CGC KLEIN
Carbon Graphite Consulting

Carbon and Graphite in the Industry
(Edition: Secondary Metallurgy)

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Range of Services

Graphite Electrodes

Electrodes

Nipple

Electrode - Grades:

RP: ”Regular Power“-graphite electrodes are made from high quality petroleum coke and pitch coal from petrochemical production. The production process consists of: calcining the graphite, kneading, molding, sintering, graphitization and machining. The nipples are made by additional impregnation and sintering twice.

HP: "High-Power" graphite electrodes are made from high quality petroleum coke from petrochemical production, as well as needle coke and modified pitch coal as raw materials. The production process consists of: calcination, kneading, molding, sintering, high-pressure impregnation, second sintering, graphitization and machining. The nipples are made by impregnating with needle coke twice and sintering three times.

UHP: „Ultra-high-power graphite electrodes are manufactured using high-quality needle cokes and modified pitch coal as raw materials. The production process consists of: calcination, kneading, molding, sintering, high-pressure impregnation, second sintering, graphitization and machining. The nipples are made by impregnating three times with needle coke and four times sintering.

ELECTRO GRAPHITE
GRAPHITE ELECTRODES
- PROPERTIES -

Qualität / Grade		***RP***	***HP***	***UHP***
SPZ. ELEKT. WIDERSTAND / SPC. ELECTR. RESISTANCE µ Ω m	Elektrode / Electrode Nippel / Nipple	7,5 – 8,5 6,5 – 7,0	5,2 - 6,8 4,8 - 5,2	4,8 – 5,6 3,6 – 4,5
BIEGEBRUCHFESTIGKEIT / FLEXURAL STRENGTH MPa	Elektrode / Electrode Nippel / Nipple	7,8 - 8,5 ≥ 13,0	≥ 11,0 ≥ 16,0	≥ 11,0 ≥ 18,0
E-MODL / MODULUS OF ELASTICITY GPa	Elektrode / Electrode Nippel / Nipple	≤ 9,3 ≤ 13,0	≤ 11,0 ≤ 15,0	≤ 13,0 ≤ 17,0
ASCHEGEHALT ASH CONTENT %	Elektrode / Electrode Nippel / Nipple	≤ 0,3	≤ 0,3	≤ 0,3
DICHTE / DENSITY g/cm3	Elektrode / Electrode Nippel / Nipple	1,55 - 1,60 1,63 - 1,68	1,63 - 1,70 1,73 - 1,79	1,65 - 1,74 1,75 - 1,82
THERM. AUSDEHNUNG / THERM. EXPANSION $k^{-1}x10^{-6}$	Elektrode / Electrode Nippel / Nipple	≤ 2,9 ≤ 2,8	≤ 2,4 ≤ 2,2	≤ 1,5 ≤ 1,4
MITTL. KORNGRÖSSE AVER. GRAIN SIZE mm	Elektrode / Electrode Nippel / Nipple	> 0,8	> 0,8	> 0,8
Zulässiger Strom Allowable Current				
Ø 200 – 300 mm	A A/cm²	10000 - 13000 15 - 21	13000 - 17400 17 - 24	13000 - 22000 20 - 30
Ø 350 – 600 mm	A A/cm²	13500 - 32000 14 - 19	17400 - 58000 15 - 23	20000 - 72000 19 - 24
Ø 780 – 1400 mm	A A/cm²	57000 - 108000 12 - 8	-	-

The values of physical properties shown above are approximate, which can be less changable
Angegebene Daten sind Mittelwerte, welche sich geringfügig verändern können.

Graphite Electrodes Diameter Tolerance acc. IEC-Norm*
Unit: mm

Nominal diameter		Actual diameter			Nominal length
Inch	mm	Max.	Min.	Rough spot	
8"	200	205	200	197	1600/1800
9"	225	230	225	222	1600/1800
10"	250	256	251	249	1600/1800
12"	300	307	302	299	1600/1800/1900/2000
14"	350	357	352	349	1600/1800/1900/2000/2200
16"	400	409	403	400	1600/1800/1900/2000/2200/2400
18"	450	460	454	451	1600/1800/1900/2000/2200/2400
20"	500	511	505	502	1800/1900/2000/2200/2400
22"	550	562	556	553	1800/2000/2200/2400
24"	600	613	607	604	2000/2200/2400/2700
26"	650	663	657	654	2400/2700/3000
28"	700	714	708	705	2400/2700/3000

Graphite Electrodes Length Tolerance acc. IEC-Norm*
Unit: mm

Nominal length	Tolerance		Shorter length tolerance	
	Maximum	Minimum	Maximum	Minimum
1600	+75	-100	-100	-275
1800	+75	-100	-100	-275
1900	+75	-100	-100	-275
2000	+75	-100	-100	-275
2200	+75	-125	-100	-275
2400	+75	-125	-100	-275
2700	+150	-150	-150	-300
3000	+150	-150	-150	-300

*IEC-Norm 60239:2005
Further sizes on demand

Dimension of Tapered Nipple acc. IEC-Norm*
Unit: mm

Diameter			Nippel				Socket		
			D	d2	L	Neigung	d1	H	Pitch
			Tolerances			≤	Tolerances		≤
Thread	mm	Inch	（-0.30～0）	（-0.30～0）	（-1～0）		（0～0.3）	（0～7）	
3TPI	225	9″	139.70	91.22	203.20	7	141.22	107.60	8.47
	250	10″	155.57	104.20	220.00		157.09	116.00	
	300	12″	177.16	117.39	270.90		148.68	141.50	
	350	14″	215.90	150.48	304.80		217.42	158.40	
	400	16″	215.90	150.48	304.80		217.42	158.40	
	400	16″	241.30	170.23	338.70		242.82	175.30	
	450	18″	241.30	170.23	338.70		242.82	175.30	
	450	18″	273.05	199.17	355.60		274.57	183.80	
	500	20″	273.05	199.17	355.60		274.57	183.80	
	500	20″	298.45	221.73	372.60		299.97	192.20	
	550	22″	298.45	221.73	372.60		299.97	192.20	
	600	24″	336.55	245.73	457.30		338.07	234.60	
3TPIL	350	14″	215.90	144.85	338.70		217.42	175.30	
	400	16″	241.30	167.43	355.60		242.82	183.80	
	450	18″	273.05	182.23	457.30		274.57	234.60	
4TPI	200	8″	122.24	81.48	177.80	7	115.92	94.90	6.35
	225	9″	139.70	98.94	177.80		133.38	94.90	
	250	10″	152.40	109.52	190.50		146.08	101.30	
	300	12″	177.80	130.69	215.90		171.48	114.00	
	350	14″	203.20	149.74	254.00		196.88	133.00	
	400	16″	222.25	160.32	304.80		215.93	158.40	
	450	18″	241.30	179.37	304.80		234.98	158.40	
	500	20″	269.88	199.49	355.60		263.56	183.80	
	550	22″	298.45	228.06	355.60		292.13	183.80	
	600	24″	317.50	247.11	355.60		311.18	183.80	
	650	26″	355.60	268.27	457.20		349.28	234.60	
	700	28″	374.65	287.32	457.20		368.33	234.60	
4TPIL	300	12″	177.80	124.34	254.00		171.48	133.00	
	350	14″	203.20	141.27	304.80		196.88	158.40	
	400	16″	222.25	151.86	355.60		215.93	183.80	
	450	18″	241.30	170.91	355.60		234.98	183.80	
	500	20″	269.88	182.55	457.20		263.56	234.60	
	550	22″	298.45	211.12	457.20		292.13	234.60	
	600	24″	317.50	230.17	457.20		311.18	234.60	
	650	26″	355.64	251.38	558.80		349.28	285.40	
	700	28″	374.65	270.39	558.80		368.33	285.40	

“IEC-Norm 60239:2005

Manufacturing process (1/2)

Raw materials

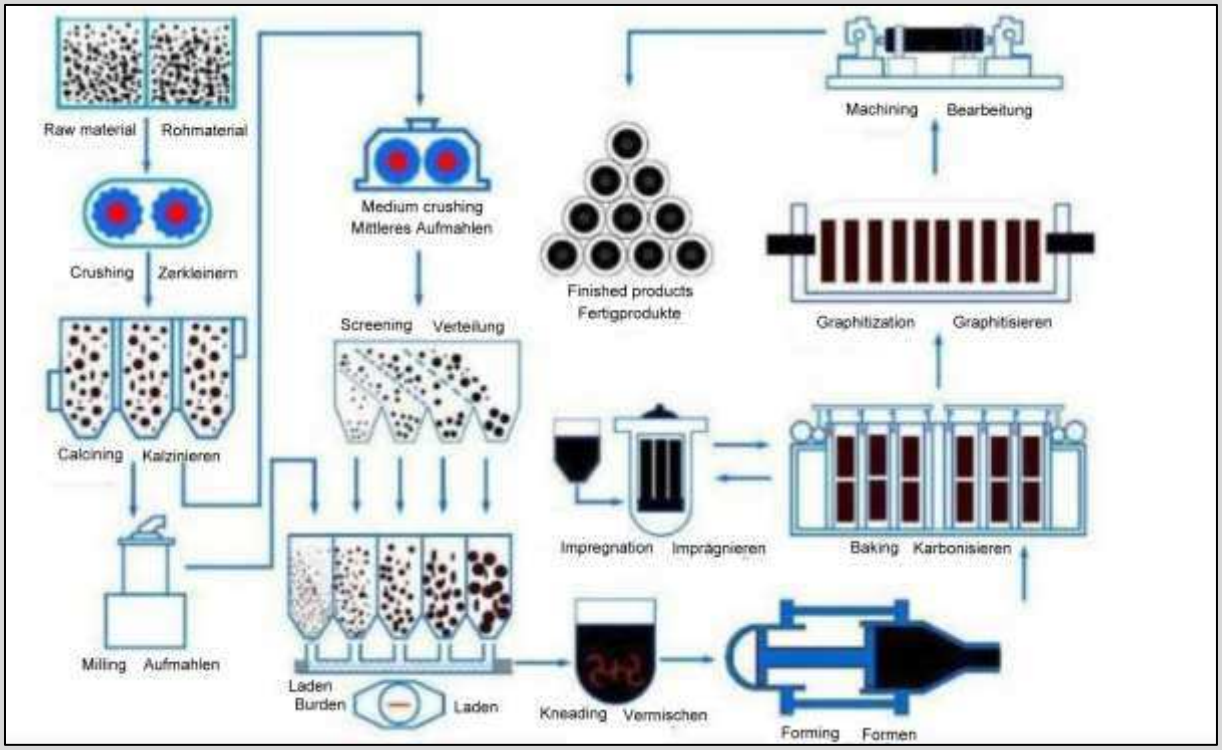
The raw materials to be used are divided into so-called fillers and binding agents. As solid raw materials (fillers) serve graphite, cokes and carbon blacks. In terms of quantity, petroleum coke is by far the most important filler. For the production distillation residues of petroleum are cooked in large quantities. The binders used are modified petroleum pitches or coal tar pitches.

Formulation

The specific properties of each filler (type and grain size), their proportions in the recipe and the type, amount and condition of the binder essentially determine the properties of the finished product. For example, a material with increasing graphite content in the raw material shows growing values of electrical and thermal conductivity, while hardness and modulus of elasticity decrease.

In addition to the application properties, the development of formulations must also take into account the production technology and, in particular, the dimensions of the products. Thus, e.g. Graphite electrodes for the steel industry with a diameter > 500 mm and a length of about 4m can only be produced if the blanks show only little shrinkage in the sintering process. This requires small amounts of binder with a high coke residue.

Manufacturing Process Graphite Electrodes



Manufacturing process (2/2)

Mix preparation and shaping

The fillers must be mixed intensively and homogeneously with the binders. This occurs at elevated temperature (150-300°C) either in batch mode in kneaders or continuously on twin-screw extruders. Important criteria besides mixing are good wetting of the filler particles and conditioning of the binder. After mixing, the manufacturing processes are divided according to the size of the blanks and the intended use of the materials.

For large components (electrodes) made of coarse-grained materials, the still hot mixture is shaped by extrusion or vibration compression. For smaller components and materials with better mechanical properties, the mixture is ground again and then pressed on hydraulic or isostatic presses to green bodies.

Baking

The annealing of the green bodies under exclusion of oxygen at temperatures of up to 600-1200°C converts the binder into carbon. The heating rates are precisely adapted to the products. During annealing, the binder forms a coke matrix. This process is accompanied by the elimination of volatile components. This requires a pore system (i.e., gusset between filler and / or compound particles) b which the volatiles can escape from the component. Therefore, practically all carbon and graphite materials have an open pore volume of 10-20%.

Graphitization

A high-temperature treatment of annealed material in the temperature range of 1800-3000 ° C leads to two major changes: on the one hand, the size and perfection of individual graphite crystallites increases and, on the other hand, the material becomes more and more pure as almost all impurities evaporate. At the same time, the graphitization process provides improved thermal and electrical conductivity and oxidation resistance. The mechanical properties, in particular hardness and modulus of elasticity, on the other hand, decrease.

Impregnation

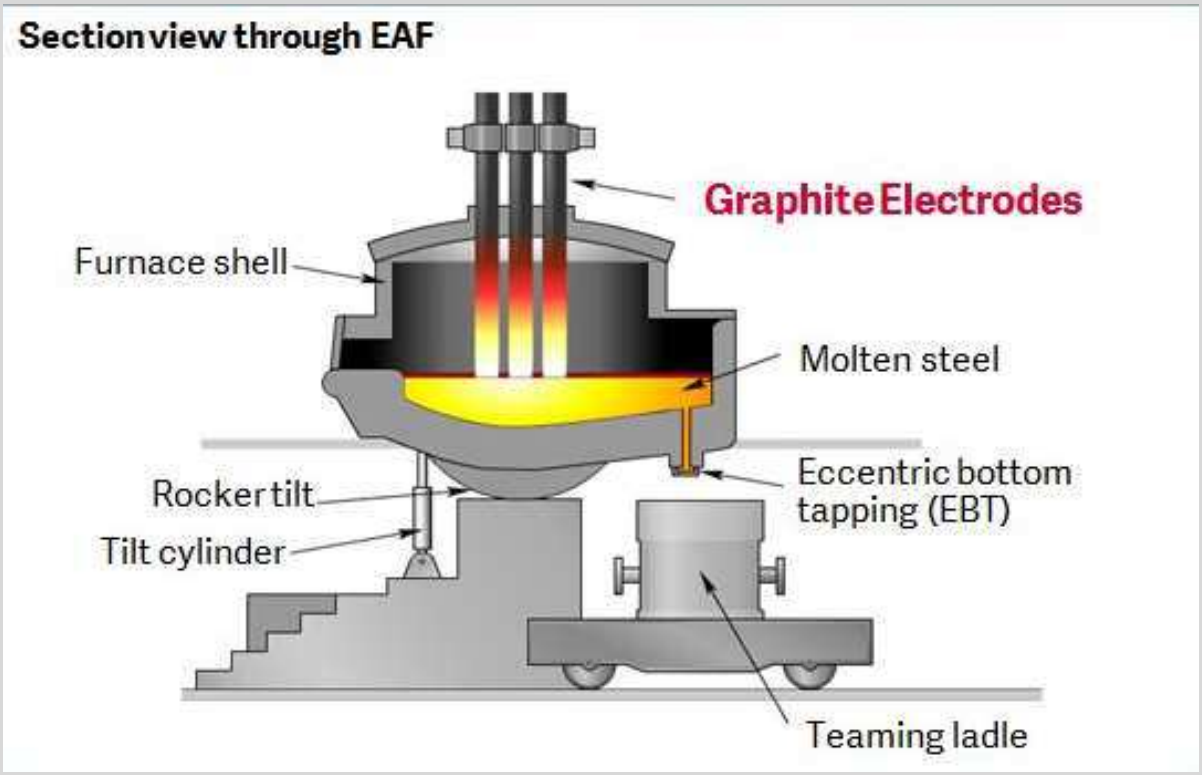
By impregnation with liquid pitch the resulting pore system of the annealed and graphitized electrodes is filled. This impregnation process followed by re-graphitization, on the one hand seals the electrode and also increases its strength. Depending on the degree of application, this process can be repeated several times.

Tooling

The raw bodies are processed on CNC processing machines to their intended size. In this case, a "socket" are screwed with defined thread in each end faces of the electrode body and from a smaller green body the "nipple" is made with a corresponding mating thread as connecting elements.

In general:

Graphite electrodes are used for the production of scrap steel in electrically heated electric arc furnaces (about 3MT p.a. worldwide). In these furnaces, ignited arcs between graphite electrodes cause the energy required to melt the metal in a very short time. The electrodes are exposed to extreme temperature peaks and temperature gradients. The reduction of oxides on graphite, the solution of carbon in molten steel and the oxidation of graphite in air lead in this application to a continuous consumption of the electrodes.



Graphite Roughs

Graphite electrodes, tooled