Dimensions (LxWxH):	88 x 54 x 79 cm
Weight:	102 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 1.30 kW, 6 A
Certified Reference Material:	RDC 1143
Database Connection:	Yes
Consumable:	Distilled water

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–149)
Drying oven (min. temperature 180°C)

RDC 1143

Technical information

Weight per unit:	N/A
Number of tests:	N/A

RDC-144

Name

COMPRESSIVE STRENGTH AND YOUNG'S MODULUS

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The measurement of the mechanical properties of electrodes, such as the compressive strength and Young's modulus (also called static elasticity modulus), is vital to quantify the mechanical behavior and the thermal shock resistance of the electrodes for two main reasons:

- A high Young's modulus, typically combined with high compressive strength, is an indication of a brittle material that is very sensitive to temperature differences.
- The ratio between the compressive strength and the flexural strength (RDC-187 apparatus) gives an indication of the presence of macrocracks.

The measurement is conducted with the RDC-144 apparatus, where the uniaxial compressive load on a core sample with a diameter of 50 mm and a height of 50 mm is increased until the sample breaks. The maximal load applied onto the sample will be divided by its surface area to calculate its compressive strength in MPa.

At the same time, the change in length is recorded and the Young's modulus, corresponding to the slope of the stress/strain graph, is calculated and expressed in GPa.

Technical information

Standard Method:	ISO 18515
Property:	
Compressive Strength	[MPa]
Static Elasticity Modulus	[GPa]
Sample:	Core Ø50 x 50 mm
Process Time:	~ 2 minutes
Installation:	Workbench
Dimensions (LxWxH):	70 x 62 x 67 cm
Weight:	170 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Database Connection:	Yes

Additional Recommended Equipment:

Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)

RDC-145

Name **AIR PERMEABILITY**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The air permeability, corresponding to the open pores larger than 50 µm, strongly influences the burning reaction that can occur due to the presence of both air and CO_2 gases. For minimum excess carbon consumption in the electrolysis cells, low permeability is important, which reduces the anode surface area in direct contact with air or CO_2. The air permeability is also a good indicator of some process parameters, such as the mixing conditions, the variations of recycled anode butts or the binder pitch used during the electrode production process. The measurement is conducted with the RDC-145 apparatus, where the time required by a certain volume of air to pass through a sample with a 50 mm diameter and a height of 20 mm is measured. The method is based on a comparative measurement: the actual time is compared to the time required from a reference material with a known permeability. The calculated permeability is expressed in nanoperm (nPm).

Technical information

Standard Method:	ISO 15906
Property:	
Air Permeability	[nPm]
Sample:	Core Ø50 x 20 mm
Process time:	1–5 minutes
Installation:	Workbench
Dimensions (LxWxH):	60 x 62 x 69 cm
Weight:	53 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Certified Reference Material:	RDC 1145
Database Connection:	Yes

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148 or RDC–149)
Drying oven (min. temperature 180°C)

RDC 1145

Technical information

Weight per unit:	N/A
Number of tests:	N/A

RDC-146

Name

CO_2 REACTIVITY ANODE

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

During the electrolysis, CO_2 is formed at the bottom of the anode, where the carbon anode reacts with the oxygen from the electrolyte bath. Depending on the anode quality, a back reaction can occur between the CO_2 and the anode, which increases the net anode consumption. If a selective attack of the binder matrix occurs, carbon particles get excavated from the anode and end up in the electrolysis bath. This phenomenon is referred to as carbon dusting. It leads to a higher bath resistivity and temperature to the extent that the current efficiency may be decreased. It may also trigger spikes formation. It is of primary importance to produce anodes with a minimum CO_2 reactivity to avoid such performance problems, which have a strong influence on the smelter cost.

The measurement is conducted with the RDC-146 apparatus, where a core sample of Ø50 mm and a length of 60 mm is placed in a furnace at 960°C with a saturated CO_2 atmosphere for 7 hours. After cooling, the sample is weighed and tumbled with steel balls using the RDC-181 apparatus, to remove any loosely bound particles. The final weight of the residual body is then measured. The following three results are reported:

- CO_2 reactivity residue: corresp. to the residual sample.
- CO_2 reactivity dust: corresp. to the removed grains.
- CO_2 reactivity loss: corresp. to the loss due to CO_2 burning.

RDC-146 is available with one or three furnaces, in which two samples per furnace can be placed simultaneously.

Technical information

Standard Method:	ISO 12988–1
Property:	
Residue	[%]
Loss	[%]
Dust	[%]
Sample:	Core Ø50 x 60 mm
Process Time:	~ 12 hours
Installation:	Floor standing under fume hood
Dimensions (LxWxH):	175 x 70 x 190 cm
Weight:	465 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 6 kW, 15 A
Fluid Property:	CO_2, 600 l/h, 3–7 bar
Certified Reference Material:	RDC 1146
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Tumbling Apparatus (RDC–181)
Drying oven (min. temperature 180°C)
Weighing scale with an accuracy 0.1 g

RDC 1146

Technical information

Weight per unit:	N/A
Number of tests:	12

RDC-147

Name **RESIFLEX**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The specific electrical resistance of the electrode, strongly influenced by the coke, is an important property to minimize, as it directly affects the voltage drop and, thus, the metal production cost. Measuring the electrical resistance of the coke also provides an indication of the heat treatment that the material has undergone during calcination. Its information is, therefore, valuable for the process control of coke calciners.

The measurement is conducted with the RDC-147 apparatus, where a given weight of sample from a specific fraction is pressed in a chamber where a constant direct current is applied. The voltage drop, combined with the height of the sample, is measured to calculate its specific electrical resistance in µΩm. By measuring the height of the sample, the pressed density in kg/dm³ can be calculated at the same time.

Technical information

Standard Method:	ISO 10143
Property:	
Specific Electrical Resistance	[µΩm]
Pressed Density	[kg/dm³]
Sample:	15 g of granular carbon (1.4–1 mm)
Process Time:	~ 2 minutes
Installation:	Workbench
Dimensions (LxWxH):	60 x 67 x 73 cm
Weight:	100 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Certified Reference Material:	RDC 1147
Database Connection:	Yes

Additional Recommended Equipment:
Oil content (RDC–176 or RDC–208)
Drying oven (min. temperature 110°C)
Weighing scale with an accuracy of 0.01 g
Crusher (< 1.5 mm)
Sieving machine (1.4 mm and 1 mm sieves)

RDC 1147

Technical information

Weight per unit:	180 g
Number of tests:	12

RDC-148

Name **DIAMOND WHEEL SAW**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Depending on the analysis to be performed, cutting the electrode core to different lengths is required.
This can be done by using the RDC-148 saw, which is equipped with a single blade. The length of the sawing table is initially adjusted to 130 mm and steel stoppers with different lengths are used to obtain the required sample dimensions.
Samples with a diameter of up to 50 mm and a length of up to 350 mm can be cut with this equipment. Water is sprayed onto the blade during operation, a drying step is then required prior to performing any subsequent testing.
For information, this equipment is not suitable for the sample preparation of the thermal conductivity test (RDC-143). These samples should be prepared with the RDC-149 Grinding Machine to ensure the parallelism required for this test.
Alternatively, for a typical anode evaluation, the cutting operation can be done in one step by using the RDC-140 equipment.

Technical information

Sample:	Core up to Ø50 mm with length up to 350 mm
Process Time:	~ 1 minute
Installation:	Workbench
Dimensions (LxWxH):	80 x 53 x 44 cm
Weight:	85 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Fluid Property:	Water 3–7 bar, 150 l/h
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Drying oven (min. temperature 180°C)

RDC-149

Name **GRINDING MACHINE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

To measure the thermal conductivity with the RDC-143 apparatus, high precision of the parallelism of the sample's surfaces is required to obtain correct measurements.
The RDC-149 apparatus provides the required precision. A core sample with a diameter of 30 or 50 mm can be cut to a height of 20 mm by two planar and parallel discs.
Alternatively, for a typical anode evaluation, this sample preparation can be done in one step by using the RDC-140 equipment.

Technical information

Sample:	Core up to Ø50 mm with length up to 300 mm
Process Time:	~ 1 minute
Installation:	Workbench
Dimensions (LxWxH):	81 x 54 x 44 cm
Weight:	116 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Fluid Property:	Water 3–7 bar, 150 l/h
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Drying oven (min. temperature 180°C)

RDC-150

Name **SPECIFIC ELECTRICAL RESISTANCE ANODE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The specific electrical resistance of the electrode is an important property to minimize, as it directly affects the voltage drop and, thus, the metal production cost. It not only characterizes the behavior of the electrode during its use, but it also gives interesting information about the production of the electrode, such as its structural condition due to baking or graphitization processes, as well as the raw materials and the production parameters. The potential presence of cracks can also be detected with this test.

The measurement is conducted with the RDC-150 apparatus, where a core sample with a diameter of 50 mm and a length of 130 mm is clamped between surfaces with a specific load. A constant direct current is applied to the sample and the voltage drop is measured to calculate its specific electrical resistance in μΩm.

Technical information

Standard Method:	ISO 11713
Property: Specific Electrical Resistance	[μΩm]
Sample:	Core Ø50 x 130 mm
Process Time:	~ 1 minute
Installation:	Workbench
Dimensions (LxWxH):	54 x 52 x 57 cm
Weight:	62 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Certified Reference Material:	RDC 1150
Database Connection:	No

Additional Recommended Equipment:
Drilling Machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)

RDC 1150

Technical information

Weight per unit:	N/A
Number of tests:	N/A

RDC-151

Name **AIR REACTIVITY**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

During electrolysis, air can be present at the anode top. A burning reaction can occur between the air and the anode, which increases the net anode consumption and potentially deteriorates the quality of the butts for the next anode generation. If a selective attack of the binder matrix occurs, carbon particles get excavated from the anode and end up in the bath (carbon dusting). It leads to a higher bath resistivity and temperature, so the current efficiency may be decreased. It may also trigger spikes formation. It is important to produce anodes with a minimum CO_2 reactivity to avoid such performance problems.
The measurement is done with the RDC-151 apparatus, where a core sample of Ø 50 mm and a length of 60 mm is placed in a furnace at 550°C under air atmosphere and cooled down to 400°C with a rate of 15°C/h. After cooling, the sample is weighed and tumbled with steel balls using the RDC-181 apparatus to remove any loosely bound particles. The final weight of the residual body is then measured. The following three results are reported:

- Air reactivity residue: corresponds to the residual sample.
- Air reactivity dust: corresponds to the removed grains.
- Air reactivity loss: corresp. to the loss due to air burning.

RDC-151 is available with 1 or 3 furnaces, in which one sample per furnace can be placed at the same time. During the sample preparation, a hole must be drilled in the center of the sample's surface area with the RDC-180 Bench Drilling Machine.

Technical information

Standard Method:	ISO 12989–1
Property:	
Residue	[%]
Loss	[%]
Dust	[%]
Sample:	Core Ø50 x 60 mm
Process Time:	~ 12 hours
Installation:	Floor Standing under Fume Hood
Dimensions (LxWxH):	160 x 60 x 200 cm
Weight:	377 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 3.3 kW, 8.3 A
Fluid Property:	Air, 600 l/h, 3–7 bar
Certified Reference Material:	RDC 1151
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Bench Drilling Machine (RDC–180)
Tumbling Apparatus (RDC–181)
Drying oven (min. temperature 180°C)
Weighing scale with an accuracy of 0.1 g

RDC 1151

Technical information

Weight per unit:	N/A
Number of tests:	6

RDC-152

Name **REAL DENSITY**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General information

Commercially available carbon products show a wide range of properties, particularly in the degree of calcination, baking, or graphitization and, as a result, in density. The measurement of the real density is essential to ensure and understand the heat treatments that the different materials have undergone during their production, which can lead to issues during their use. Combined with other measurements, such as the crystallite size measured by X-Ray diffraction, it could be used to determine the nature of a given coke or to perform temperature distribution profiles in a baking furnace.
With the RDC-152 apparatus, the real density at 25°C of a milled product is determined by pycnometry. The equipment is composed of several vacuum chambers where the pycnometers containing the samples are filled with xylene or water determined by the type of material to be measured. The number of chambers may be increased depending on the required testing capacity. After filling, the pycnometers are placed in a water bath at 25°C until the temperature has stabilized. By measuring the weights at different analysis steps, the real density is calculated and reported in kg/dm³.

Technical information

Standard Method:	ISO 8004, ISO 9088, ISO 6999
Property:	
Real Density	[kg/dm³]
Sample:	5 g of powder (< 63 µm) or of pitch (2–1 mm)
Process Time:	~ 2 hours
Installation:	Workbench
Dimensions (LxWxH):	
Vacuum Unit	150 x 60 x 80 cm
Bath	92 x 43 x 48 cm
Weight:	
Vacuum Unit	37 kg
Bath	45 kg
Electrical Property:	
Vacuum Unit	230 V 1/N/PE, 50 Hz 0.42 kW, 2 A
Bath	230 V 1/N/PE, 50 Hz 0.35 kW, 1.6 A
Certified Reference Material:	RDC 1152–C
Database Connection:	No
Consumable:	Distilled Water and Xylene

Additional Recommended Equipment:
Drying oven (min. temperature 180°C)
Dessicator
Weighing scale with an accuracy of 0.0001 g
Crusher (< 4 mm)
Vibratory Mill (< 63 µm)
Sieving machine for the pitch (2 mm and 1 mm sieves)

RDC 1152-C

Technical information

Weight per unit:	150 g
Number of tests:	30

RDC-153

Name **BULK DENSITY COKE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The porosity of the different raw materials used for the production of electrodes has a very big impact on the electrode performance, not only for its quality but also in terms of process parameters to be optimized accordingly, such as the binder content. A simple and easy way to determine the porosity level is to determine the Bulk Density of the materials. Measuring fractions from different grain sizes allows having an overview of the material quality. Its information is vital for adequate process control.

The measurement is conducted with the RDC-153 apparatus, where a given quantity of grains from specific fractions is filled under controlled conditions into a graduated cylinder. This cylinder is then tapped for a given number of strokes and the volume of the sample is measured after the test. The bulk density is calculated and reported in kg/dm^3, as the ratio of the sample's mass to its volume.

According to the ISO 10236 standard method, this measurement is done on natural sieved material (no crushing during the sample preparation) and five different fractions (8-4, 4-2, 2-1, 1-0.5 and 0.5-0.25 mm) are measured separately.

Technical information

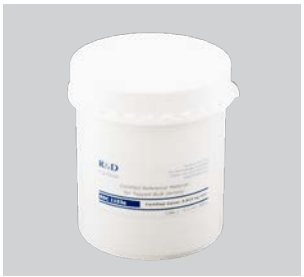
Standard Method:	ISO 10236
Property: Tapped Bulk Density	[kg/dm^3]
Sample:	100 g of each natural fraction
Process time:	~ 6 minutes
Installation:	Workbench
Dimensions (LxWxH):	45 x 37 x 84 cm
Weight:	38 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.05 kW, 0.2 A
Certified Reference Material:	RDC 1153
Database Connection:	No

Additional Recommended Equipment:
Drying oven (min. temperature 110^{0}C)
Weighing scale with an accuracy of 0.1 g
Sieving machine (8, 4, 2, 1, 0.5 and 0.25 mm sieves)

RDC 1153

Technical information

Weight per unit:	400 g
Number of tests:	N/A



RDC-154

Name **BULK DENSITY RECIPE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The porosity of the different raw materials used for the production of electrodes has a very big impact on the electrode performance. The porosity (or density) level of each raw material separately can be measured with the RDC-153 apparatus; its information is relevant to ensure stable process conditions. Defining the bulk density of the entire dry aggregate recipe is vital for process optimization.

The measurement is conducted with the RDC-154 apparatus, where a given quantity of the representative dry aggregate recipe is filled under controlled conditions into a graduated cylinder. This cylinder is then tapped for a given number of strokes and its volume is measured after the test. The bulk density is calculated and reported in kg/dm^3, as the ratio of the sample's mass to its volume.

Technical information

Property:	
Bulk Density Recipe	[kg/dm^3]
Sample:	1 kg of dry aggregate recipe
Process Time:	~ 15 minutes
Installation:	Workbench
Dimensions (LxWxH):	
Bulk Volumeter	33 x 30 x 52 cm
Rotating Mixer	46 x 61 x 77 cm
Weight:	
Bulk Volumeter	9 kg
Rotating Mixer	60 kg
Electrical Property:	
Bulk Volumeter	230 V 1/N/PE, 50 Hz 0.05 kW, 0.3 A
Rotating Mixer	230 V 1/N/PE, 50 Hz 0.55 kW, 2.4 A
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g

RDC-155

Name **DUST FINENESS BLAINE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The fines fraction, consisting of mill product along with filter fines, contributes to more than 90% of the total dry aggregate surface area and largely impacts the optimum binder requirement during the green electrode production, and hence the overall electrode quality and performance. For adequate process control, it is vital to monitor the fineness of all dust fractions in the dry aggregate and ensure stable conditions.

The measurement is conducted with the RDC-155 apparatus, where the time required by a given volume of air to pass through a dust sample is measured. The method is based on a comparative measurement: the actual time is compared to the time required for reference material with a known fineness level. The calculated fineness (or Blaine number) is expressed in Blaine units.

The advantage of this test is that the Blaine number directly corresponds to the overall surface area of the dust. This information is much broader than the results provided by (air forced) sieving, where the quantity below a given grain size is reported.

Technical information

Property:	
Blaine Value	[Blaine]
Sample:	70 g of carbon dust
Process Time:	1–15 minutes
Installation:	Workbench
Dimensions (LxWxH):	60 x 63 x 69 cm
Weight:	60 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Certified Reference Material:	RDC 1155A
Database Connection:	Yes

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g

RDC 1155A

Technical information

Weight per unit:	800 g
Number of tests:	N/A

RDC-156

Name

VIBRATORY BALL MILL FOR GRAIN STABILITY

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

When raw materials with coarse grains and low mechanical stability are used, breakage can occur during the green electrode preparation. When this happens, the surface area of the broken grains is not entirely covered by the binder. This can lead to crack formation during baking, graphitization, or during the utilization of the electrodes. In addition, low grain stability may also result in a grain size distribution finer than expected. For this purpose, it is important to ensure good grain stability of the different raw materials.

The measurement is conducted with the RDC-156 apparatus, where grains of the coarse fraction 8-4 mm are placed in a vibratory mill with steel balls for a given period of time. After the test, the grain stability is calculated and reported in %, as the ratio of grains still coarser than 4 mm to the initial sample weight.

Technical information

Standard Method:	ISO 10142
Property: Grain Stability	[%]
Sample:	100 g of granular carbon (natural 8–4 mm)
Process Time:	~ 5 minutes
Installation:	Workbench
Dimensions (LxWxH):	58 x 56 x 40 cm
Weight:	90 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 0.2 kW, 0.5 A
Certified Reference Material:	RDC 1156
Database Connection:	No

Additional Recommended Equipment:
Drying oven (min. temperature 110°C)
Weighing scale with an accuracy of 0.1 g
Sieving machine (8 and 4 mm sieves)

RDC 1156

Technical information

Weight per unit:	600 g
Number of tests:	6

RDC-157

Name **CORE DRILLING MACHINE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

To achieve a good and stable electrode performance, a well-defined routine quality control with unbiased sample preparation is required. The sample preparation is often underestimated, as a sampling procedure with inappropriate equipment will falsify the test results.
The RDC-157 apparatus is a specifically designed core drilling machine to ensure a correct sample preparation. The apparatus consists of a core bit driven by an electrical motor. A pressure gauge combined with an adjustment valve allows controlling the speed for automatic drilling operations. Cores with a diameter of 50 mm and a length of approximately 250 mm are prepared for the subsequent evaluation of properties. The installation of the RDC-157 apparatus requires a specific frame determined by customer requirements which is not supplied with the equipment.

Technical information

Function:	Drilling of electrode cores
Sample:	Electrode block
Process Time:	~ 5 minutes
Installation:	On specific frame
Dimensions (LxWxH):	97 x 61 x 180 cm
Weight:	270 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 2.1 kW, 5.3 A
Fluid Property:	Water 3–7 bar, 480 l/h
Database Connection:	No

RDC-158

Name **THERMAL EXPANSION**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The coefficient of thermal expansion of an electrode is an important parameter to predict its thermal shock resistance. When an electrode at ambient temperature is put in operation at a high temperature, a heat wave will penetrate the block body and create a temperature gradient. A high coefficient of thermal expansion increases the strain in the body and, thus, the thermal stresses to the extent that cracking can occur.

The measurement is conducted with the RDC-158 apparatus, where a core sample with a diameter of 50 mm and a height of 50 mm is placed in a furnace, preheated at 300°C, for a given period of time. The length change at the end of the test is recorded and used for the calculation of the coefficient of thermal expansion in 10^{-6}/K.

This equipment is not suitable for the quality control of graphite electrodes, as different temperature ranges and a higher precision level would be required.

Technical information

Standard Method:	ISO 14420
Property: Coefficient of Thermal Expansion	[10^{-6}/K]
Sample:	Core Ø50 x 50 mm
Process time:	Maximum 3 hours
Installation:	Draft–free workbench
Dimensions (LxWxH):	48 x 56 x 120 cm
Weight:	65 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Fluid Property:	Air, 3–7 bar
Certified Reference Material:	RDC 1158
Database Connection:	Yes

Additional Recommended Equipment:
Drilling Machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)

RDC 1158

Technical information

Weight per unit:	[-]
Number of tests:	[-]

RDC-159

Name **SOFTENING POINT METTLER**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The softening point of the binder corresponds to its change from solid to liquid state. It is one of the main properties to qualify the binder, as it is usually a production target for the pitch producer and impacts most of the other binder properties. Its level should be chosen to remain below the limits of the thermal capacity of the paste plant to ensure optimum processing conditions.

The measurement is conducted with the RDC-159 apparatus, where a pressed sample (prepared with the RDC-182 apparatus) is placed in a preheated furnace. The temperature is increased with a given heat-up rate until the softened material interrupts a light barrier below the sample. The softening point Mettler is directly read from the display of the equipment and reported in °C.

Technical information

Standard Method:	ISO 5940–2
Property: Softening Point Mettler	[°C]
Maximum Temperature:	400°C
Sample:	Pitch pressed in a cup
Process Time:	~ 15 minutes
Installation:	Workbench
Dimensions (LxWxH):	20 x 32 x 22 cm
Weight:	5 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.9 kW, 4 A
Certified Reference Material:	RDC 1159
Database Connection:	No

Additional Recommended Equipment:
Mettler Sample Press (RDC–182)

Mettler Toledo TM

RDC 1159

Technical information

Weight per unit:	5 g
Number of tests:	3

RDC-160

Name **PILOT PRESS**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

When appropriate raw materials are selected and correct process parameters are chosen, the properties of the resulting electrodes can be predetermined on pilot scale. The selection of the optimum process parameters is not an easy task, especially when starting a new green mill or when changes in an existing plant occur. Optimization trials on full production scale should be avoided, as they bear the risk of generating batches of sub-standard quality. Furthermore, they create logistical challenges to separate the test electrodes from the regular production, and they may be lengthy until the test results are available. To avoid this, optimization trials should be conducted on pilot scale. With the methodology of the dynamic process optimization (DPO), processing parameters are systematically changed, while pilot electrodes are produced from the real production paste. The electrodes are then baked and tested for the relevant properties to determine the impact of the changes on the final electrode quality.

The RDC-160 apparatus is used for the preparation of the pilot green electrodes. Batches of paste are pressed under pressure to form 146 mm diameter electrodes with an approximate height of 200 mm. These electrodes are then baked in the RDC-167 Pilot Baking Furnace, drilled with the RDC-179 Pilot Core Drilling Machine, and tested for their properties.

This equipment can also be used for evaluation of ramming paste or for other research & development projects.

Technical information

Function:	Pressing Pilot Electrode Ø146 mm
Sample:	~ 6 kg of electrode paste
Process Time:	~ 5 minutes
Installation:	Floor standing
Dimensions (LxWxH):	180 x 94 x 235 cm
Weight:	1500 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 3 kW, 7.5 A
Database Connection:	No

Additional Recommended Equipment:

Baking Furnace (RDC–167)
Pilot Core Drilling Machine (RDC–179)
Test equipment for analysis
Weighing scale with an accuracy of 0.1 g

RDC-161

Name **BENCH SCALE ANODE PRODUCTION**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The evaluation of critical process parameters and raw materials such as calcined petroleum coke, binders, recycled materials, and additives on bench scale is essential to conduct research and development projects for continuous improvement in anode manufacturing. The production of anodes at the bench scale under controlled conditions is a fast, reliable, and cost effective approach to assess the quality of raw materials and optimize process parameters, avoiding the expensive exercise of full-scale trials.

Key components of the RDC-161 setup include:

- Preheating oven: used to bring the dry aggregate to a target temperature before mixing.
- Eirich mixer: an intensive impeller mixer equipped with temperature control to ensure consistent, homogeneous paste production.
- Forming Press: designed for shaping green bench scale anodes with a standardized 50 mm diameter and approximately 100 mm length.

Depending on the application, additional equipment is potentially needed to prepare the dry aggregate, bake the green electrodes, and test their properties.

Technical information

Function:	Production of Bench Scale Electrodes
Maximum Temperature:	180°C
Sample:	Electrode Paste up to 8 kg
Installation:	Floor standing under Fume hood
Dimensions (LxWxH):	
Furnace	125 x 82 x 180 mm
Mixer	162 x 82 x 210 mm
Press	122 x 82 x 220 mm
Weight:	
Furnace	260 kg
Mixer	510 kg
Press	550 kg
Electrical Property:	
Furnace	400 V 3/N/PE, 50 Hz 3.4 kW, 8.5 A
Mixer	400 V 3/N/PE, 50 Hz 7.1 kW, 18 A
Press	400 V 3/N/PE, 50 Hz 1.5 kW, 4 A
Database Connection:	No

Additional Recommended Equipment:
Baking Furnace (RDC–164 or RDC–167)
Test equipment for analysis
Weighing scale with an accuracy of 0.1 g

RDC-163

Name **WETTABILITY & WETTING POWER**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The manufacturing of high-quality electrodes requires a good interaction between the dry aggregate and the binder. Analysis of the individual raw material properties only does not provide direct information regarding the wetting behavior of a specific granular carbon with a specific binder material.
The RDC-163 apparatus can be used for evaluating the Wettability of a coke (with use of a standard pitch) or the Wetting Power of a pitch binder (with use of a standard coke). For this purpose, a given mass of pitch is added to the top of the coke sample in a cylinder, firstly tapped for a given number of strokes in the bulk volumeter and then placed in a preheated air-forced cabinet for a given period of time. After cooling down, the weight of coke agglomerated with pitch is determined by calculating the Wettability or the Wetting Power [-].

Technical information

Property:	
Wettability	[-]
Wetting Power	[-]
Sample:	15 g of coke (0.5–0.25 mm) 5 g of pitch (2–1 mm)
Process Time:	~ 3 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	
Bulk Volumeter	35 x 35 x 40 cm
Air Forced Cabinet	90 x 64 x 70 cm
Weight:	
Bulk Volumeter	14 kg
Air Forced Cabinet	38 kg
Electrical Property:	
Bulk Volumeter	230 V 1/N/PE, 50 Hz 0.05 kW, 0.2 A
Air Forced Cabinet	230 V 1/N/PE, 50 Hz 1.6 kW, 7.5 A
Certified Reference Material:	RDC 1163
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.01 g
Crusher (< 1.5 mm)
Sieving machine (2, 1, 0.5 and 0.25 mm sieves)

RDC 1163

Technical information
Weight per unit: 800 g
Number of tests: 53

Technical information
Weight per unit: 150 g
Number of tests: 30

RDC-164

Name **FURNACE BF12**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Performing raw material or electrode evaluations under laboratory conditions is necessary in terms of time consumption and cost optimizations. For this purpose, the RDC-164 apparatus can be used for the calcination or baking of different materials under well-controlled laboratory conditions.
In the case of green coke, a vertical shaft kiln calcination can be simulated, or a specific calcination degree can be achieved for a semi-calcined coke. This furnace can also be used for the baking of green electrodes or electrodes produced at the bench scale (see RDC-161). Depending on the application, typical calcination and baking curves with given heat-up rates are already programmed, the goal being to reach typical calcination or baking temperature. Custom-made heating curves can also be implemented for research projects, such as simulating the impact of the final baking temperature on the electrode quality in well-controlled conditions or creating calibration curves for comparison with the real production (for instance, for evaluating the temperature distribution of a baking furnace).
Approximately 4 kg of green coke or ten electrode cores with Ø50 mm can be loaded in one batch. The electrode samples or the green coke bucket are surrounded by packing material to prevent any air oxidation. The equipment is supplied with a tar incinerator unit for fume treatment purposes.
When a greater quantity of material is needed, the RDC-167 furnace is an option instead of the RDC-164 furnace.

Technical information

Function:	Calcination of green coke or baking of electrodes
Maximum Temperature:	1100°C
Sample:	Bench scale electrodes or green coke
Process time:	~ 70 hours
Installation:	Floor standing under fume hood
Dimensions (LxWxH):	130 x 80 x 196 cm
Weight:	380 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 8 kW, 20 A
Fluid Property:	Air, 3000 l/h, 3–7 bar
Database Connection:	No

Additional Recommended Equipment:
Test equipment for analysis
Bench Scale Anode Production (RDC–161)
Weighing scale with an accuracy of 1 g

RDC-165

Name

SÖDERBERG BAKING FURNACE BF12

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

For the quality control of Söderberg paste used in the aluminium or arc furnaces industries, some properties can be measured on the green paste itself, while others require the production of baked pilot electrodes.
These Söderberg pilot electrodes can be baked with the RDC-165 apparatus, in which a metallic bucket is placed that contains the green Söderberg paste. The temperature is increased according to a specific heat-up schedule. A given pressure is applied to the paste to ensure a density level like the real production conditions, the sample is protected with packing material to avoid any air oxidation during the heat treatment. The equipment is supplied with a tar incinerator unit for fume treatment purposes.
After baking, the metallic bucket that holds the baked pilot electrode can be removed and up to five core samples with 50 mm diameter can be drilled for analysis purposes by using the RDC-179 Pilot Core Drilling Machine.

Technical information

Function:	Baking of Söderberg paste
Maximum Temperature:	1100°C
Sample:	Söderberg paste
Process Time:	~ 60 hours
Installation:	Floor standing under fume hood
Dimensions (LxWxH):	130 x 80 x 196 cm
Weight:	380 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 8 kW, 20 A
Fluid Property:	Air, 3000 l/h, 5–7 bar
Database Connection:	No

Additional Recommended Equipment:
Pilot Core Drilling Machine (RDC–179)
Test equipment for analysis
Weighing scale with an accuracy of 1 g
Oven (min. temperature 200° C)

RDC-167

Name **PILOT BAKING FURNACE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Performing raw material or electrode evaluations under laboratory conditions is necessary in terms of time consumption and cost. For this purpose, the RDC-167 apparatus can be used for the calcination or baking of different materials under well-controlled laboratory conditions.
In the case of green coke, a shaft kiln calcination can be simulated, or a specific calcination degree can be achieved for a semi-calcined coke. This furnace can also be used for the baking of green electrodes, or electrodes produced at the pilot scale (see RDC-161 and RDC-160). Depending on the application, typical calcination and baking curves with given heat-up rates are already programmed, the goal being to reach typical calcination or baking degrees. Custom-made heating curves can also be implemented for research projects, like simulating the impact of the final baking temperature on the electrode quality in well-controlled conditions, or creating calibration curves for comparison to the real production (for instance for evaluating the temperature distribution of a baking furnace).
70 kg of green coke or 100 cores with a 50 mm diameter, or six pilot electrodes with 146 mm diameter can be loaded in one batch. The electrode samples or the green coke bucket is surrounded by packing material to prevent any air oxidation.
When a smaller quantity of material shall be baked or calcined, the RDC-164 Furnace BF12 could be an option instead of the RDC-167 Pilot Baking Furnace.

Technical information

Function:	Calcination of green coke or baking of electrodes
Maximum Temperature:	1100°C
Sample:	Electrodes or green coke
Process Time:	~ 70 hours
Installation:	Floor standing under fume hood
Dimensions (LxWxH):	252 x 172 x 338 cm
Weight:	~ 2500 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 24 kW, 60 A
Database Connection:	No

Additional Recommended Equipment:
Pilot Press (RDC-160)
Bench Scale Anode Production (RDC-161)
Pilot Core Drilling Machine (RDC–179)
Test equipment for analysis
Weighing scale with an accuracy of 1 g

RDC-168

Name

HARDGROVE GRINDABILITY & PULVERIZING FACTOR

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

For the green electrode preparation, fines must be produced by milling from the initial raw materials in the paste plant. For this purpose, the hardness of the material is a crucial factor. Changes can lead to variations of the resulting fineness of the fines or of the mill throughput, which can lead to disturbances in the plant and can cause inferior electrode quality. In addition, the hardness, combined with the measurement of the volatile matter (see equipment RDC-175), gives the possibility to estimate the nature of a coke (isotropic, anode grade, or anisotropic microstructures).

The measurement is conducted with the RDC-168 apparatus, where a prepared sample with a given grain size fraction is subjected to a milling operation with steel balls for a given number of revolutions. In a second step, the sample is taken out and the quantity of fines < 75 µm is determined by using an air forced sieving machine. This weight is used for the calculation of the Hardgrove grindability index (HGI) or of the pulverizing factor.

The HGI is normally used for the measurement of green cokes, while the pulverizing factor is used for calcined coke to increase the sensitivity of the test. The same equipment can be used for both properties; the only differences being the initial grain size of the sample, the number of revolutions and the calculation of the final result.

Technical information

Standard Method:	ISO 5074
Property:	
Pulverizing Factor	[-]
Hardgrove Grindability Index	[-]
Sample:	50 g of granular carbon (1–0.5 or 1.18–0.6 mm)
Process Time:	~ 15 minutes
Installation:	
Hardgrove Mill and Air Jet Sieve	Workbench
Vacuum Cleaner	Floor standing
Dimensions (LxWxH):	
Hardgrove Mill	60 x 40 x 62 cm
Air Jet Sieve	40 x 50 x 40 cm
Vacuum Cleaner	40 x 65 x 60 cm
Weight:	
Hardgrove Mill	90 kg
Air Jet Sieve	18 kg
Vacuum Cleaner	14 kg
Electrical Property:	
Hardgrove Mill	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Air Jet Sieve	230 V 1/N/PE, 50 Hz 1.5 kW, 6.6 A
Certified Reference Material:	RDC 1168
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g
Drying oven (min. temperature 110°C)
Crusher (< 1.5 mm)
Sieving machine (1.16, 1, 0.6 and 0.5 mm sieves)

RDC 1168

Technical information

Weight per unit:	700 g
Number of tests:	14

RDC-169

Name **FURNACE FOR ASH CONTENT**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Impurities present in the different raw materials and in the final products have a significant impact on the entire process. Depending on the type of impurities, their presence can lead to potential issues in terms of metal quality, carbon and energy consumption, current efficiency, or environmental pollution. The exact chemical composition should be determined by X-Ray fluorescence (XRF), while the sum of all impurity compounds corresponds to the ash content. It is the first indication of the material overall purity.

The ash content can be measured by using the RDC-169 furnace, where a given quantity of milled sample is placed in a furnace at a high temperature for a given period of time to burn it. At the end of the test, the residual material is weighted; it corresponds to the ash content in the sample. Up to fifteen samples can be loaded in the furnace.

Technical information

Standard Method:	ISO 8005 or ISO 8006
Property: Ash Content	[%]
Sample:	2 g of powder (< 63 µm) or 4 g of pitch (< 0.25 mm)
Process Time:	~ 12 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	68 x 78 x 54 cm
Weight:	80 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 5.5 kW, 14 A
Certified Reference Material:	RDC 1169
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.0001 g
Drying oven (min. temperature 110°C)
Crusher (< 4 mm)
Vibratory mill (< 63 µm)
Desiccator
Oil content (RDC–176 or RDC–208)

RDC 1169

Technical information

Weight per unit:	150 g
Number of tests:	30

RDC-170

Name **FRACTIONATED DISTILLATION**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

During the baking of the carbon electrodes, the binder pitch is converted into pitch coke with a more ordered structure. During this process, volatile compounds from the binder are released, which substantially increases the porosity in the baked electrodes. Due to the very complex molecular structure of the pitch, vapors evolve at different temperature ranges, and the heat-up rate in the baking furnace must be adapted accordingly to avoid increased porosity or electrode cracking. Determining the different fractions of volatiles allows a prediction for the adjustment of the baking process. In addition, defining the quantity of low molecular weight fractions can give an indication of possible pitch contamination or the addition of solvent.

The measurement is conducted with the RDC-170 apparatus, where a pitch sample is heated with a given heat-up rate, while the quantity of volatiles is measured for two temperature levels of 270°C and 360°C. The weight of volatiles is expressed as a percentage of the initial sample weight to calculate the fractionated distillation up to 270°C and to 360°C.

Technical information

Standard Method:	ASTM D2569
Property: Fractionated Distillation	[%]
Sample:	100 g of pitch (< 4 mm)
Process Time:	~ 45 minutes
Installation:	Workbench under fume hood
Dimensions (LxWxH):	86 x 24 x 72 cm
Weight:	8 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.3 kW, 1.3 A
Database Connection:	No
Consumable:	Propane

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.01 g
Oven for cleaning (min. temperature 550°C)
Crusher (< 4 mm)

RDC-171

Name **QUINOLINE INSOLUBLE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The quality of the pitch binder used during the electrode production has a strong impact on the final electrode quality. To characterize it, different solvents, mainly quinoline and toluene, are used for evaluating the composition of different fractions:

- Alpha resins: corresponding to the heavy fraction or the quinoline insoluble
- Gamma resins: corresponding to the light fraction or toluene soluble (determined with RDC-172 apparatus).
- Beta resins: corresponding to the intermediate fraction (calculated from the difference of the toluene insoluble and the quinoline insoluble).

The measurement is conducted with the RDC-171 apparatus. A given mass of a pitch sample is heated and dissolved in hot quinoline, before being filtered under vacuum. After drying, the quantity of undissolved particles remaining on the filter is weighed to calculate the quinoline insoluble content expressed as a percentage of the initial sample weight.

Technical information

Standard Method:	ISO 6791
Property: Quinoline Insoluble	[%]
Sample:	1 g of pitch (< 0.25 mm)
Process Time:	~ 3 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	50 x 30 x 100 cm
Weight:	16 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.15 kW, 0.7 A
Database Connection:	No
Consumable:	Quinoline Toluene

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.001 g
Oven for cleaning (min. temperature 550°C)
Oven (min. temperature 140°C)
Crusher (< 4 mm)
Hot plate

RDC-172

Name **TOLUENE INSOLUBLE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The quality of the pitch binder used during the electrode production has a strong impact on the final electrode quality. To characterize it, different solvents, mainly quinoline and toluene, are used for evaluating the composition of different fractions:

- Alpha resins: corresponding to the heavy fraction or the quinoline insoluble (determined with RDC-171 apparatus).
- Gamma resins: corresponding to the light fraction or toluene soluble (100% - toluene insoluble).
- Beta resins: corresponding to the intermediate fraction (calculated from the difference of the toluene insoluble and the quinoline insoluble).

The measurement is conducted with the RDC-172 apparatus. A given mass of a pitch sample is heated and dissolved in hot toluene, before being filtered under vacuum. After drying, the quantity of undissolved particles remaining on the filter is weighed to calculate the toluene insoluble content expressed as a percentage of the initial sample weight.

Technical information

Standard Method:	ISO 6376
Property: Toluene Insoluble	[%]
Sample:	1 g of pitch (< 0.25 mm)
Process Time:	~ 3 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	50 x 30 x 100 cm
Weight:	16 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.15 kW, 0.7 A
Database Connection:	No
Consumable:	Toluene

Additional Recommended Equipment:

Weighing scale with an accuracy of 0.001 g
Oven for cleaning (min. temperature 550°C)
Oven (min. temperature 140°C)
Crusher (< 4 mm)
Hot plate

RDC-173

Name **WATER CONTENT PITCH**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Depending on the production process of pitch and its storage conditions, moisture can be present in solid pitch. When this happens, the excess water is removed when the solid pitch is processed in the mixer of the electrode paste plant, leading to lower mixing efficiency and higher energy consumption. In addition, from a commercial point of view, the presence of water in a pitch shipment would mean buying water at a very high price.

The measurement is conducted with the RDC-173 apparatus with an azeotropic distillation method. A given weight of pitch sample is boiled with xylene under reflux, while the present water is collected in a graduated cylinder. At the end of the test, the volume of water with a known density is used for calculating the water content expressed as a percentage of the initial sample weight.

Technical information

Standard Method:	ISO 5939
Property:	
Water Content	[%]
Sample:	100 g of pitch (< 4 mm)
Process Time:	~ 2 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	50 x 30 x 100 cm
Weight:	9 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.3 kW, 1.3 A
Fluid Property:	Water
Database Connection:	No
Consumable:	Xylene Distilled water

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g
Crusher (< 4 mm)
Oven for cleaning (min. temperature 550^{0}C)

RDC-174 Name ANODE BINDER CONTENT

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

To reach an optimum and stable electrode quality level, one of the main and important process parameter to determine the optimum binder content for a given dry aggregate recipe. This is not an easy task to perform, as almost all process steps can be of influence. Finding this optimum requires steady process conditions and ideally a process optimization (see RDC-160 equipment for more information). For research & development purposes, it is of interest to determine the actual binder content of a green paste or of a green electrode.
The measurement is conducted with the RDC-174 apparatus, where a given mass of green electrode or paste sample is washed by hot quinoline until all the binder is dissolved. The binder content is calculated as the dissolved part expressed as a percentage of the initial sample weight. To increase the accuracy of the test, the quinoline insoluble, measured with the RDC-171 equipment, needs to be considered.

Technical information

Standard Method:	ISO 14423
Property:	
Binder Content	[%]
Maximum Temperature:	250°C
Sample:	200 g of green electrode (< 8 mm)
Process Time:	~ 2 days
Installation:	Workbench under fume hood
Dimensions (LxWxH):	30 x 35 x 105 cm
Weight:	9 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.3 kW, 1.3 A
Fluid Property:	Water
Database Connection:	No
Consumable:	Quinoline

Additional Recommended Equipment:
Quinoline Insoluble (RDC–171)
Weighing scale with an accuracy of 0.01 g
Oven (min. temperature 140°C)
Oven for cleaning (min. temperature 550°C)
Desiccator

RDC-175

Name

FURNACE FOR VOLATILE MATTER

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

Green coke from the petroleum or pitch industry firstly needs to be calcined before it can be used as a raw material for electrode production. The aim of the calcination is to remove the water and light compounds that would be detrimental for the electrode quality. The quantity of these light compounds corresponds to the volatile content. It has a substantial influence on the resulting calcined coke porosity depending also on the calcination technology. The information of the volatile content combined with the Hardgrove grindability index (see equipment RDC-168) gives the possibility to estimate the nature of a green coke (isotropic, anode grade, or anisotropic microstructures).

The measurement is conducted with the RDC-175 furnace, where a given mass of a milled sample is heated up to 900°C in a crucible for a given period of time. At the end of the test, the weight loss is expressed as a percentage of the initial weight to calculate and report the volatile content.

Technical information

Standard Method:	ISO 9406
Property: Volatile Matter	[%]
Sample:	2 g of granular carbon (< 0.25 mm)
Process Time:	~ 45 minutes
Installation:	Workbench under fume hood
Dimensions (LxWxH):	68 x 78 x 54 cm
Weight:	80 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 5.5 kW, 14 A
Database Connection:	No

Additional Recommended Equipment:

Weighing scale with an accuracy of 0.001 g
Crusher (< 1.5 mm)
Sieving machine (0.25 mm sieve)
Desiccator
Drying oven (min. temperature 110°C)

RDC-177

Name **DUST FORMING FACTOR**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Handling of calcined coke potentially creates dust emission during loading and transportation, especially when its grain size distribution is fine. To prevent this, a dedusting agent is usually added after calcination. To optimize the quantity of oil necessary for limiting dust emissions, the dusting propensity of a specific calcined coke should be determined.
The measurement is conducted with the RDC-177 apparatus, where a given mass of sample is placed. A valve allows the sample to fall into a chamber, while an airflow carries the finest particles to a filter on top of the equipment. The dust forming factor is calculated and reported as the percentage of dust in the filter compared to the initial sample weight.

Technical information

Property:	
Dust Forming Factor	[%]
Sample:	100 g of granular carbon (natural < 4 mm)
Process Time:	~ 5 minutes
Installation:	Fix on a wall
Dimensions (LxWxH):	26 x 36 x 81 cm
Weight:	30 kg
Fluid Property:	Air, 300 l/h, 3–7 bar
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.0001 g
Oven (min. temperature 110°C)
Desiccator
Sieving machine (4 mm sieve)

RDC-178

Name **FURNACE FOR COKING VALUE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

During the production of electrodes, binder pitch is added to a dry aggregate recipe to form green blocks that are then baked. During baking, the binder pitch is converted to pitch coke; the aim being to retain as much carbon as possible in the electrode to ensure a high density level. The coking value is one of the key properties to qualify a pitch. It corresponds to the measurement of the residual carbon from the pitch after its cokefaction.

The measurement is conducted with the RDC-178 apparatus, where a pitch sample will be heated up to 550°C under controlled conditions in a crucible, to remove its volatile compounds. The residual material during this cokefaction process is used for the calculation of the coking value and expressed as a percentage of the initial sample weight.

Technical information

Standard Method:	ISO 6998
Property:	
Coking Value	[%]
Sample:	1 g of pitch (< 0.25 mm)
Process time:	~ 4 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	68 x 78 x 54 cm
Weight:	80 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 5.5 kW, 14 A
Database Connection:	No

Additional Recommended Equipment:

Weighing scale with an accuracy of 0.0001 g
Crusher (< 4 mm)
Desiccator
Sieving machine (0.25 mm sieve)

RDC-179

Name **PILOT CORE DRILLING MACHINE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The evaluation of raw materials, green pastes and electrodes under laboratory conditions is advantageous in terms of time consumption and cost optimizations. The pilot electrodes can be prepared with the RDC-160 and RDC-165 equipment. To obtain samples for the measurement of their properties, the baked pilot electrodes need to be core drilled, the aim being to obtain samples with a 50 mm diameter and a length of approximately 200 mm.

The core drilling is conducted with the RDC-179 apparatus, where the pilot electrode is first clamped. A core bit, driven by an electrical motor, automatically drills a core sample with a given speed, while water is sprayed to ensure a smooth core geometry and surface. No further operation from the operator is required, except for placing the electrode in the right position for drilling. After drilling, the cores are ready for the cutting operation (see equipment RDC-140, RDC-148 and RDC-149), depending on the properties to analyze.

Technical information

Function:	Drilling of cores in pilot electrodes
Sample:	Pilot electrode up to Ø 180 mm x 200 mm
Process Time:	~ 5 minutes
Installation:	Floor standing
Dimensions (LxWxH):	140 x 80 x 316 cm
Weight:	465 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 2.2 kW, 5.5 A
Fluid Property:	Water, 480 l/h, 3–7 bar
Database Connection:	No

Additional Recommended Equipment:
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)
Test equipment for analysis

RDC-180

Name **BENCH DRILLING MACHINE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The anode air reactivity is measured with the RDC-151 equipment. For this test, a center hole of a given depth is required in the face side of the sample.
The center hole can be drilled with the RDC-180 apparatus. It consists of a drilling machine specifically adjusted to meet the geometry requirements of the air reactivity test.

Technical information

Function:	Sample preparation for RDC–151
Sample:	Core Ø50 x 60 mm
Process Time:	~ 1 minute
Installation:	Workbench
Dimensions (LxWxH):	23 x 39 x 84 cm
Weight:	27 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.54 kW, 2.5 A
Database Connection:	No

Additional Recommended Equipment:
Air Reactivity Anode (RDC–151)
Vacuum cleaner

RDC-181

Name **TUMBLING APPARATUS**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The anode CO_2 and air reactivities are measured with the RDC-146 and RDC-151 equipment respectively. After cooling down to ambient temperature, any loosely bound particles on the residual sample have to be removed to quantify the dusting propensity.
The removal of the loosely bound particles is conducted with the RDC-181 apparatus, where the residual core sample is tumbled with steel balls for a given number of revolutions.
RDC–181 is available with 2 or 6 tumbling units.

Technical information

Standard Method:	ISO 12988–1, ISO 12989–1
Sample:	Core Ø50 x 60 mm after reactivity testing
Process Time:	~ 25 minutes
Installation:	Workbench
Dimensions (LxWxH):	72 x 62 x 45 cm
Weight:	65 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.2 kW, 1 A
Database Connection:	No

Additional Recommended Equipment:
CO_2 Reactivity Anode (RDC–146)
Air Reactivity Anode (RDC–151)

RDC-182

Name **METTLER SAMPLE PRESS**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The measurement of the softening point Mettler is conducted with the RDC-159 equipment. The sample preparation for performing this test can be done in a simple and efficient way by pressing the solid pitch into a small cup.
The pitch sample is prepared with the RDC-182 apparatus, where a given quantity of pitch is pressed under specific conditions into a cup that can then be placed and measured in the RDC-159 equipment.

Technical information

Function:	Sample preparation for RDC–159
Sample:	~ 1 g of pitch (2–1 mm)
Process Time:	~ 5 minutes
Installation:	Workbench
Dimensions (LxWxH):	40 x 40 x 44 cm
Weight:	35 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.4 kW, 1.8 A
Database Connection:	No

Additional Recommended Equipment:
Softening Point Mettler (RDC–159)
Weighing scale with an accuracy of 0.1 g
Crusher (< 4 mm)
Sieving machine (2 and 1 mm sieves)

RDC-185

Name **PASTE FLOWABILITY**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

Söderberg pastes are used in the aluminium and arc furnaces industries. In contrast to prebaked technology where anodes must regularly be replaced, the Söderberg technology is a continuous process. Green carbon paste is added to the top of the cell or of the furnace. During its consumption, the fresh paste is moving down to the hot zone of the furnace and is baked in situ with the process heat. Given by the process, the flowability of the paste is an important property to ensure constant electrode quality with smooth and stable operations.
The measurement is conducted with the RDC-185 apparatus, where the deformation of a paste cylinder is measured after being exposed to a specific temperature for a given time. The equipment includes a table and molds for the preparation of the paste cylinders. It is also equipped with weights that can be applied to the sample during the test to increase the sensitivity for dry Söderberg pastes.

Technical information

Property:	
Flowability	[%]
Sample:	~ 500 g of Söderberg paste
Process Time:	~ 3 hours
Installation:	
Furnace	Workbench
Sample Preparation Table	Floor standing
Dimensions (LxWxH):	
Furnace	70 x 67 x 72 cm
Sample Preparation Table	80 x 60 x 95 cm
Weight:	
Furnace	75 kg
Sample Preparation Table	275 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 3.3 kW, 14.4 A
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g

RDC-187

Name **FLEXURAL STRENGTH**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

Low mechanical strength of the electrodes, as well as the presence of cracks inside the blocks, are detrimental to the electrode performance during its use. A low flexural strength potentially results in a low thermal shock resistance. The blocks can break when they are loaded from ambient temperature to the hot cells. In addition, measuring the flexural strength combined with other properties can give valuable information about the optimization of production process parameters.
The measurement is conducted with the RDC-187 apparatus, where an increasing load is applied to the center (three points method) of a core sample with a 50 mm diameter and 130 mm length until it breaks. The maximal load applied to the sample and the cross section are used to calculate the flexural strength in MPa.

Technical information

Standard Method:	ISO 12986–1
Property: Flexural Strength	[MPa]
Sample:	Core Ø50 x 130 mm
Process Time:	~ 2 minutes
Installation:	Workbench
Dimensions (LxWxH):	60 x 55 x 56 cm
Weight:	87 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Database Connection:	Yes

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)

RDC-188

Name **HARDNESS TESTER**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

Depending on their reactivity levels, prebaked anodes can be attacked by CO_2 and air gases during their use in the electrolysis cell. When a strong burning occurs, the porosity of the anodes increases and soft anode butts are created. Recycling this material will make the next anode generation even more reactive. A vicious circle then starts, with consequences such as increased carbon consumption, carbon dusting, spikes, pot instability and reduced current efficiency.
Measuring the butts hardness is an efficient tool to timely react to a deterioration of the anode butts quality. The measurement is conducted with the RDC-188 hardness tester, which consists of measuring the penetration depth of two steel pins into the anode butts surface.

Technical information

Property:	
Hardness	[mm]
Sample:	Full anode butts
Process Time:	~ 2 minutes
Installation:	Portable
Dimensions (LxWxH):	25 x 25 x 10 cm
Weight:	1 kg
Database Connection:	No

RDC-193

Name **RAPOPORT SWELLING TEST**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The resistance towards the deterioration of cathode carbon materials, used as bottom blocks of an aluminium electrolysis cell, following an attack by sodium and electrolyte is one of the predominant properties affecting the lifetime of a cell. The knowledge of the cathode expansion due to sodium penetration is essential for the optimization of the cell design. The Rapoport expansion test has specifically been developed for this purpose.

The measurement is conducted with the RDC-193 apparatus, consisting of a small electrolysis reduction cell where the length change of the cathode material can be measured. A cathode sample with a diameter of 30 mm and a length of 60 mm is placed into a graphite crucible surrounded by electrolyte bath with a given cryolite ratio. After heating the furnace to 980°C, the electrolysis process is started for a given period of time and the length change of the cathode sample is recorded. The Rapoport expansion is calculated as the maximum expansion expressed as a percentage of the initial length of the sample.

Technical information

Standard Method:	ISO 15379–1
Property:	
Rapoport Expansion	[%]
Sample:	Cathode Ø30 x 60 mm
Process Time:	~ 24 hours
Installation:	Floor standing under fume hood
Dimensions (LxWxH):	120 x 80 x 190 cm
Weight:	530 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 2 kW, 9 A
Fluid Property:	Argon, 100 l/h, 10 bar
Database Connection:	No
Consumable:	Standard bath granulates

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Drying oven (min. temperature 180°C)

RDC-194

Name **RAMMING BEHAVIOUR**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

The bottom of aluminium electrolysis cells is lined with cathode blocks that are sealed with a ramming paste to avoid any leakage. When lining a cell, the green paste is directly rammed between the cathode blocks and baked in situ during the start-up of the pot with the process heat. The quality of the paste is of primary importance to ensure long operation without disturbances. For this purpose, the optimum temperature at which the paste must be rammed, called the temperature windows, should be determined. To measure the properties of the paste (such as the green apparent density and the paste shrinkage), a cylinder must first be prepared.
The paste cylinder is prepared with the RDC-194 apparatus, which is an automatic ramming device combined with software for result calculation and interpretation. A given quantity of paste is placed in the sample preparation mold and is then rammed for a specific number of strokes. The change in height in function of the number of strokes during the test is recorded. This operation is repeated for at least three different paste temperature levels. This allows the software to automatically calculate the optimum temperature range at which the paste shall be rammed. Alternatively, a special mode can be selected for performing a sample preparation only for the RDC-195 Paste Shrinkage equipment.

Technical information

Standard Method:	ISO 17544
Function:	Sample preparation for RDC–195
Property:	
Temperature Window	[°C]
Sample:	Ramming paste
Process Time:	~ 15 minutes
Installation:	
Ramming device	Floor standing
Control box	Workbench
Dimensions (LxWxH):	
Ramming device	69 x 56 x 164 cm
Control box	56 x 50 x 34 cm
Weight:	
Ramming device	196 kg
Control box	24 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 0.5 kW, 2.2 A
Database Connection:	Yes

Additional Recommended Equipment:
Paste Shrinkage (RDC–195)
Weighing scale with an accuracy of 0.1 g
Oven or refrigerator

RDC-195

Name **PASTE SHRINKAGE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The bottom of aluminium electrolysis cells is lined with cathode blocks that are sealed with a ramming paste to avoid any leakage. When lining a cell, the green paste is directly rammed between the cathode blocks and baked in situ during the start-up of the pot with the process heat. The quality of the paste is of primary importance as to ensure long operation without disturbances. As the baking of the paste is performed during its usage, it is important to know the dimensional changes of the paste from its solidification up to when the final temperature is reached.

The measurement is conducted with the RDC-195 apparatus, where a green paste sample with 50 mm diameter and 50 mm height (prepared with the RDC-183 or RDC-194 equipment) is placed in a furnace at room temperature under an inert atmosphere. The temperature is increased up to 950°C while the length change of the paste sample is recorded. The expansion of the paste between the point where it became non-plastic, which depends on the binder type, to the point at the maximum temperature, is used for the calculation of the paste shrinkage and expressed as a percentage of the initial sample length. In addition, the length change during a holding period at the maximum temperature can also be recorded.

Technical information

Standard Method:	ISO 14428
Property: Paste Shrinkage	[%]
Sample:	Rammed core Ø50 x 50 mm
Process Time:	~ 24 hours
Installation:	Floor standing under fume hood
Dimensions (LxWxH):	95 x 60 x 195 cm
Weight:	180 kg
Electrical Property:	230 V 1/N/PE, 50 Hz 2.2 kW, 10 A
Fluid Property:	Argon, 100 l/h, 3-7 bar Air, 1000 l/h, 3–7 bar
Certified Reference Material:	RDC 1195
Database Connection:	Yes

Additional Recommended Equipment:
Ramming device (RDC-194)

RDC 1195

Technical information

Weight per unit:	N/A
Number of tests:	N/A

RDC-200

Name **PNEUMATIC HAMMER AND RAMMING CASE**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

The bottom of aluminium electrolysis cells is lined with cathode blocks that are sealed with a ramming paste to avoid any leakage. When lining a cell, the green paste is directly rammed between the cathode blocks and baked in situ during the start-up of the pot by the process heat. The quality of the paste is of primary importance as to ensure long operation without disturbance. The quality control requires the preparation of pilot electrodes, which can be done with the RDC-160 Pilot Press. To evaluate the cohesion between layers during the ramming procedure, a pilot rammed block should also be produced and tested.

The ramming can be done by using the RDC-200 apparatus, which consists of a ramming case and a pneumatic hammer. The case is filled in several layers of green ramming paste that are then compacted with the pneumatic hammer. When the entire case is filled, the green rammed block can be taken out for baking in the RDC 167 baking furnace. Drilling of core samples in both vertical and horizontal directions by using the RDC-157 drilling machine provides samples that are ready for further measurements of the paste properties.

Technical information

Function:	Rammed block preparation
Sample:	~ 100 kg of green ramming paste
Process Time:	~ 1 hour
Installation:	Floor standing
Dimensions (LxWxH):	120 x 80 x 60 cm
Weight:	250 kg
Fluid Property:	Air, 3–7 bar
Database Connection:	No

Additional Recommended Equipment:
Core Drilling Machine (RDC–157)
Test equipment for analysis
Baking Furnace (RDC–167)

RDC-201

Name **GRAPHITIZATION FURNACE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

To obtain high quality graphite electrodes and cathodes produced from calcined coke, a heat-treatment to a temperature close to 3'000°C is mandatory. The aim of this step is to obtain a graphitized structure of the material, essentially to reach very low electrical resistivity levels. At the production scale, breakage of the electrodes could occur, mainly because of their puffing propensity, when the power curve is not optimized by taking into account the length change of the electrodes during the graphitization process. Knowing in advance the electrode behavior by pilot evaluations is necessary. The graphitization can be conducted with the RDC-201 apparatus, which has the exact same principle as a full-scale lengthwise graphitization furnace. A column of sample core with a diameter of 50 mm and a total length of 470 mm is clamped between two graphite electrodes with a specific pressure. The heat-up rate is automatically controlled by the regulation of the electrical current flowing through the column of samples. Specific heat-up schedules can be defined up to a maximum temperature of 3'000°C and a heat-up rate up to approximately 500°C/h. During the entire process, the length change of the column is measured and recorded. In addition, the column can be replaced by a graphite box to graphitize granular carbon samples (approximately 500 g per run depending on the bulk density of the material). After the graphitization step, the materials are ready for the measurement of their properties.

Technical information

Function:	Graphitization
Property:	Length change vs temperature curve
Maximum Temperature	3000°C
Sample:	Electrode cores Ø50 x max. 470 mm
Process Time:	~ 48 hours
Installation:	Floor standing
Dimensions (LxWxH):	410 x 370 x 510 cm
Weight:	5500 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 100 kW, 160 A
Fluid Property:	Air, 6–8 bar Argon, 50 l/h, 4–6 bar
Database Connection:	No

Additional Recommended Equipment:
Core Drilling Machine (RDC–157)
Resiflex (RDC-147)
Saw (RDC–148)
Drying oven (min. temperature 180°C)
Test equipment for analysis

RDC-204

Name **FURNACE FOR WATER CONTENT COKE**

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

Due to the cutting operation when removing the material from the delayed coker drums, green cokes usually show a high water content. This excess water would be removed during the calcination step, which would increase the fuel consumption or reduce the calcination degree of the coke. Depending on the storage and shipment conditions, calcined cokes could also potentially contain some moisture. In addition, from a commercial point of view, the presence of water in the green or calcined coke would mean buying water at a very high price. Last but not least, any moisture must be removed before performing any material analysis.

For this purpose, the water content in granular carbon can be measured and moisture can be removed by using the RDC-204 apparatus. A given quantity of granular carbon sample is weighted and heated in a furnace at a specific temperature for a given period of time. The weight loss is measured and expressed as a percentage of the initial sample weight for the calculation of the water content.

Technical information

Standard Method:	ISO 11412
Property:	
Water Content	[%]
Sample:	Max. 5 kg of granular carbon
Installation:	Workbench
Process Time:	~ 14 hours
Dimensions (LxWxH):	57 x 64 x 82 cm
Weight:	55 kg
Electrical Property:	230 V 3/N/PE, 50 Hz 3 kW, 13 A
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g

RDC-208

Name

OIL CONTENT HEATING METHOD

Material type

GRANULAR
PITCH
ELECTRODES
LINING

Utilization

R&D
IN-PLANT
LAB

General description

Handling of calcined coke potentially creates dust emission during loading and transportation, especially when its grain size distribution is fine. To prevent this, a dedusting agent is usually added after calcination. Excessive addition of dedusting oil creates devolatilization problems during baking of the electrodes. A correct oil content is thus mandatory for a smooth production. In addition, the presence of oil can influence other testing procedures, such as the real density or the specific electrical resistance. Therefore, removing any dedusting agent should always be part of the typical sample preparation.
The thermal removal of the oil can be conducted with the RDC-208 apparatus, where the oil present in the calcined coke is burnt. After the test, the losses are expressed as percentage of the initial sample weight for the calculation of the oil content.
The dusting propensity of a calcined coke can be tested with the RDC-177 equipment to determine the requirement of dedusting agent.
Alternatively, the RDC-176 equipment can be used for the same purpose.

Technical information

Standard Method:	ISO 6997
Property:	
Oil Content	[%]
Sample:	80 g of granular carbon (< 4 mm)
Process Time:	~ 5 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	68 x 78 x 54 cm
Weight:	80 kg
Electrical Property:	400 V 3/N/PE, 50 Hz 5.5 kW, 14 A
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.001 g
Crusher (< 4 mm)

EXT-100

Name **BROOKFIELD VISCOMETER**

Material type
- GRANULAR
- **PITCH**
- ELECTRODES
- LINING

Utilization
- R&D
- IN-PLANT
- **LAB**

General description

The viscosity of a binder is one of its main properties, as it has a strong impact on the mixing and forming steps of the electrode production, and ultimately on the final electrode quality. The viscosity is a function of the temperature. Defining its value for given temperature levels is the basis to determine the optimum mixing and forming temperatures to obtain a constant green paste viscosity.

The measurement is conducted with the EXT-100 apparatus, where a given quantity of binder is first heated in an external oven and then placed into the viscosimeter at a regulated temperature level. A spindle turns in the molten sample while the torque on the spindle is used for the calculation of the viscosity in centipoise (cP). Several temperature levels, usually between 140°C and 180°C, are measured to determine the temperature at which a given viscosity level is reached.

Technical information

Standard Method:	ASTM D5018
Measurement:	
Viscosity	[cP]
Maximum Temperature:	300°C
Sample:	9 g of pitch (< 4 mm)
Process Time:	~ 2 hours
Installation:	Workbench under fume hood
Dimensions (LxWxH):	28 x 56 x 56 cm
Weight:	10 kg
Electrical Property:	230 V 3/N/PE, 50 Hz 0.3 kW, 1.3 A
Certified Reference Material:	RDC 1100
Database Connection:	No

Additional Recommended Equipment:
Weighing scale with an accuracy of 0.1 g
Oven (min. temperature 180°C)

RDC 1100

Technical information

Weight per unit:	200 g
Number of tests:	22

EXT-110

Name **GRINDOSONIC MK7**

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Utilization
R&D
IN-PLANT
LAB

General description

To calculate the thermal shock resistance of an electrode, several properties must be measured, such as its thermal conductivity (RDC-143), coefficient of thermal expansion (RDC-158), flexural strength (RDC-187) and elasticity modulus. A good combination of all these properties allows avoiding breakage of the blocks when the cold electrode is subjected to fast heating. Two methods exist for the evaluation of the brittleness of an electrode core: the static elasticity modulus, measured during the compressive strength test (RDC-144), and the dynamic elasticity modulus measured with the EXT-110 Grindosonic apparatus.

This measurement is a non-destructive test where the resonant frequency of a core sample with a 50 mm diameter and 130 mm length is measured and used for the calculation of the dynamic elasticity modulus in GPa according to a specific equation. Almost any sizes of prismatic samples can be measured with this equipment. Moreover, this test is a good indicator as to detect the presence of microcracks.

Technical information

Standard Method:	ISO 18142
Measurement:	
Dynamic Elasticity Modulus	[GPa]
Sample:	Core ∅ 50 x 130 mm
Process Time:	~ 1 minute
Installation:	Workbench
Dimensions (LxWxH):	31 x 29 x 10 cm
Weight:	7 kg
Electrical Property:	230 V 3/N/PE, 50 Hz 0.12 kW, 0.5 A
Database Connection:	No

Additional Recommended Equipment:
Drilling machine (RDC–157 or RDC–179)
Saw (RDC–140 or RDC–148)
Weighing scale with an accuracy of 0.1 g
Drying oven (min. temperature 180°C)

ADDITIONAL CERTIFIED REFERENCE MATERIALS

RDC 1104

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Certified reference material for the control of the crystallite size measured by X-Ray diffractometry

Technical information

Weight per unit:	150 g
Number of tests:	75

RDC 1105

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Certified reference material for the control of the apparent density Péchiney measured by Hg porosimetry

Technical information

Weight per unit:	180 g
Number of tests:	90

P601-P609

Material type
GRANULAR
PITCH
ELECTRODES
LINING

Calibration standards for impurities in coal tar pitch measured by X-Ray spectrometry

Technical information

Weight per unit:	200 g
Number of tests:	20

A501-A514

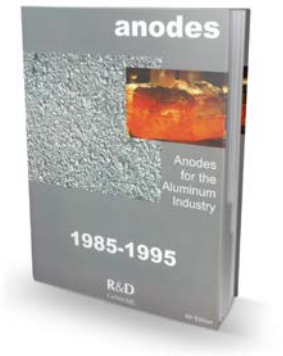
Material type
GRANULAR
PITCH
ELECTRODES
LINING

Calibration standards for impurities in granular carbon and electrodes measured by X-Ray spectrometry

Technical information

Weight per unit:	200 g
Number of tests:	13

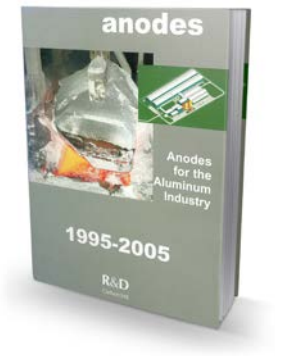
DOCUMENTATION



ANODES FOR THE ALUMINIUM INDUSTRY

1st edition published in 1995
by R&D Carbon Ltd.

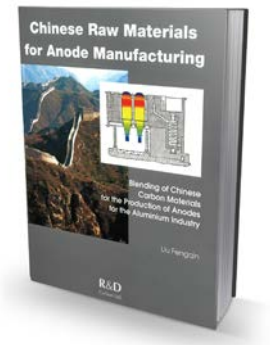
This book contains a compilation of key papers
from 1985 to 1995 about:
› Petroleum coke
› Pitch
› Anode manufacturing
› Anode baking
› Anode behaviour



ANODES FOR THE ALUMINIUM INDUSTRY

2nd edition published in 2006
by R&D Carbon Ltd.

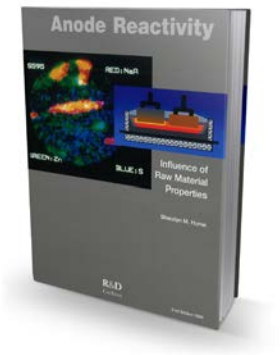
This book contains a compilation of key papers
from 1995 to 2005 about:
› Raw materials (pitch, coke, butts)
› Green anode manufacturing
› Anode baking
› Anode quality
› Environmental aspects
› Anode performance in the cell



CHINESE RAW MATERIALS FOR ANODE MANUFACTURING

Thesis by Liu Fengqin, published in 2004 by R&D Carbon Ltd., ISBN 3-9521028-7-3

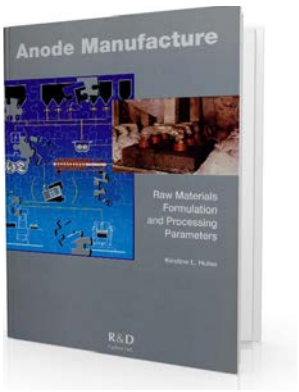
This book contains the results of an investigation carried out by Liu Fengqin from the Zhengzhou Light Metals Research Institute in Zhengzhou, Henan Province in China. The work was sponsored and supported by R&D Carbon Ltd.



ANODE REACTIVITY: INFLUENCE OF RAW MATERIAL PROPERTIES

Thesis by Sheralyn Marie Hume, published in 1999 by R&D Carbon Ltd.
ISBN 3-9521028-2-2

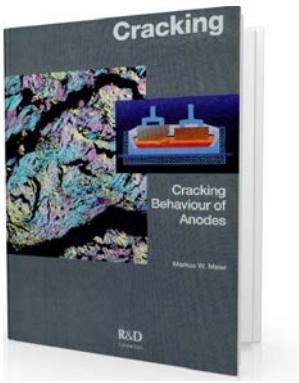
This book contains the results of Dr. Sheralyn M. Hume's thesis for which she received her Ph.D. from the School of Engineering, University of Auckland, New Zealand. The thesis gives a detailed overview from refinery operation and coke calcination to the anode performance in the electrolysis cell.



ANODE MANUFACTURE

Thesis by Kirstine L. Hulse, published in 2000 by R&D Carbon Ltd.
ISBN 3-9521028-5-7

This book contains the results of Dr. Kirstine L. Hulse's thesis for which she received her Ph.D. from the School of Engineering, University of Auckland, New Zealand. This thesis incorporates how different parameters influence anode quality in anode manufacture from the raw materials to the compacted green anode.
Thereby the sensitivity of the process variables from the raw materials and the equipment is investigated with respect to the resulting anode quality.



CRACKING BEHAVIOUR OF ANODES

Thesis by Markus W. Meier, published in 1996 by R&D Carbon Ltd.
ISBN 3-9521028-1-4

This book contains the results of Dr. Markus W. Meier's thesis for which he received his Ph.D. from the Swiss Federal Institute of Technology (ETHZ) in Zürich, Switzerland. The research work allows distinguishing the different cracking mechanism of anodes and demonstrates the influence of raw material quality, process parameters during anode manufacturing and operating conditions in the electrolysis cell on thermal shock resistance of anodes.

DOCUMENTATION

ANODE BAKING

Felix Keller, Peter O. Sulger; published in 2008 by R&D Carbon Ltd.
ISBN 978-2-940348-19-0

Prebaked anodes are vital for aluminum smelters, and anode baking is a crucial step in their production claim. The baking process is decisive for anode quality and cost, and for bake furnace environmental impact. So far there is little reference information available about how performance can be judged and improved.
This book provides the know-how to optimize a bake furnace operation to satisfy current priorities, such as optimum output, quality, cost, or impact on the environment. It presents the facts in such a very that they are easy to apply in daily furnace operation.

Raw material and green anode quality are essential for baked anodes, so the explanations cover these aspects as well.
Although R&D Carbon Ltd. specializes in anodes, our philosophy promotes an integrated approach. It therefore focuses on the interaction between anode manufacture and metal production cost.
For making rational decisions and for choosing priorities, for routine daily operation and for optimizing the process, anode plant and baking plant staff will find this book invaluable.

R&D Carbon

MISSION

R&D Carbon's long experience and intense research in carbon technology provide solid support to our constant quest to improve product quality. RDC substantially contributes to reduce metal production costs, to lower capital investment for production plants and hence reduce greenhouse gas emissions.

SCOPE OF ACTIVITIES

Our multi-disciplinary and laterally-thinking team supplies the worldwide aluminum, steel, petroleum coke, pitch and electrode industries with technical assistance, test equipment, laboratory services and courses to improve the quality of carbon anodes, cathodes and electrodes.

RESEARCH AND DEVELOPMENT

The metals industry must continually adapt to changes in raw material quality and availability, and to technological progress aimed for lowering production cost. We at R&D Carbon Ltd identify these new challenges far in advance through our close contact with production plants and our strong links to other technology providers.

TECHNICAL SERVICES & AUDITS

Our services range from technical support for the production of all carbon materials, to plant audits and process optimizations. In our technology center we conduct pilot or bench scale trials and any kind of laboratory analysis with detailed evaluations. Technical assistance to worldwide active trading companies is an important way to improve anode and cathode qualities supplied to the world market.

BAKE FURNACE PROCESS CONTROL SYSTEM

Anode baking is the most expensive production step. Only a fully automatic process control system can achieve the highest furnace output, the best achievable anode quality, lowest energy consumption, smallest possible workload and minimal emissions.
R&D Carbon has licenced its technology to the chinese firing system supplier AUTOSKY. The new AUTOSKY firing system based on R&D Carbon technology in available as the ARFS Firing System.

TECHNOLOGY DEVELOPMENT

Through our know-how and practical experience in operating and optimizing anode plants for customers all over the world, we have proposed and implemented many modern, efficient concepts and feasibility studies for paste plants and electrode baking furnaces, as well as for technologies of petroleum coke calcination.

TRAINING & COURSES

RDC regularly organizes training courses about anode raw materials, anode production and anode performance in the pots. These training courses are hold in Switzerland and at the smelter locations.

OUR CONTACT DETAILS

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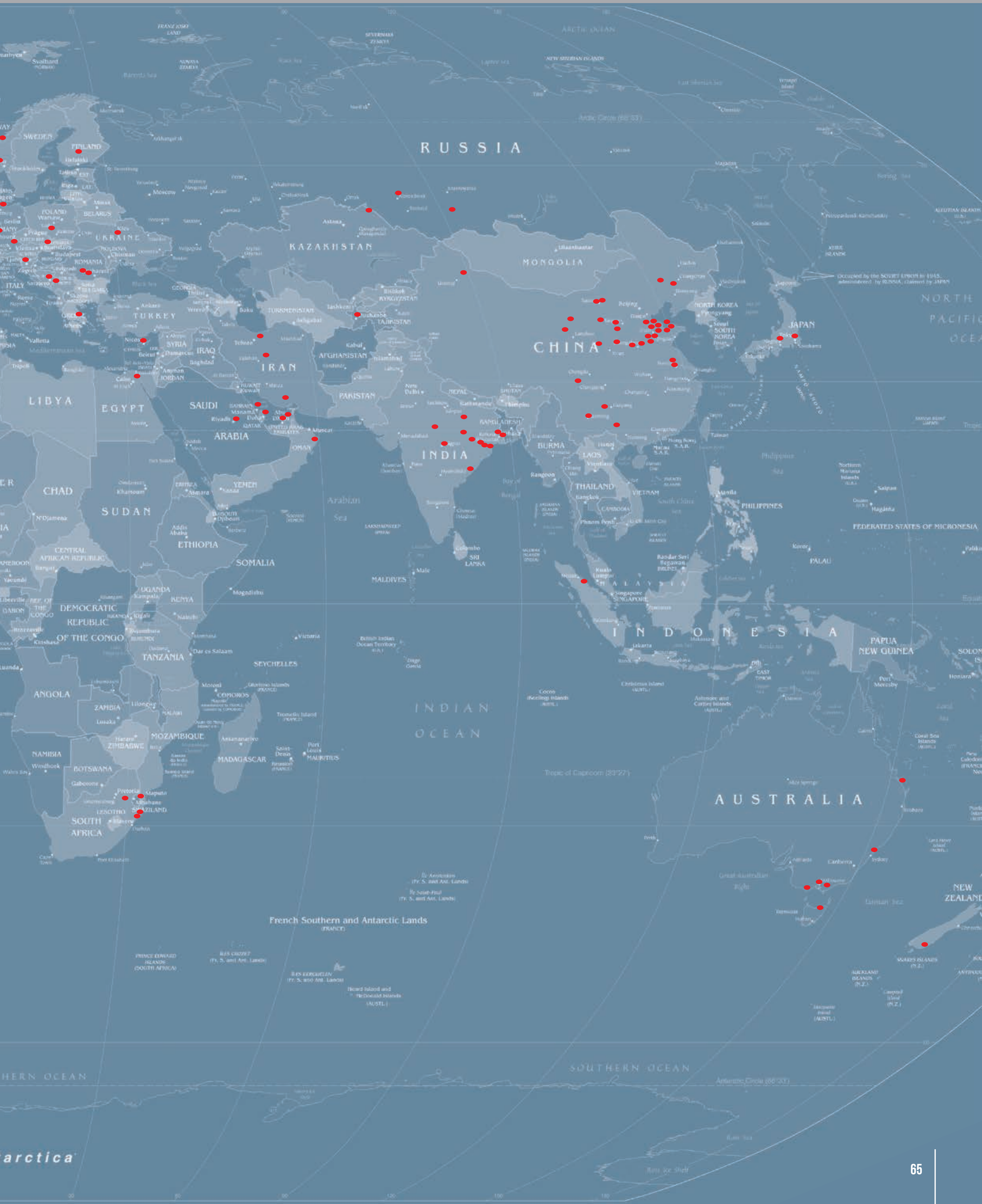
REFERENCES WORLDWIDE

R&D CARBON TESTING EQUIPMENT WORLD MAP 2024

Test equipment	ISO Test methods	Sold worldwide
GRANULAR	12	591
PITCH	7	129
ELECTRODES	13	1097
LINING	4	52
TOTAL	36	1869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SWEDEN
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PHILIPPINES
MALAYSIA
SINGAPORE
INDONESIA
PAPUA NEW GUINEA
PALAU
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BOTSWANA
SOUTH AFRICA
MADAGASCAR
COMOROS
MAURITIUS
SEYCHELLES
Arabian Sea
INDIAN OCEAN
AUSTRALIA
French Southern and Antarctic Lands
SOUTHERN OCEAN

Our activities with our customers are based on our profound expertise gained from extended research, ongoing enhancements and vast practical experience. With this basis we come up with convincing solutions in many fields of industrial carbon applications.

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R&D CARBON LTD 2025-June