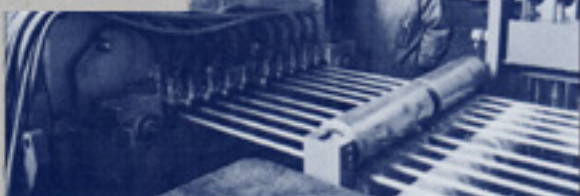
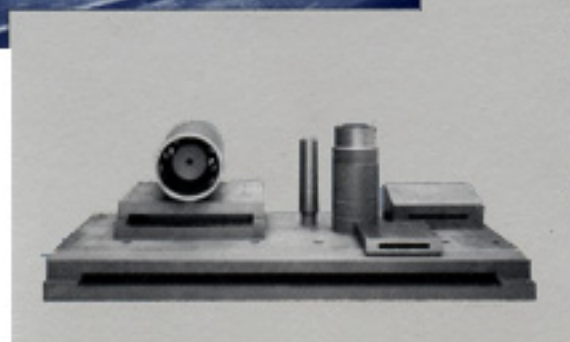
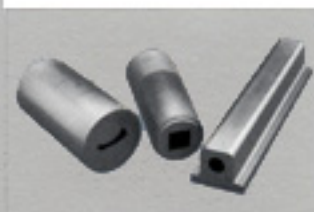
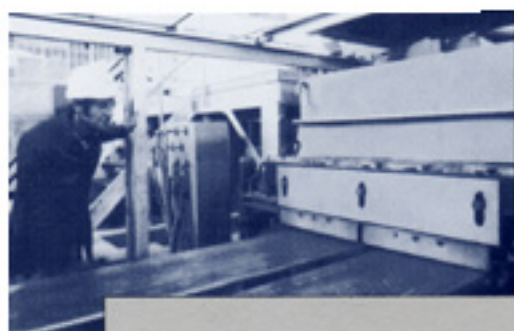


SGL Carbon's Graphites Specialties

Materials and Products for Continuous Casting Technology



SGL CARBON GROUP

Graphite Specialties

SGL carbons' Graphite Specialties: Custom-Made Products for Key Industries

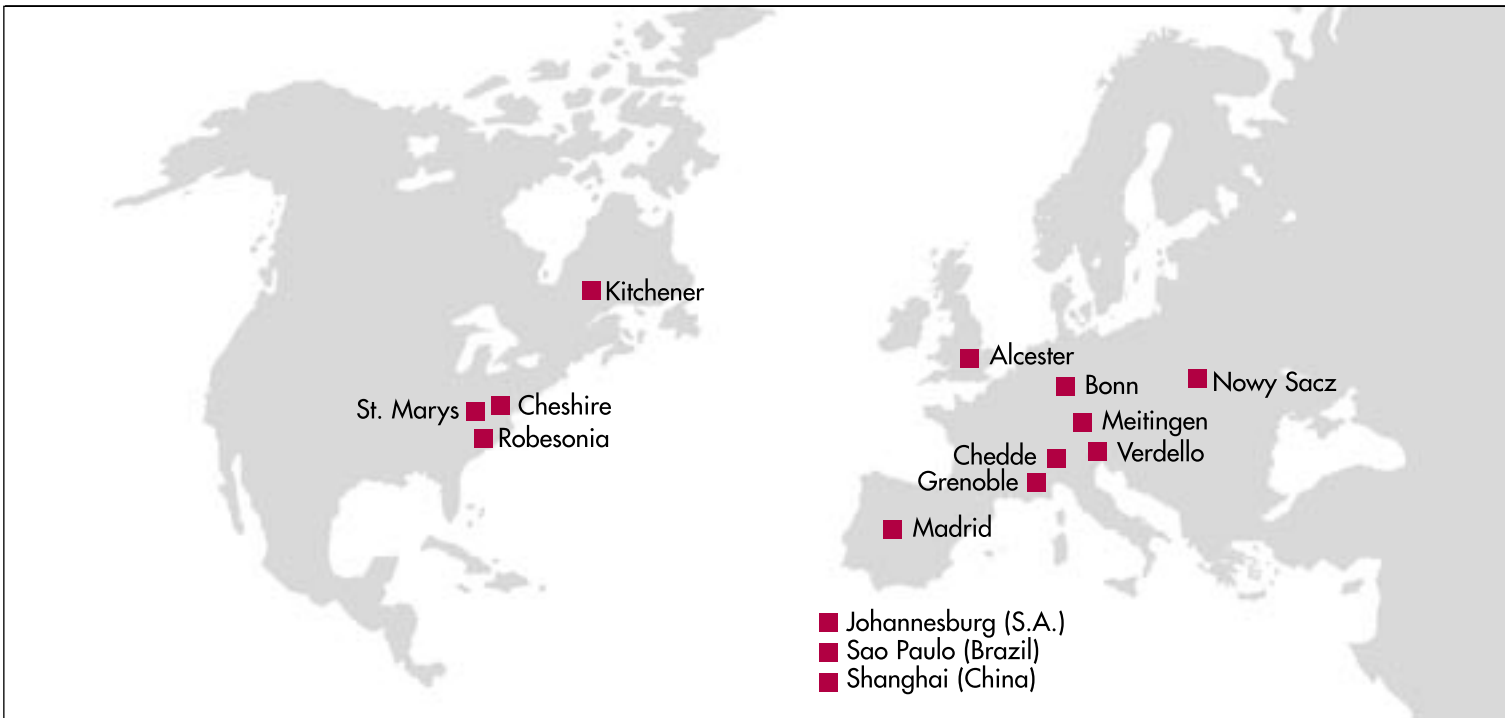


- Good mechanical strength
- Good sliding properties
- High temperature resistance
- High thermal shock resistance
- Low wettability
- High corrosion resistance
- High thermal conductivity
- High purity
- Good electrical conductivity
- High oxidation resistance

Specialty Graphites made by SGL Carbon are designed to handle particular applications.



Graphite Specialties



SGL Carbon is the biggest manufacturer of carbon and graphite products worldwide. Graphite Specialties is one of its core businesses. SGL Carbon is the only manufacturer mastering all of the methods of graphite production, including that of isostatically pressed fine-grain graphites as well as of graphites produced by extrusion, die casting and vibrational compaction. Furthermore, SGL Carbon supplies carbon and graphite modifications such as carbon-fibre reinforced carbons, carbon and graphite felts, graphite sheets, laminate plates and carbon strings. Owing to this wide variety of modifications and types of materials adjusted to the special requirements of the different applications, SGL Carbon's specialty

graphites are key materials in secondary metallurgy. This market segment is attended inside of the Business Unit Graphite Specialties to the Business Area Technical Carbon.

Production facilities of the Business Unit Graphite Specialties are located in Europe, North America and Asia. Moreover, the BU is integrated into the global marketing network of the SGL Carbon Group, with its own companies and local agencies in more than 90 countries all over the world. Due to the customer orientation of its manufacturing and marketing network, SGL Carbon's delivery performance is of high quality and great flexibility.

Continuous Casting



Continuous casting of non-ferrous and precious metals and grey-iron casting are extensively used manufacturing methods.

This process offers the advantage of non-stop production and ensures optimum material quality.

A most interesting aspect is the uniformness of product structure and the absence of shrinkholes.

Due to neat and smooth cast metal surfaces, extensive finishing is not usually needed.

A distinction can be made between

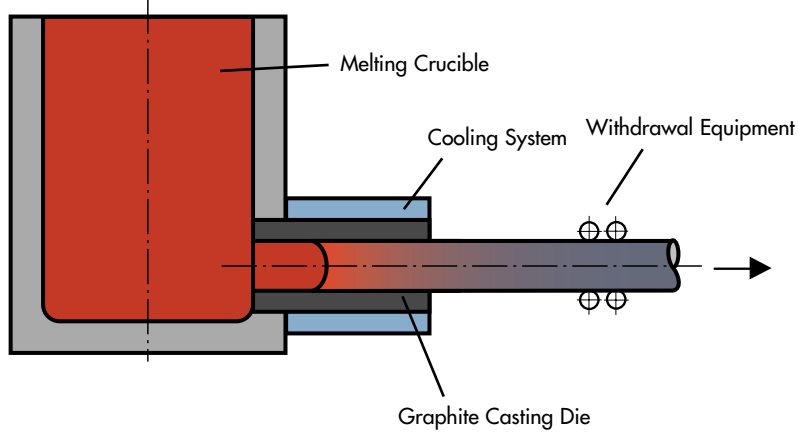
- horizontal continuous casting,
- vertical continuous casting with furnace-dependent and
- vertical casting with non furnace-dependent.

The design of the casting equipment and the casting process are similar in all cases.

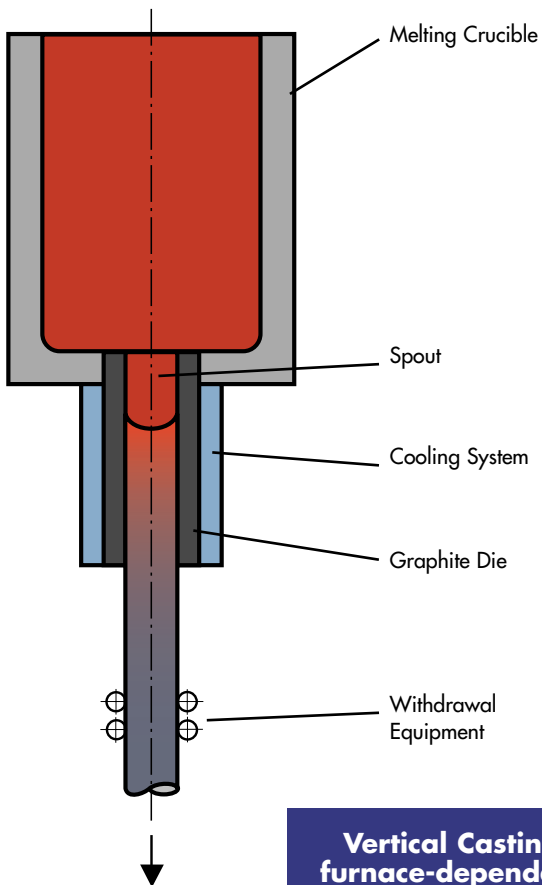
An important component of the continuous casting machine is the cooling device, which consists of a water-cooled jacket and a mould (die).

Graphite combines a number of favourable properties and is therefore used as a die material.

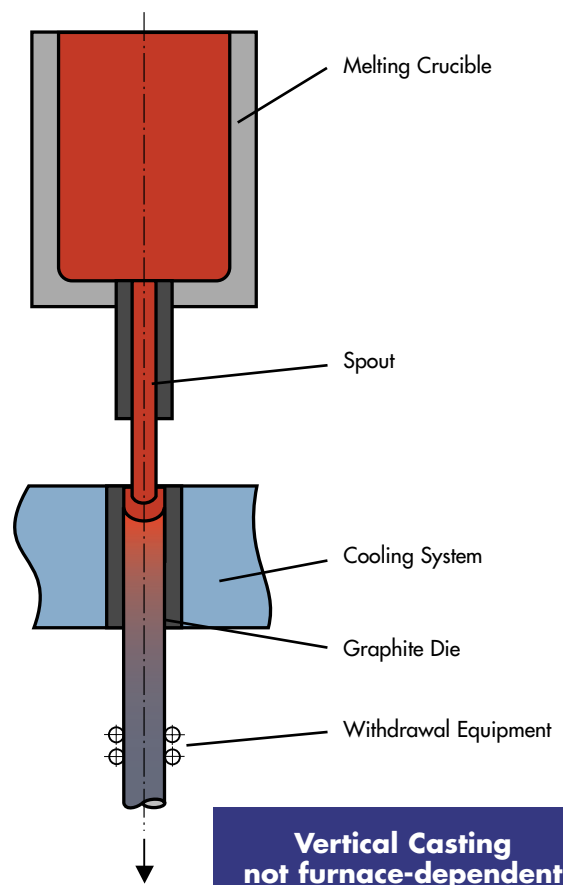




Horizontal Casting



**Vertical Casting
furnace-dependent**



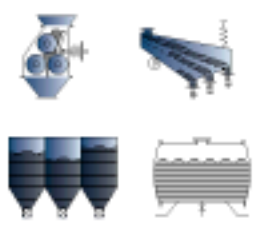






**Vertical Casting
not furnace-dependent**

Graphite – a Material with Extraordinary Properties

Specialty Graphite

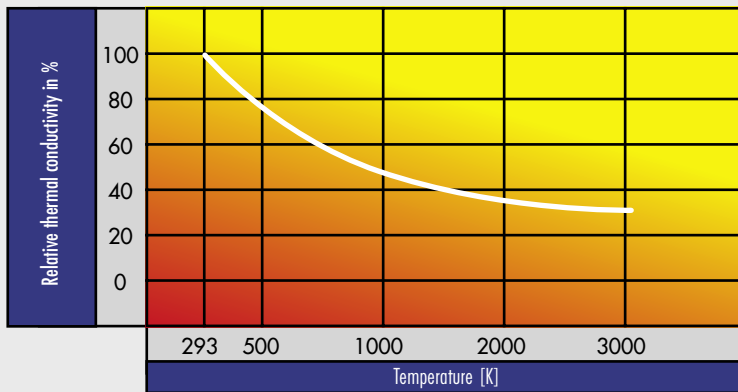
Thanks to a combination of extraordinary properties and to the opportunity to influence certain product characteristics by varying the raw materials and the manufacturing technologies, graphite has become an indispensable key material.

The manufacturing process of specialty graphites is comparable to that of ceramics. In a first step, mostly synthetic fillers are reduced to an appropriate grain size and evenly mixed with a binding agent to form a homogeneous mass. Four procedures are available to process this mixture: continuous casting or extrusion, die pressing, isostatic pressing and vibration-moulding. After pressing, the moulded pieces are baked or coked at about 1,000°C under exclusion of air in the first thermal processing step. The binder bridges between the solid particles are carbonized, i. e. converted into carbon, to give the required strength to the moulded piece. Graphitization – the second thermal processing step – induces the transformation of the more or less preordered carbon into 3-D ordered carbon at about 3,000°C. To densify the material by reducing its cell space, it may optionally be impregnated with pitch or an artificial resin after baking or graphitization. Thus, the density, strength and conductivity of graphite can be increased as appropriate.

MANUFACTURING OF CARBON AND GRAPHITE	
Raw materials processing: filler, binder	
Mixing	
Moulding: extrusion, die moulding, isostatic moulding, vibration-moulding	
Baking	
CARBON GRAPHITE	
Graphitizing	
GRAPHITE	
Graftage: Impregnation	
Machining	



Thermal conductivity



Density

Depending on the brand used, density ranges between 1.7 g/cm³ and 1.9 g/cm³, which is equivalent to 1/4 of the strength of iron or 1/5 of that of copper.

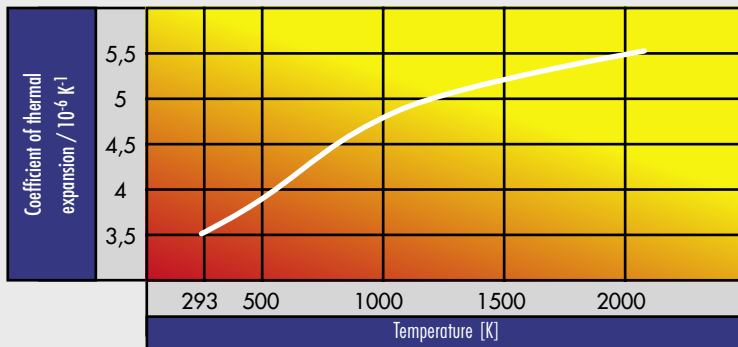
Surface wetting

Graphite is not wetted by most molten metals.

Thermal resistance

Graphite is not fusible and sublimates at about 3,900 K. When exposed to air, it is stable up to about 750 K.

Thermal expansion



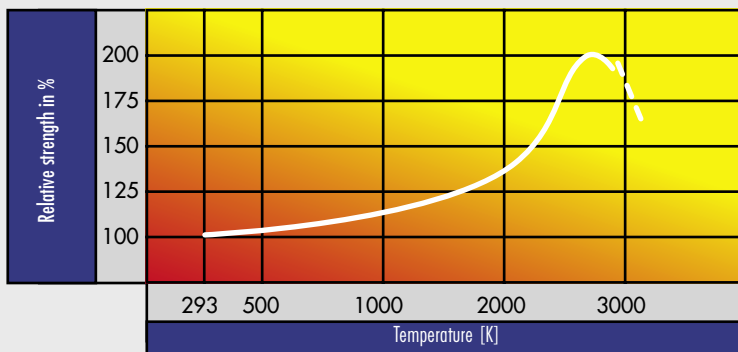
Thermal shock resistance

Graphite is extremely resistant to thermal shocks. Thus, short heat-up and cool-down times are no problem.

Thermal conductivity

The thermal conductivity of graphite exceeds that of many metals. It decreases with rising temperature and varies with the degree of graphitization.

Mechanical strength



Thermal expansion

Between 20°C and 200°C, the coefficient of thermal expansion is in the order of 3 to 5 x 10⁻⁶ K⁻¹, which is equivalent to approximately 1/4 of that of iron. It differs from brand to brand and depends on the anisotropy of the material and upon temperature.

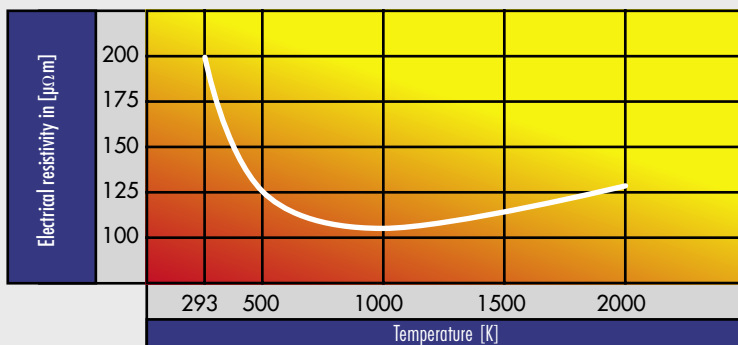
Specific heat capacity

There is little difference between the graphite brands as regards specific heat capacity.

Mechanical strength

Contrary to most other materials, up to 2,700 K the tensile, compressive and bending strength of graphite increases with a rise in temperature. At temperatures over 2,700 K, its mechanical strength goes down. At 2,700 K, the mechanical strength of graphite is about twice its strength at room temperature.

Electrical resistivity



Machinability

Graphite is characterized by good mechanical machinability, edge tear and abrasion resistance. Complicated parts with close tolerances can be machined with ease into required shapes.

Carbon and Graphite Brands for Continuous Casting Technology

In view of the various demands on specialty graphites used for continuous casting, SGL Carbon has developed special graphite brands meeting the specific requirements of the different applications. The R 4340 brand used as a casting material covers a wide range of alloys for a large number of different sections and sizes. The R 4550 and R 4820 brands have been developed as critical metal alloys having a very high affinity with carbon (carbide-forming alloys).

These brands are characterized above all by great mechanical strength and high density. As a rule, this leads to longer dwell times in the die and to perfectly uniform surface quality of the withdrawn metal strands.

Due to the high thermal conductivity of graphite, there is a risk of "chilling in" at the edges of rectangular or square sections of cast iron. To avoid these undesirable and extremely hard structures, the corner strips of split moulds are made of carbon graphite brands having low thermal conductivity. Thus, the cooling process at these critical points is delayed. The R 4261 H brand has proved to be very effective in this respect.

In the range of the precious metals industry isotatically pressed graphite, e. g. the brands R 4340 and R 4550 or extruded graphites like the brands FLM and HLM are employed for the production of small crucibles. To come to a decision between this trademarks is in individual

Graphite Brands

		R 4261 H	R 4340	R 4500	R 4550	R 4650	R 4820
Moulding		die pressed	isotatic pressed				
Properties							
Average grain size	µm		15	10	10	7	20
Bulk density	g/cm ³	1.70	1.72	1.77	1.83	1.84	1.82
Open porosity	Vol.-%		15	13	10	10	10
Pore size	µm		2.0	1.5	1.5	0.8	2.5
Permeability	cm ² /sec		0.15	0.10	0.04	0.03	0,10
Hardness	HR 10/100		80				100
Hardness	HR 5/100	105		70	95	95	
Spec. electrical resistivity	µΩm	27.0	12.0	14.0	13.0	14.0	11.5
Flexural strength	MPa	55	45	50	60	65	45
Compressive strength	MPa	155	90	120	125	150	105
Young's strength	GPa	22.0	10.5	10.5	11.5	12.5	11.0
Thermal conductivity	W/mK	12	90	80	100	90	125
Thermal exp. 20 - 200°C	10 ⁻⁶ K ⁻¹	3.0	2.9	3.9	4.0	3.9	4.2
Ash content	ppm	200	200	200	20	200	50



cases against the requirements at durability and purity of the crucibles materials.

In the event of extraordinary demands on graphite quality with regard to the purity and ash content of the crucibles or dies, purified materials can be used to reduce the ash content from 50 ppm to less than 5 ppm.

The extruded and vibration-moulded graphites are in the main used in the range of the continuous

casting technology as melting and casting crucibles. Large-size crucibles (round and rectangular castings) for copper and copper alloys should be made with our HLM-B and MKUS-B brands.

Also extruded graphites are used as die-material for vertical casting of large formats and low throughput. For this propose the graphite brand HLM proved excellent.

			FLM	HLM		HLM-B		MKUS-B
Moulding			extruded					vibration-moulded
Properties			typ. values for		typical values for widths of			
			Ø 30 - Ø 60 mm		≤ 670 mm	760 mm	1220 mm	
Max. grain size	µm		0.4	0.8	0.8	0.8	0.8	0.8
Bulk density	g/cm ³		1.73	1.74	1.75	1.77	1.83	1.83
Open porosity	Vol.-%		17	16	12	15	12	9
Spec. electrical resistivity	µΩm	II	6.0	7.5	7.2	7.0	8.5	7.7
		⊥	12.0	10.0	9.2	10.5	10.5	8.7
Flexural strength	MPa	II	24.0	23.0	25.0	23.0	22.0	21.5
		⊥	15.0	16.5	22.0	18.0	20.0	21.0
Compressive strength	MPa	II	38	48	50	48	46	51
		⊥	36	35	35	38	42	47
Young's modulus	GPa	II	16.0	12.0	11.5	13.0	12.0	10.8
		⊥	6.0	9.0	11.0	10.0	11.0	9.6
Tensile strength	MPa	II	13.0	16.0	16.5	16.0	15.0	14.0
		⊥	7.0	12.0	15.0	13.0	14.0	12.5
Thermal conductivity	W/mK	II	200	190	190	190	160	165
		⊥	110	135	150	130	130	155
Thermal exp. 20 - 200°C	10 ⁻⁶ K ⁻¹	II	0.7	2.1	2.1	1.5	2.5	2.7
		⊥	3.2	3.7	3.2	3.3	3.9	3.2
Ash content	ppm		500	500	1000	1500	1500	1000

Recommended Use of Die Materials

Experience in the production of the same alloys with certain graphite brands has shown that the results may be quite variable. Nevertheless, some recommendations can be made depending on

- the metal to be used,
- the segment to be cast,
- the size of the segment,
- the quantity of metal to be cast and
- the casting parameters.

Before making a decision as to what brand will be used, the issue should be discussed by the moulder and SGL Carbon, and tests should be performed, if appropriate.

The brands listed in this brochure are used for both the dies and – in case of hollow bars – for the extruder cores.

In addition to the above mentioned brands, further graphite brands can be provided on request.

Application Recommendation

Alloy	Size	Die-Material				
		R 4340	R 4500	R 4550	R 4650	R 4820
	Round	x	x			
CuZn	Strip			x		x
	Rod			x	x	x
	Round	x	x			
CuSn	Strip			x		x
	Rod			x	x	x
	Round			x		x
CuNiZn	Strip			x		x
	Rod			x	x	x
	Round			x		x
CuNi	Strip			x		x
	Rod			x	x	x
	Round	x	x	x		x
Ag-Leg.	Strip	x	x	x		x
	Rod	x	x	x		x
	Round	x	x	x		x
Au-Leg.	Strip	x	x	x		x
	Rod	x	x	x		x
GG / GGG		x	x			



Product Range



SGL Carbon supplies various types of finished dies and crucibles as per the customers' drawings and specifications as well as semi-finished products.

A wide variety of different standard sizes are available, depending on the manufacturing process and the graphite brand to be used.

Production of crucibles and round dies made of isostatically pressed graphites:

- round castings with diameters of 150 to 420 mm, 1230 mm in length
- special sizes up to 1100 mm in diameter

Production of band or cakes dies made of isostatically pressed graphites:

- rectangular castings 1230 x 500 x 400 mm
- rectangular castings 1550 x 410 x 210 mm

Production of round dies and crucibles made of extruded graphite:

- round castings with diameters of 75 to 1015 mm, 1830 mm in length

Production of crucibles made of vibration-compacted graphite:

- round castings with diameters of 960 to 1550 mm, 600 mm in length

Thanks to an intensive exchange of ideas with our customers, our brands are always adjusted to the current requirements of the market.

Basically, special sizes of semi-finished products can be provided after examination of feasibility and appropriate lead times.



Dwell Times



Definite dwell times in the mould cannot be specified, since there is a wide variety of factors influencing this parameter and only a few of them can be controlled in casting practice. Thus, the table contains only guide values relating to a continuous casting process. The dies can be reworked several times to further extend die life.

Metal	Dwell time in hr (guide values)
Cast iron	8-24
Copper	72-120
Aluminium bronze	72-120
Tin bronze	72-120
Brass	48-120
China silver	8-48
Copper nickel	8-20

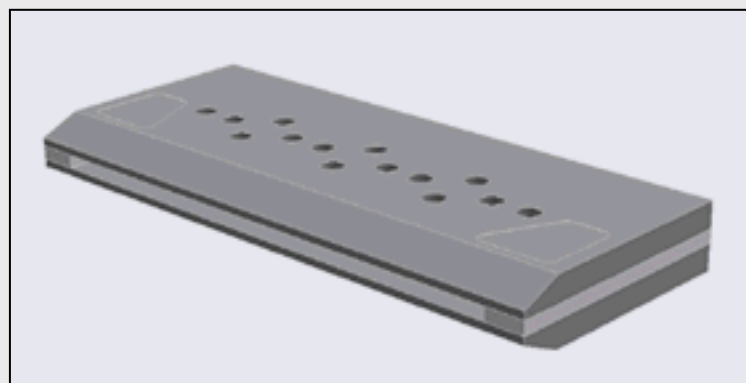
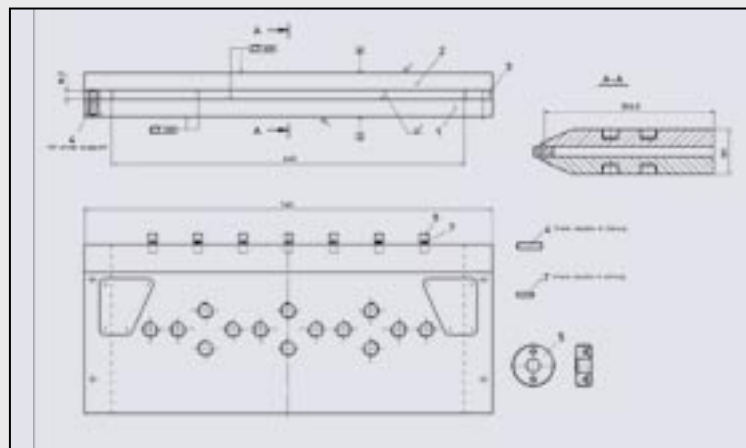
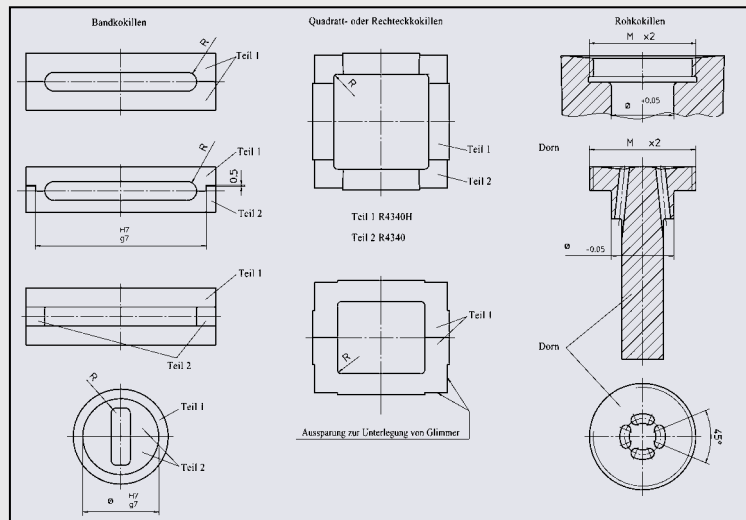


Layout Guidelines

The die layout depends on the continuous casting machine concerned and should therefore be planned by the designing engineer and SGL Carbon. The above examples are conventional designs of graphite dies. However, this list is by no means exhaustive.

Basically, the active surfaces of the die and the extruder core, i. e. the surfaces coming into contact with the molten metals, should be of very high quality to avoid surface wetting and to extend graphite die life. To ensure mechanical strength, the wall of round dies should be at least 5 mm thick, while that of band dies should not be less than 10 mm in thickness.

At the start of the casting process, the humidity in graphite dies may cause gas formation and build up tensions which adversely affect the system consisting of molten metal, graphite die and metal cooler. We therefore recommend drying graphite dies for 12 hr at 450 K or for 24 hr at 390 K prior to the withdrawal of the strand.



Quality Assurance

Based on its quality management system according to DIN EN ISO 9001 and upon a thorough examination of all of the produced slabs, SGL Carbon guarantees an ever perfect quality of the materials supplied.

The cost of the graphite die is low in comparison to the overall cost of the casting process. Nevertheless, the die and, thus, the choice of the die material are crucial for product quality and the productivity of the process.

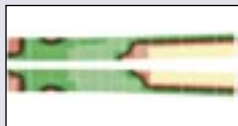


Technical Service

Methodology of Simulation

Mechanical Model of the Graphite Die

Distribution of internal stress (IS) and distortion



IS and distortion after 480s



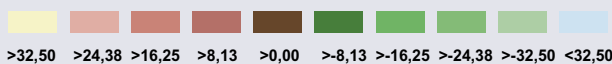
3D-Diagramm of IS and distortion



IS and distortion after 540s



3D-Diagramm of IS and distortion



In addition to technical consulting with regard to the selection of appropriate materials and the design of the die, SGL Carbon offers the opportunity to continuously improve the manufacturing processes by a direct dialogue with materials specialists and designing engineers. Extensive laboratory equipment is available for the assessment of graphite materials and their wear characteristics. This includes FEM calculations carried out in cooperation with external partners, institutes and universities.



This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as guaranteeing specific properties of the products described or their suitability for a particular application. Any existing industrial property rights must be observed. The quality of our products is guaranteed under our "General Conditions of Sale."

06 03 / 3 E Printed in Germany



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Graphite Specialties

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