Materials and Products for Continuous Casting Technology

Industrial Applications

Broad Base. Best Solutions.
SGL Group – The Carbon Company – is one of the world’s leading manufacturers of carbon-based products. Focusing on creating innovative solutions and value for our customers.
Graphite Specialties from the SGL Group: Customized Products for Key Industries

SGL Group’s Graphite Specialties Business Line manufactures customized products in carbon, graphite and carbon fiber-reinforced composites for use in a large and varied range of industrial applications.

No company anywhere in the world can match SGL Group’s total mastery of every graphite shaping process, from isostatic pressing and extrusion, die molding, and vibration molding to injection molding and press-to-size technologies.

Besides its expertise in materials technology, the SGL Group has built up decades of experience in the machining of precision components, as well as in the planning and design of complete plant facilities.

The range of products and services thus includes not only semi-finished items and straightforward machining operations but also complex CNC milling technology and the manufacture of chemical plants such as heat exchangers, HCl synthesis units, columns and pumps. To complete our product portfolio, we also offer upgrading processes such as coating, impregnation and purification.

In short, SGL offers customized solutions for innovative applications and also develops new products in joint projects together with customers.

With the resulting wide variety of material modifications and grades designed to meet individual application requirements, SGL Group’s specialty graphites are well placed to act as key materials in the primary and secondary metallurgy sectors.

The SGL Group has close relationships with customers through a sales network that spans the globe supported by more than 30 productions sites in Europe, North America, and Asia.
Two factors have made graphite an indispensable material for continuous casting technology: First, a unique combination of exceptional properties and, secondly, the possibility of matching specific material properties to given customer specifications by varying the raw materials and/or production methods.

The most important properties of graphite are:
- High thermal/chemical resistance
- Excellent thermal shock resistance
- Increasing strength with rising temperature
- High thermal conductivity
- High electrical conductivity
- Ease of machining
- Possibility of production to very high purity standards.

The manufacturing process for carbon materials and specialty graphites is comparable to that for ceramics. As a first step the raw materials are reduced to small pieces and evenly mixed with a binding agent to form a homogeneous mass. Extrusion, die molding, isostatic molding or vibration molding is used for the subsequent shaping operation.
After shaping, the “green” pieces are baked in the first thermal processing step at about 1,000 °C in an air-free environment. It is in this process that the binder bridges between the solid particles are formed. Graphitization – the second thermal processing step – induces the transformation of the carbon into graphite with its 3-dimensional structure. This takes place at about 3,000 °C.
Graphite – The Material with Exceptional Properties

Unlike most materials, the tensile, compressive and flexural strengths of graphite increase as temperature rises to 2,700 K, beyond which they fall again, see diagram 1. At 2,700 K graphite has about double its room temperature strength.

The temperature coefficient of electrical resistivity of graphite is negative, unlike that of metals. Graphite has good electrical conductivity. Near absolute zero, graphite has only a few free electrons and acts as an insulator. As temperature rises, electrical conductivity increases.

The thermal conductivity of graphite is higher than that of many metals and falls with increasing temperature, see diagram 3. The thermal conductivity of graphite varies from one graphite grade to another but also with the degree of graphitization.

The coefficient of thermal expansion is in the order of $3 \times 10^{-6} \text{ K}^{-1}$ and is, therefore, only about one quarter that of iron. This is illustrated in diagram 4. It varies from grade to grade and depends on process conditions and the properties of the starting raw materials.

Graphite grades differ only slightly in their specific heat. The dependence of the specific heat on temperature is shown in diagram 5.

### Properties

**Open porosity**

Open porosity is that part of the whole volume which can be filled with liquid (determined according to DIN 51918).

**Machinability**

Graphite is easy to machine – both edge strength and abrasion resistance are high. Complicated parts with close tolerances can be manufactured to high precision.

**Wettability**

Graphite is not wetted by molten glass or by most molten metals.

**Resistance to temperature change**

Graphite is extremely resistant to thermal shock, so rapid heating or cooling is no problem.
Thermal stability
Graphite does not melt; it sublimes at approximately 3,900 K. In air, graphite is stable up to a temperature of around 750 K.

Density
The theoretical density of monocrystalline graphite is 2.26 g/cm³. The density of synthetic graphite is typically between 1.5 and 1.9 g/cm³, but as high as 2.1 g/cm³ for solid pyrolytic graphite. The density of the high-purity graphite grades is defined as the quotient of mass and volume, including all pores.
Continuous Casting Process

The continuous casting of non-ferrous and precious metals and the casting of gray iron represent a widely used manufacturing method. This method offers the advantage of non-stop production and ensures optimum material quality as a result of rapid solidification. Two highly useful characteristics are the uniformity of product structure and absence of shrinkholes.

As the resulting cast metal surfaces are generally smooth and unblemished, extensive finishing is not usually needed.

A distinction can be made between

- horizontal continuous casting,
- vertical casting,
- vertical casting, furnace-dependent,
- vertical casting, not 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 mold (die). Graphite combines a number of favorable properties and is therefore preferably used as a mold (die) material.
Horizontal Casting

- Melting crucible
- Withdrawal equipment
- Cooling system
- Graphite casting die

Vertical Casting

- furnace-dependent
- Vertical Casting
- melting crucible
- Spout
- Cooling system
- Graphite die
- Withdrawal equipment

- not furnace-dependent
- Vertical Casting
- melting crucible
- Spout
- Cooling system
- Graphite die
- Withdrawal equipment
RINGSDORFF® and SIGRAFORM®
Carbon and Graphite Grades for Continuous Casting Technology

In view of the various demands on specialty graphites used for continuous casting, the SGL Group has developed special graphite grades to meet the specific requirements of the different applications.

The RINGSDORFF R4340 grade used as a casting die material is suitable for a wide range of alloys in a large number of different sections and sizes.

The RINGSDORFF R4550 and RINGSDORFF R4820 grades have been developed for critical metal alloys having a very high affinity for carbon (carbide-forming alloys). These grades 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 molds are made of carbon grades with low thermal conductivity. Thus, the cooling process at these critical points is delayed. The RINGSDORFF R4261H grade has proved to be very effective in this respect.

In the precious metals industry sector, isostatically pressed graphite grades such as RINGSDORFF R4340 and RINGSDORFF R4550 or extruded graphites such as SIGRAFORM HLM are employed for the production of small crucibles.

Deciding which grade to use in individual cases will depend on the durability and purity requirements to be imposed on the crucible materials.

If exceptional demands are to be placed 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-molded graphites are used mainly in continuous casting technology as melting and casting crucibles. Large crucibles (round and rectangular castings) for copper and copper alloys should be made with our SIGRAFORM HLM and SIGRAFORM MKUN grades. Extruded graphites are also used as die materials for large-format vertical casting and low throughput production. SIGRAFORM HLM has proved excellent for this purpose.
Recommendations for Specific Uses

In cases where one particular alloy has been produced with a single graphite grade, experience has shown that the results may vary considerably. Nevertheless, some general 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 on the grade to be used, the question should be discussed jointly by the user and the SGL Group and any necessary tests carried out.

In addition to the standard grades mentioned, other graphite grades can be supplied on request.

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Layout Guidelines

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

Basically, the active surfaces of the die and mandrel, 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 strip dies should not be less than 10 mm in thickness.
Dwell Times

No specific mold dwell times can be specified, since many different factors influence this parameter and only a few of them can be controlled in actual casting operations. Thus, the table contains only guide values relating to a continuous casting process.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Dwell time in hrs</th>
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<td>Cast iron</td>
<td>8-24</td>
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<tr>
<td>Copper</td>
<td>72-120</td>
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<tr>
<td>Aluminum bronze</td>
<td>72-120</td>
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<td>Tin bronze</td>
<td>72-120</td>
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<td>Brass</td>
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<tr>
<td>Nickel silver</td>
<td>8-48</td>
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<tr>
<td>Copper nickel</td>
<td>8-20</td>
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</table>

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

Provided that their design permits, graphite dies can be reworked several times. This further extends their life.
Product Range

The SGL Group supplies finished dies and crucibles to customers’ drawings and specifications, as well as semi-finished products in various dimensions.

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

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

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

Production of strip or cake dies made of isostatically pressed graphites

- rectangular material 1230 x 500 x 400 mm
- rectangular material 1550 x 410 x 210 mm.

Production of round dies and crucibles made of extruded graphite:

- round material with diameters of 75 to 780 mm.

Production of crucibles made of vibration-molded graphite:

- round material with diameters of 960 to 1550 mm.

By conducting an intensive exchange of ideas with our customers, we can constantly adjust our standard dimensions to the current requirements of the market.

In principle, it is possible to supply semi-finished products in special sizes after checking for feasibility and allowing appropriate lead times.
Providing System Solutions Tailored to Your Needs

The SGL Group offers complete solutions customized to your requirements.

**Technical customer support**

- Application technology advice from competent experts
- Proposals for plant design projects offered in close cooperation with those constructing and operating the plants
- Detailed design proposals based on technical aspects of the proposed use
- CAD/CAM design to solve specific customer problems
- Global marketing network covering more than 90 countries

**Our core competencies**

- Comprehensive materials expertise and long-standing experience in the use of graphite for extreme applications
- Thorough knowledge of all methods for shaping graphite products
- Comprehensive research and development to provide unique technical solutions
- Local graphite machining facilities
- Clean-room operations, purification for semiconductor applications, coating and impregnation
- Continuous improvement of manufacturing processes and products
- Vast array of products ranging from semifinished goods to high-precision products, from highly standardized series production to special solutions to customer-specific problems

**Customer service**

- Global specialists for technical support
- Professional technical advice provided at customers’ own sites
- Individual advisory service based on our extensive know-how in the fields of materials and application technology, including project design work and construction
- Application-oriented training in key applications; special literature and brochures
- Extensively equipped laboratories for analyses
- Reliable and flexible delivery service
- Use of Six Sigma methods to improve customer-related processes

Our company has been certified in accordance with DIN EN ISO 9001:2000.
Trademarks of the SGL Group, Graphite Specialties

RIDURID®
Graphite filled high performance plastic

RINGSDORFF®
Isostatically pressed and die-molded specialty graphites

SIGRAFORM®
Extruded and vibration-molded specialty graphites

SIGRAMENT®
Extruded specialty graphites for electric heating elements

SIGRAMENT® MNC
Extruded tubular graphite heating elements

SIGRASIC®
Carbon fiber-reinforced silicon carbide (C/SiC)

SIGRABOND®
Carbon fiber-reinforced carbon and graphite

SIGRATHERM®
Carbon and graphite felts and carbon wool for thermal insulation

SIGRAFLEX®
Graphite foils and laminated sheets

SIGRAFIL® D2-3K
Carbon fiber-based carbon cord

CRYSTA-SIL®
Crystalline silicon carbide coatings used on graphite products for semiconductor applications

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