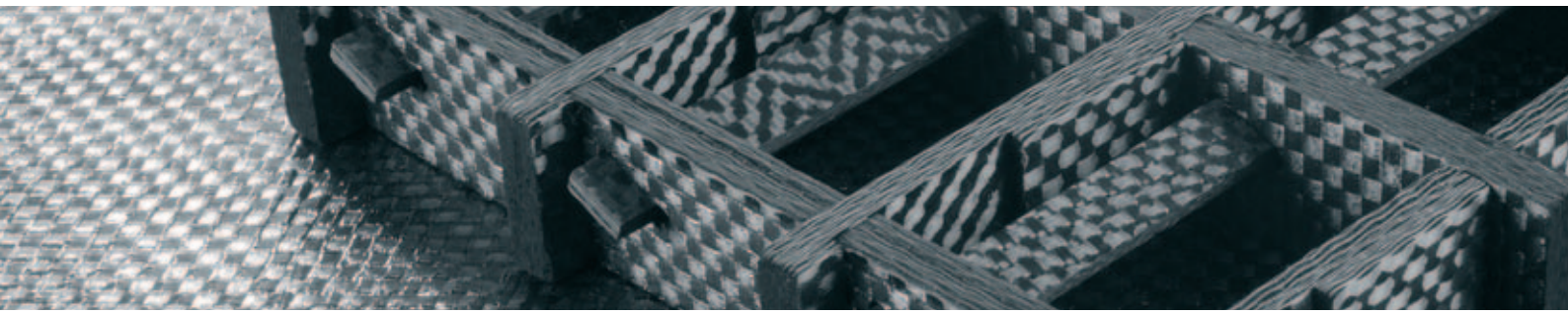
A Toyo Tanso Group Company

CFC and Graphite

for High-Temperature Applications



Jointly, We Think in Graphite

Graphite is more than just pressed carbon. To us, GTD Graphit Technologie GmbH, it is inspiring, fascinating and exciting at the same time.

We specialize in the most demanding graphite and CFC applications. We consider ourselves to be creators of ideas, development partners and suppliers for the most diverse companies and industries. Being a subsidiary of Toyo Tanso Ltd., the world's leading manufacturer for isostatically pressed fine-grain graphites, we have a market position that opens up doors to us and provides our customers with security.

It is our aim to tread new ground in cooperation with our customers, optimize processes, save the environment and become a little better every day.

We work with
- Graphite
- CFC
- Carbon graphite
- Graphite foil
- Coated graphites & CFC

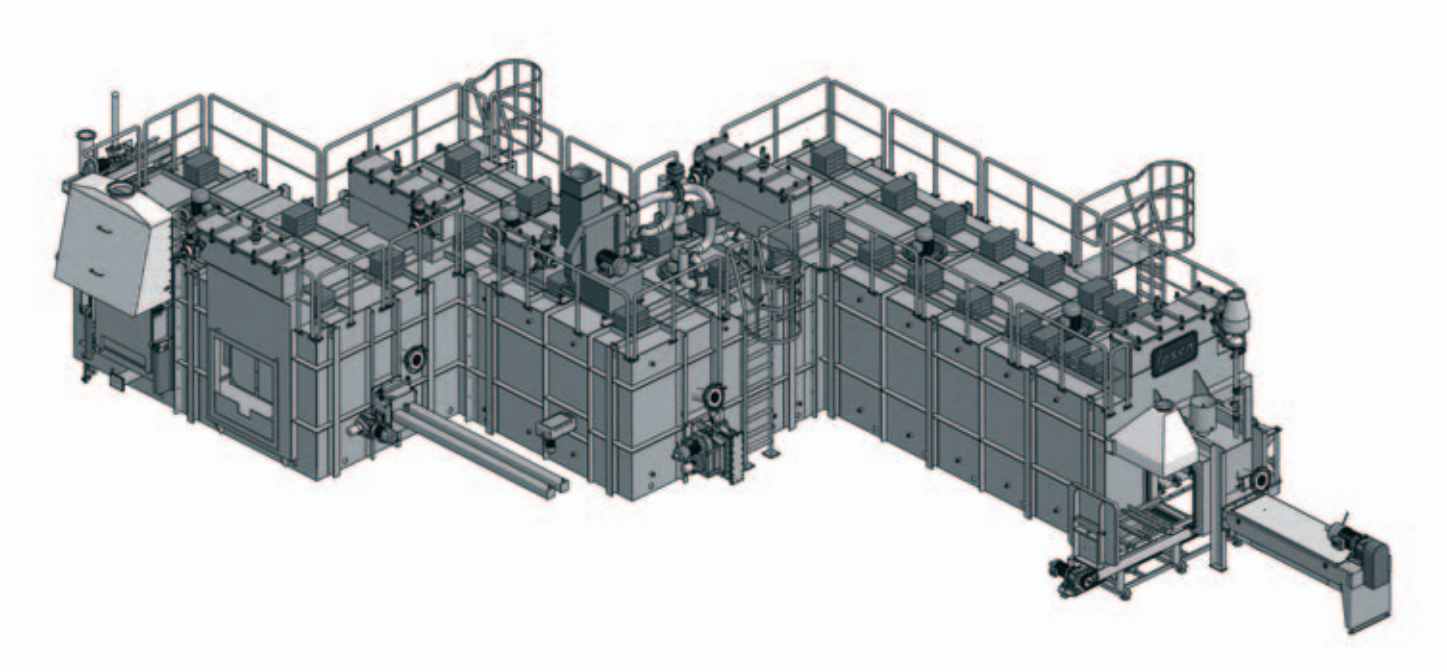
Our Fields of Competence

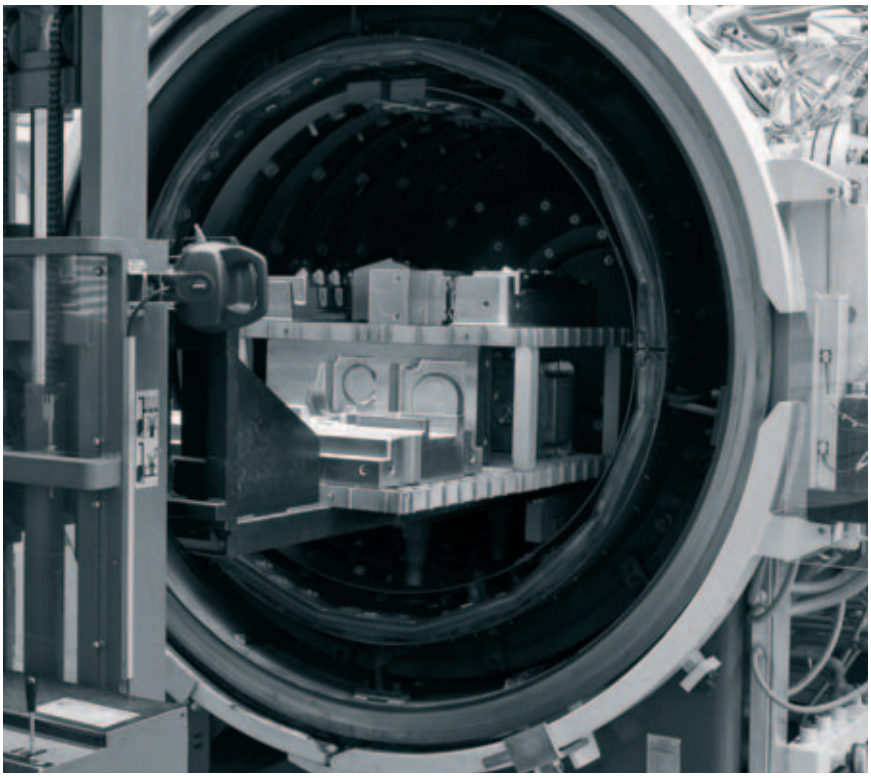
Our high-quality solutions are based on graphite production from planning all the way to processing by a single company. They are as versatile and forward-looking as our customers themselves.

We deliver ex warehouse and are a competent partner for special designs of all kind. Particularly in the specialized field of high-temperature applications, our long-term and economic CFC and graphite developments support new production approaches and improved quality.

Fields of Application

- Continuous high-temperature facilities
- Vacuum furnaces
- High-temperature soldering
- Sintering
- Special products





Continuous High-Temperature Facilities

Physical Superiority
The thermal treatment of steel in continuous facilities and multi-purpose chamber furnaces places exceptionally high demands on all components due to the extreme temperature differences. On the one hand, this applies to the furnace itself. On the other hand, it is especially the charging elements that are exposed to the highest loads.

Instead of the classical steel and cast iron trays used in the past, nowadays charging racks made of CFC are the first choice in very many cases. Their high stability and extreme distortion resistance are decisive advantages that come into play especially in automated processes. Their low density and weight not only facilitate handling, but also ensure an exceptional energy balance as compared to trays made of steel or cast iron.

Please note: before using CFC racks it is absolutely necessary to examine the operational, chemical and physical influences on the racks. We will be glad to give on-site advice.

Material Advantages
- High distortion resistance
- Low density
- Excellent energy balance
- High thermal stability
- High thermal shock resistance
- Long service life

Steel and CFC Comparison
Although its heat-absorbing capacity is 2.5 times higher, CFC has a clearly better energy balance because of its low density and high thermal stability.

		Steel 1.4818 *(example)*	CFC
Density		7,9 kg/dm³	~ 1,6 kg/dm³
Flexural strength (at 1000° C)		~ 10 MPa	~ 230 MPa
Spec. thermal cap. (at 1000° C)		0,7 kJ/kg K	1,8 kJ/kg K
Energy for heating 1 dm3 from 20° C to 1000° C	$Q = m\ c_p\ \Delta t$	5400 kJ 100 %	2800 kJ ~ 50 %
Energy with same stability	$Q = \sigma_{CFC} / \sigma_{Stahl}\ m\ c_p\ \Delta t$	~ 16000 kJ 100 %	2800 kJ < 20 %

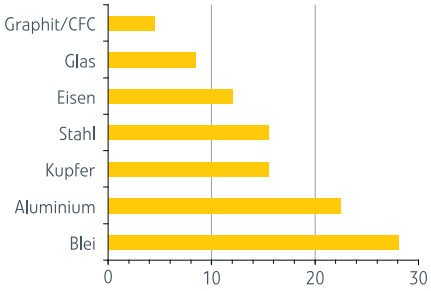
Economic Advantages
CFC charging racks pay off. They provide obvious and calculable advantages even at a higher initial price. They enable shorter cycle times with significantly longer service life, are up to ten times lighter than steel racks and do not distort at all. This makes handling easier and reduces the amount of work involved because it eliminates the straightening work on distorted racks and ensures continuous production. Especially when using automatic charging and removal systems these advantages play a key role since they enable expansion of production with unchanged facility size.

There is another factor that is becoming more and more important: with the ever-increasing costs of energy, the excellent energy balance is a very good reason for using CFC racks having a lower heat-absorbing capacity overall.

Production Advantages
- Automation possible
- Reduced costs of energy
- Easy handling
- Long service life
- No setting times
- More runs per rack
- Higher packing density achievable
- Shorter cycle times

Expansion Coefficient
The very low expansion coefficient is one of the most important advantages of CFC and graphite.

CTE Comparison

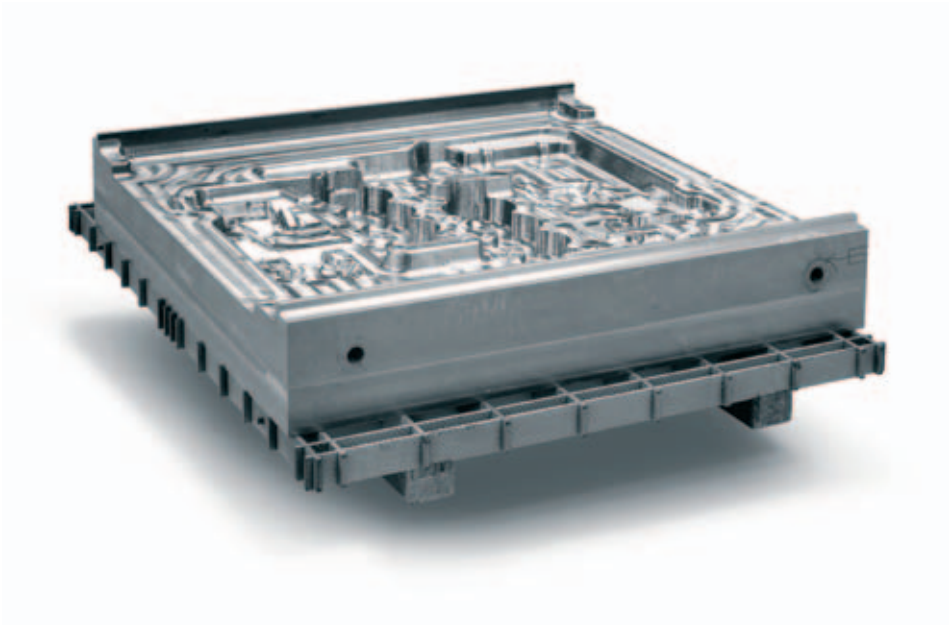


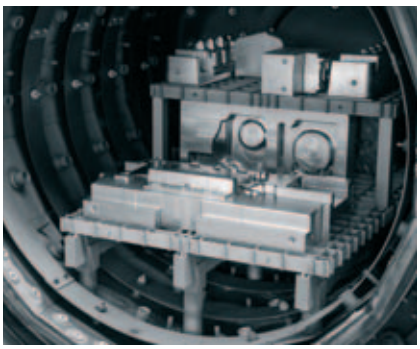
We provide charging elements as base and multi-stage trays with maximum loads of 750 kg for nearly any common furnace size. Moreover, our modular system enables us to provide custom-built charging elements quickly and economically for nearly every task.

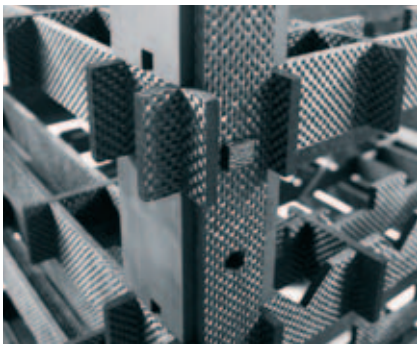
Vacuum Furnaces

Benefit of Material Properties
CFC also provides a number of clear advantages over conventional materials for vacuum furnaces. On the one hand, CFC is used for charging racks in a similar way as in continuous facilities. On the other hand, it is suitable for the construction of furnaces themselves because of its excellent material properties. You will find an excerpt of our standard components on pages 12 and 13.

Material Advantages
- High thermal, chemical and physical stability
- Optimum availability of standard products
- Individual special designs
- Increased production with unchanged facility size







Item number	Designation		Dimension	Max. Load*
4C27##0420	Base tray	GR250	900 x 600 x 30	≤ 250 kg
4C27##0421	Base tray	GR500	900 x 600 x 35	≤ 500 kg
4C27##0220	Base tray	GR750	900 x 600 x 45	≤ 750 kg
4C27##0422	Multistage tray	ERG50	900 x 600 x 22	≤ 50 kg
4C27##0423	Multistage tray	ERG100	900 x 600 x 25	≤ 100 kg
4C27##0279	Multistage tray	ERG250	900 x 600 x 45	≤ 250 kg
4C27##0424	Multistage tray	ERG500	900 x 600 x 45	≤ 500 kg
4C27##0425	Multistage tray	ERK50	600 x 450 x 25	≤ 50 kg
4C27##0426	Multistage tray	ERK100	600 x 450 x 35	≤ 100 kg
4C27##0226	Multistage tray	ERK200	600 x 450 x 40	≤ 200 kg

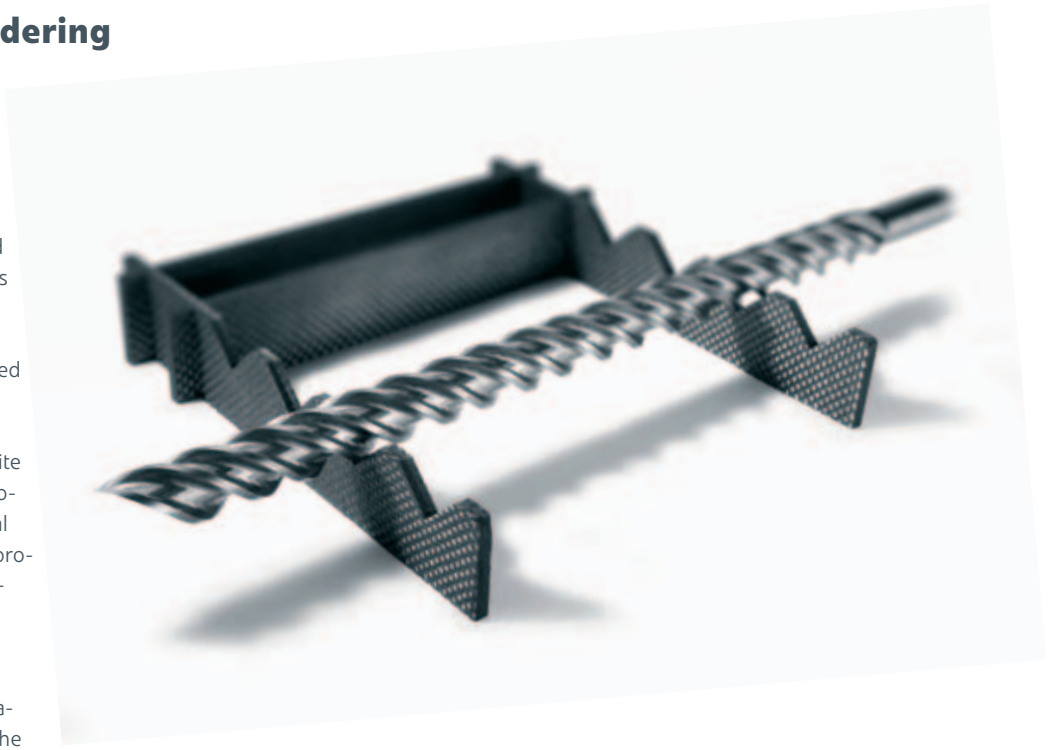
** All values are standard values. Please inquire for the maximum load of the individual stages and the complete rack depending on their arrangement. We do not assume any guarantee without prior consultation and written acceptance.*

Charging Racks
CFC charging racks are optimally suitable for use in most vacuum furnaces. At the customary temperatures in vacuum furnaces CFC does not react with process gases such as nitrogen and argon. Their high thermal shock resistance ensures a long service life and thus plannable processes and cycles. The low weight and easy handling are additional reasons for using them.

Please note: before using CFC racks it is absolutely necessary to examine the operational, chemical and physical influences on the racks. We will be glad to give you on-site advice.

Production Advantages
- Shorter cycle times
- Reduced costs of energy
- Easy handling
- Long service life
- No setting times
- Higher packing density achievable
- More runs per rack

High-Temperature Soldering



Reliable Attachment of Soldering Objects

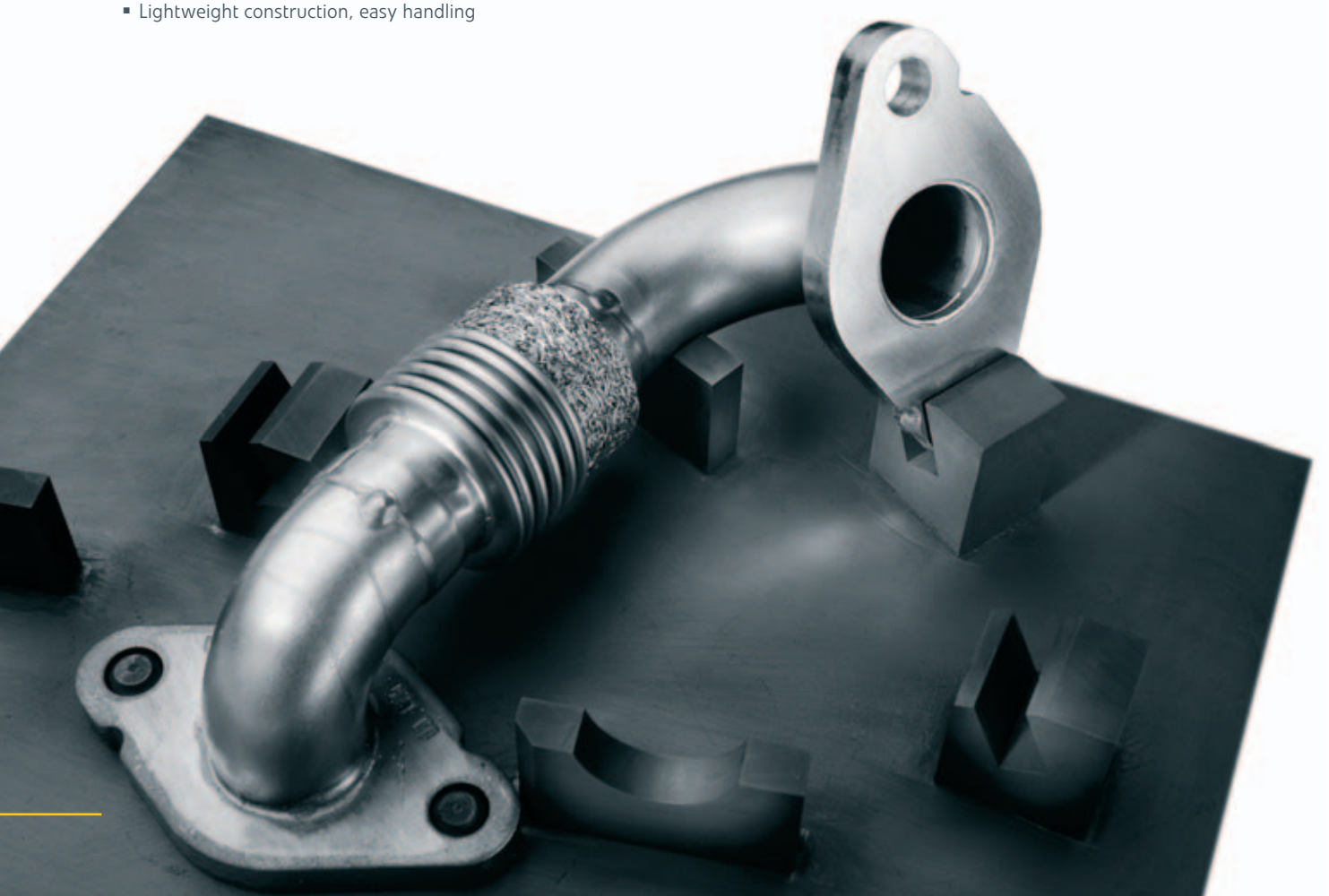
Higher quality requirements with regard to pressure resistance and flux inclusions makes high-temperature soldering increasingly necessary. This involves the risk of distortion of components hardened through cold work.

We recommend the use of CFC or graphite fastening devices to obtain reliably reproducible results. Due to their high thermal stability and distortion resistance, they provide for reliable attachment of the workpieces to be soldered.

Under all circumstances, however, the different expansion properties of the materials have to be taken into account in the design. We will be glad to provide support in developing the optimum and most inexpensive solution for your requirements.

Advantages

- Safe attaching of workpieces
- Protection from dripping solder
- Suitable for multistage charging racks
- Lightweight construction, easy handling



Sintering

Economic Realization of High Production Volumes
Sintering has become the simplest and most economical process for manufacturing large volumes of metal parts, provided that the technical basics are correct. This includes stable transport or receiving systems for the workpieces. Our graphite and CFC solutions provide excellent alternatives to classical racks.

Their special material properties make them ideal for use in temperature ranges above 1300° C that are often reached in the metallurgical field. They support the ever-increasing demands on the products' dimensional stability and the options for automating processes. We will be glad to provide advice on possible contact reactions between the sintered products and the graphite or CFC base and develop the appropriate protective measures.

Advantages
- Automation possible
- Lightweight construction, easy handling
- Lower energy costs

Reactions between Graphite / CFC and Process Gases
Reactions such as oxidation, methanation or carbide formation occur under certain conditions during thermal treatment.

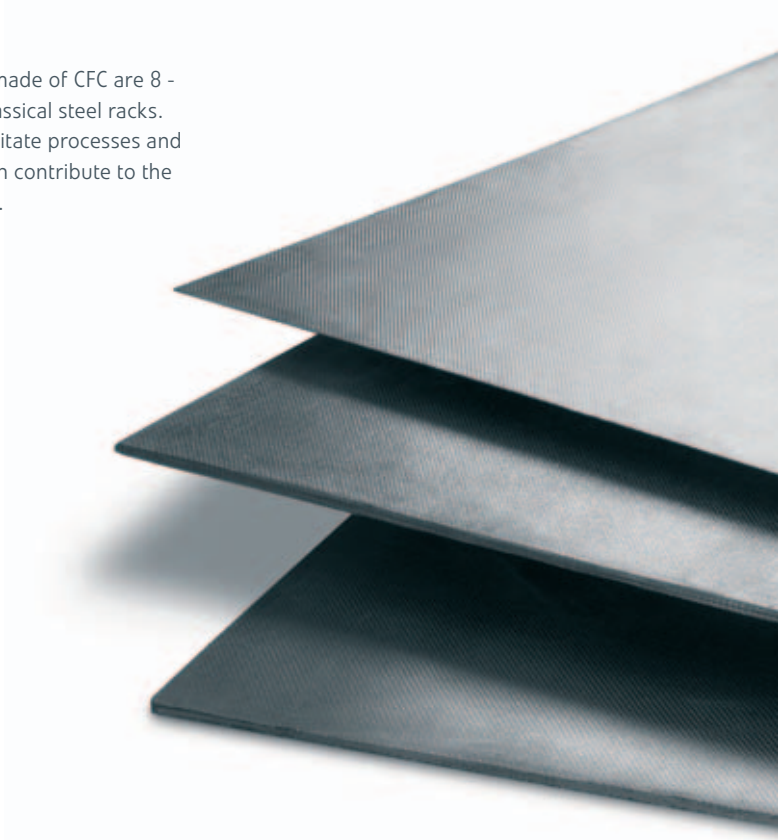
Atmosphere	Reaction starts at	Reaction
Air	500 ~ 600 °C	Oxidation
Water vapor	700 ~ 750 °C	Oxidation
CO_2	800 ~ 900 °C	Oxidation
H_2	1000 ~ 1200 °C	Methanation
N_2	2000 ~ 2500 °C	Cyanide formation
Cl_2	2500 °C	Evaporation
Ar	3000 °C	Evaporation
Vacuum	2200 °C	Evaporation

CFC

Ideally Suited for High-Temperature Ranges
CFC (carbon fiber-reinforced carbon) is a high-performance fiber composite material consisting of a carbon or graphite matrix and carbon fibers. The introducing of the fibers leads to a high-temperature resistant material that can be used under inert gas atmospheres or vacuum at temperatures much higher than 2000° C. Its high specific resistance and rigidity in combination with its excellent chemical and thermal stability make CFC a versatile construction material.

Energy Efficiency
Although its heat absorbing capacity is 2.5 times higher than that of metal, CFC provides a significantly better energy balance than all comparable materials because of its extremely low density. This means for high-temperature applications: reduced heating and cooling times as well as less energy demand.

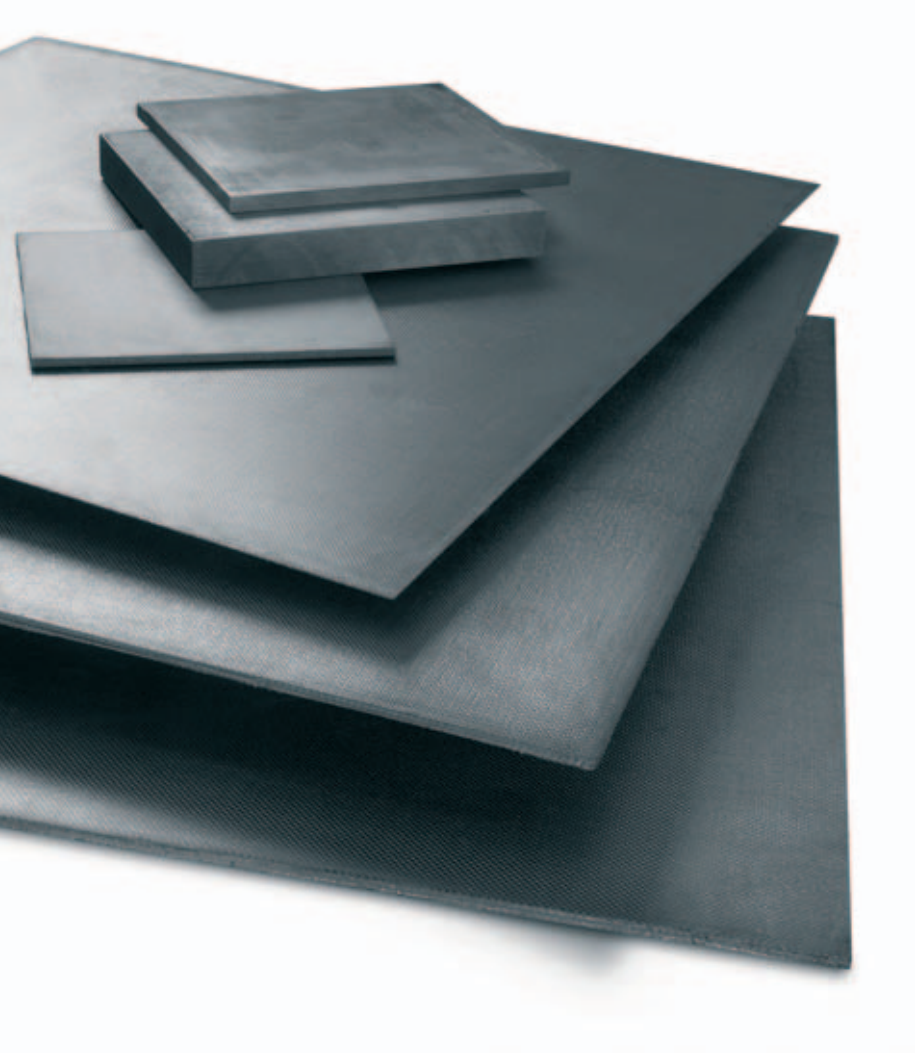
Weight Reduction
Racks and workpieces made of CFC are 8 - 10 times lighter than classical steel racks. Consequently, they facilitate processes and working cycles and even contribute to the prevention of accidents.



			CX-31	CX-74	CX-76
Reinforcing fiber			Carbon Staple fibers	Carbon 6k-Roving	Carbon 6k-Roving
Type of reinforcement			Fabric 0/90°	Fabric 0/90°	Fabric 0/90°
Density	g/cm³		1,61	1,51	1,58
Spec. electr. resistance	µΩm	(//)	22	23	20
Flexural strength	MPa	(//)	90	140	185
Shear strength	MPa	(//)	10	–	–
Pressure resistance	MPa	(//)	80	95	120
		(⊥)	220	260	260
Tensile strength	MPa	(//)	98	185	250
		(⊥)	–	–	–
Young's modulus	GPa	(//)	47	111	113
CTE (20-1000°C)	x10⁻⁶ K⁻¹	(//)	< 1	< 1	< 1
		(⊥)	4,10	8,10	8,40
Thermal conductivity	W/mK	(//)	31	35	44
		(⊥)	12	6	9
		(//) = parallel to fiber plane; (⊥) = perpendicular to fiber plane			

Distortion Resistance
Due to its molecular structure, which has almost no tendency to move even at the highest temperatures, CFC is extremely distortion-resistant and maintains its shape unchanged even after thousands of uses. It reaches its highest stability at temperatures of about 1800° C. Its expansion on 1 meter tends to zero at 1000° C. A comparable metal rack expands by about 1.1 cm (approx. 1/2").

The figures given above are typical values based on our experience and are not guaranteed. Material and production-specific variations have to be taken into account.

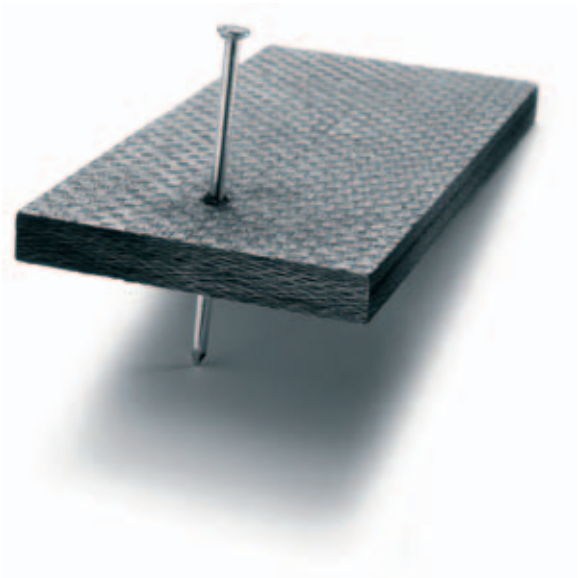


No Wear
Classical charging racks made of cast iron or steel initially tend to distort because of thermal loads and then become brittle. Furthermore, they grow due to the temperatures and atmosphere when used in high-temperature ranges, resulting in limitation of their service life. Thus there is the risk of additional financial and personnel costs as well as, in the worst case, a production loss.

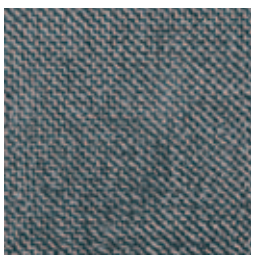
Strength
Thanks to their special fiber structure, CFC racks are very robust, permit facilitated handling and are thus the ideal choice for long-term uses in production, especially when it comes to behavior at fracture and mechanical resistance.

Thermal Shock Resistance
CFC almost does not react at all even under the extreme thermal conditions during heating and cooling in oil baths. It does not embrittle or crack or suffer any other damage.

Profitability
CFC solutions pay off despite the higher purchase costs. The exceptionally long life cycle and the advantages of automation can be calculated in concrete terms and elaborated for every project. We will be glad to help you.

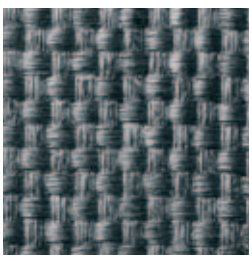


Staple fiber



CX-31

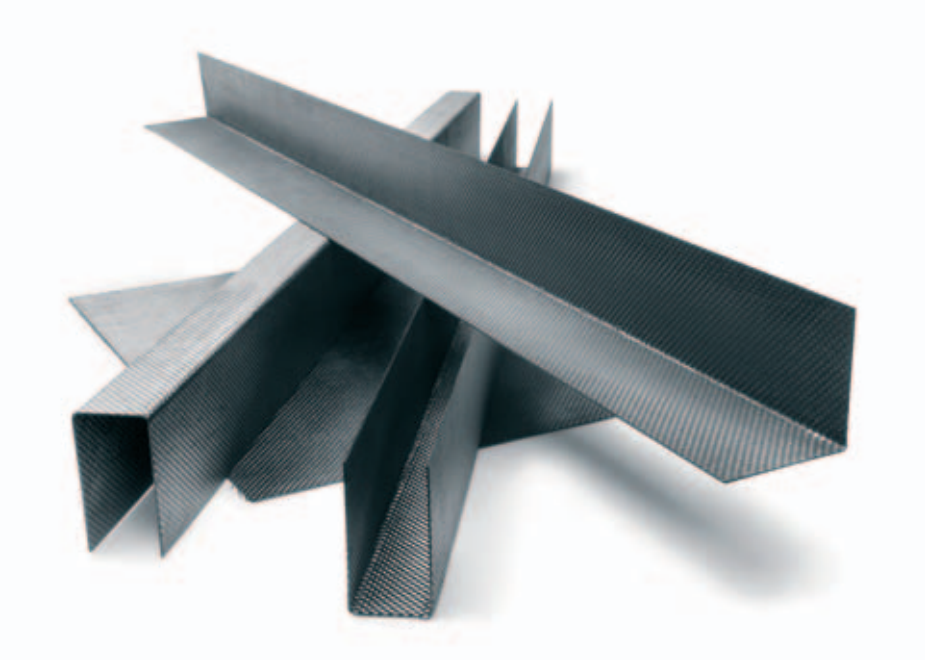
12k-Roving



CX-74/76

CFC Vacuum Furnace Components

Long-Term Assurance of Production
In vacuum furnace production industry it is important to utilize components having excellent physical, chemical and thermal properties. This is the only way to assure economical production and minimize or completely avoid the repair and maintenance costs.



Sheets and Profiles
The plates and profiles we have in stock with different standard dimensions and strengths provide the ideal base for lining the furnace chambers because of their physical properties. Their particular strength reliably protects the sensitive insulation from mechanical or chemical damage for a long period of time.

The high availability of standard products ex warehouse (we will be glad to adapt them to your special requirements) enables us to provide replacements quickly and reliably in the case of damage and thus reduce downtime and costs.

Fastening Elements
Screws and nuts made of CFC are the ideal choice for fastening elements in high-temperature ranges since their resistance increases with rising temperature. Unlike metals they do not become brittle and therefore have a longer service life.

In addition to standard dimensions we manufacture customized products such as countersunk screws and hammerhead bolts as well as other forms. Our product range comprises metric threads and nearly all other thread types such as UNC and UNF.

Graphite

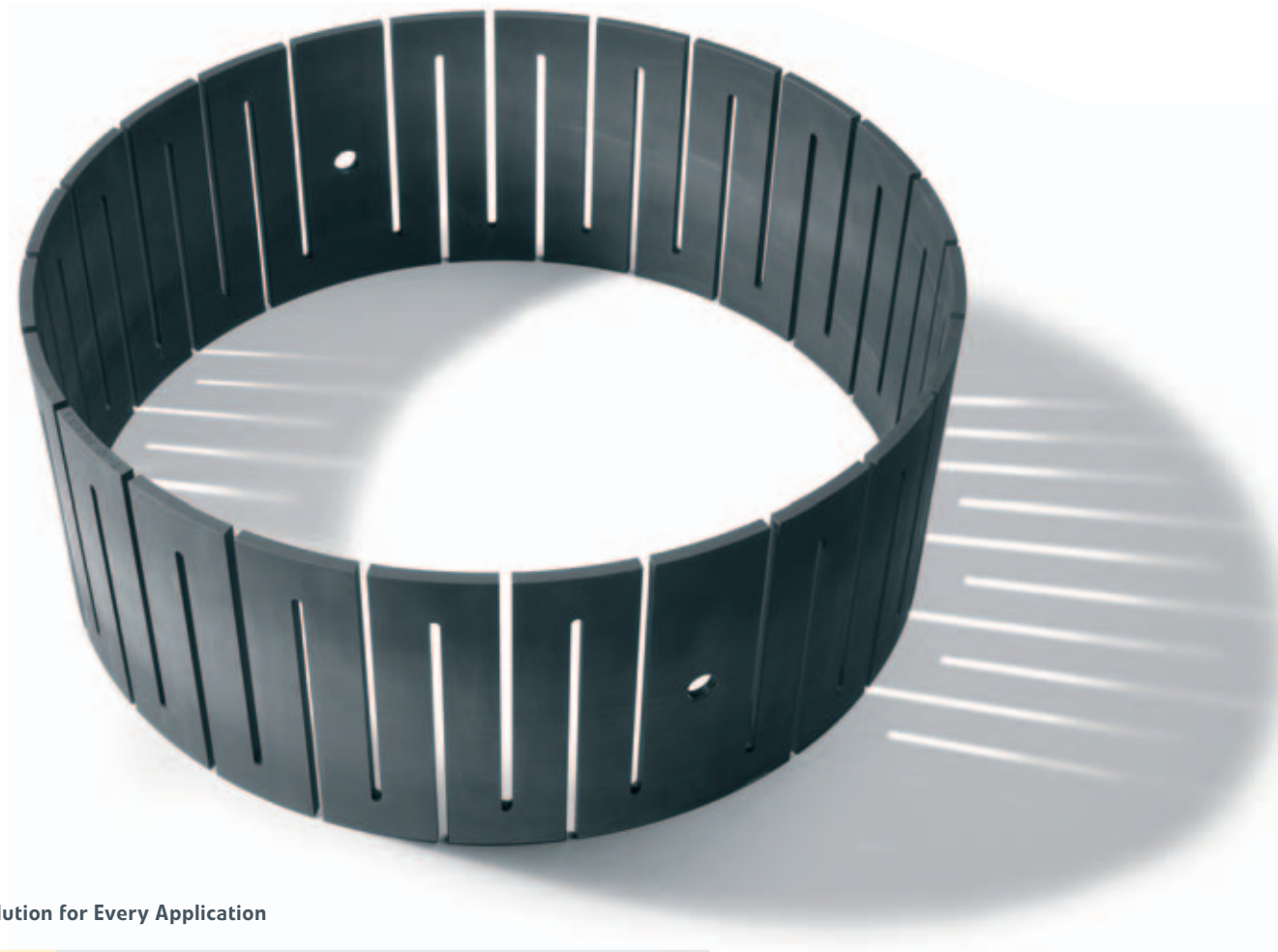
Utilizing the Diversity of Shapes and Materials
Graphite is especially suitable for high-temperature applications under vacuum or inert gas atmospheres because of its chemical, physical and thermal properties.

As a standard we work with four materials that can cover all common applications. We are able to reproduce nearly any desired shape and design requirement in-house.

If necessary, we utilize additional suitable materials from Toyo Tanso. This ensures that we employ only the best graphite qualities while maintaining our reliable supply capabilities.

High-Temperature Applications
- Resistance heaters
- Charging elements
- Pillars of charging elements
- Furnace components (support systems, fastening elements)

Advantages of Graphite
- Low weight
- Relatively low expansion
- High thermal stability
- High thermal shock resistance
- Excellent processability



The Right Solution for Every Application

		SG-8	IG-11	IG-43	ISO-63
Pressing type		Extruded	Isostatic	Isostatic	Isostatic
Raw density	g/cm^3	1,75	1,77	1,81	1,80
Spec. electr. resistance	µΩm	7,5*	10,5	9,0	16,5
Flexural strength	MPa	19,5**	39	50	70
CTE $_{(350\text{-}450°C)}$	x10^{-6} K^{-1}	2,8**	4,6	4,8	5,5
Thermal conductivity	W/mK	200*	120	145	85
Ash	%	< 0,14	< 0,04	< 0,04	< 0,04

** measured in strand direction;*
*** measured across strand direction.*

Design, Construction, Realization

Competent Initial Consultation
Thanks to our long-term experience in the design, production and processing of graphites and CFC we are able to advise our customers in a comprehensive and foresighted manner. It all starts with an initial conversation to work out the precise tasks and an analysis of optimization potential.

Well-Coordinated Design Phase
Right from the development phase we use computer-aided strength calculations aimed at providing cost and material optimization. By doing so, we can process nearly all common CAD formats (2D: DXF, DWG; 3D: SolidWorks, STEP, IGES). Our long-term intensive cooperation with renowned research institutes helps us to find new approaches and optimize existing ones consistently.

Computer-Optimized Evaluation
Finished constructions are subjected to standardized evaluation methods with integrated collision tests. This enables us to detect and eliminate potential problems before making prototypes and saves costs and precious time. Moreover, tested constructions can be realized with maximum reliability.

Assured Production
Since we only use our own iso-graphites from Toyo Tanso, we can guarantee constant graphite and CFC qualities to our customers. Our leading-edge manufacturing plants provide manifold application options for CNC-controlled processing methods even including our own high-temperature furnace.

Design of grate model using SolidWorks as 3D visualization.

Standardized Process Flow
Production schedules that we develop in cooperation with our customers are stipulated as the binding basis for determining and monitoring the running times of the individual development stages of construction. Thus we always keep optimal track of all deadlines and costs and can identify deviations and initiate countermeasures at an early stage, if necessary.

Special Solutions and Volume Production
We are prepared for all batch sizes, manufacture one-off parts and implement large-scale production. We see to it that the processing times are as fast as possible and that the resources are used responsibly.

Our Aim: Win-Win
We regard the sale of a product in its entirety. It does not end when delivered and will be continued systematically afterwards. This means that we want to know about our customers' experiences with our products and learn from that. Continuous improvement is not a catchword for us, but the basis of our work.

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Ideas for Innovations

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