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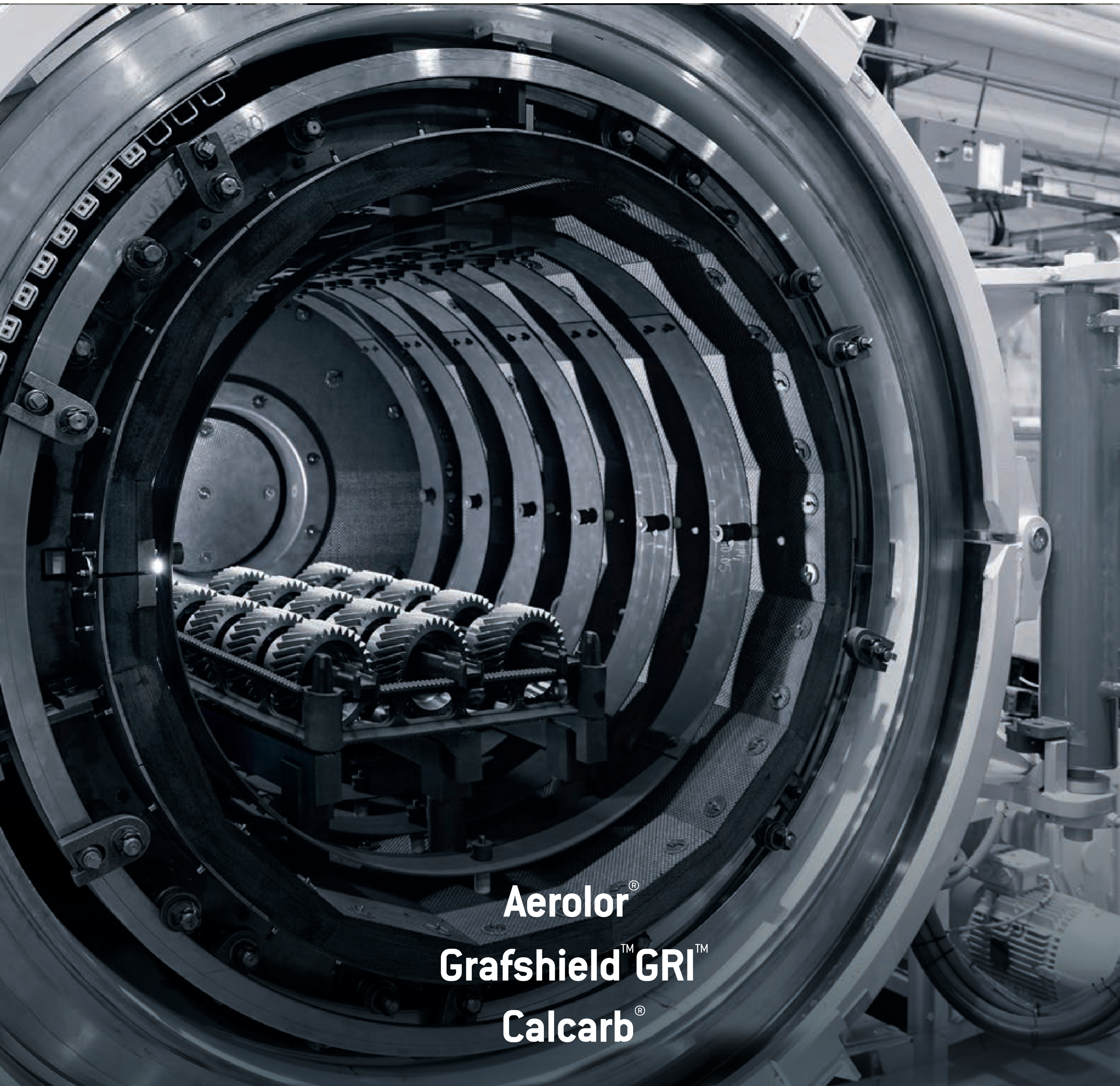
HEAT TREATMENT

MERSEN
Expertise, our source of energy

GRAPHITE, CARBON INSULATION AND CFC COMPOSITE SOLUTIONS FOR YOUR HEAT TREATMENT PROCESS



Vacuum heat treatment

Vacuum heat treatment is capable of achieving almost all heat treatment processes including quenching (gas quenching, oil quenching, water nitrate quenching), annealing, tempering, carburizing, nitriding, vacuum brazing, sintering and surface treatment while maintaining higher levels of component cleanliness when compared to traditional processes.

PART 1
Hot Zone

photo: courtesy of PVA Tepla

HOW IMPORTANT IS **THE TEMPERATURE?**

RAMPING RATE, TEMPERATURE ACCURACY, STABILITY AND THERMAL UNIFORMITY

Uniformity of temperature is of great importance to heat treatment results.

In many cases, even though the product temperature may be uniform at the end of a cycle, the product may not be acceptable because different sections of the product will have had different time at temperature histories.

For hot zone insulation, most vacuum furnaces use carbon based materials for their unique properties.

YOUR HOT ZONE: **WHICH MATERIAL TO SELECT?**

Graphite and metallic hot zones are available on the market, each having their own specific properties with a direct impact on the:

- process efficiency and its duration,
- quality of the pieces heat treated,
- maintenance cost,
- energy needed during the entire cycle.

All in all, selecting the right material will impact significantly your total cost of ownership.

HOT ZONE

CARBON AND GRAPHITE

HEATING ELEMENTS

GRAPHITE IS THE VERSATILE MATERIAL FOR YOUR HOT ZONE

High running temperature; high strength

+ up to 3,000°C (based on the vacuum level).
+ x2: at 2,500°C, graphite has 2 times more strength than at room temperature!

Extended lifecycle and reduced maintenance costs

+ graphite is unaffected by thermal shock and will not degrade due to frequent heating and cooling.
+ graphite hot zones are easily repairable.

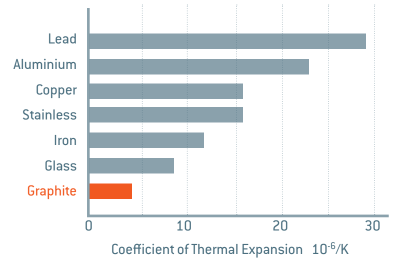
Improved quality through a higher thermal uniformity

+ carbon and graphite have a low density, reduced weight and modest thermal capacity. It creates the ideal conditions inside the heating chamber for obtaining high uniformity.

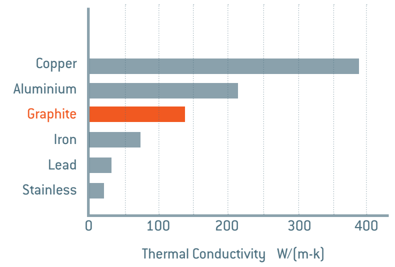
Reduced total cost of ownership

+ all in all, the quality of the final piece improves, the power costs are better controled for a lower total cost of ownership.

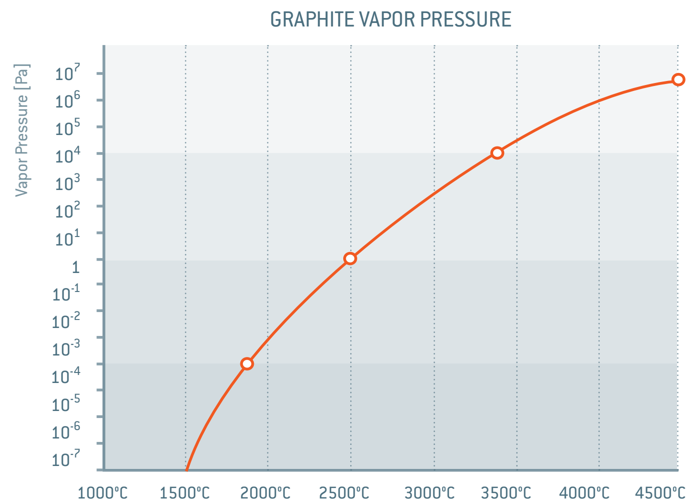
Why graphite is the ideal material for heat treatment?



Compared with general metals, the coefficient of thermal expansion for graphite is extremely low. As a result, when used in high temperature applications, the dimensional accuracy is very stable.



The thermal conductivity of graphite is fairly high, while the coefficient of thermal expansion is very low. These characteristics contribute to its superior thermal shock resistance.



Graphite is an extremely stable material in temperatures under 2,200°C, making it an ideal solution for heat treatment processes.

CARBON AND GRAPHITE MATERIAL VS MOLYBDENUM

+ Molybdenum becomes brittle above 1,700°C limiting its versatility in some furnaces. Any movement of the material causes cracking and ultimately failure which cannot be repaired.
+ High heat resistance - at 2,500°C, graphite has 2 times more strength than at room temperature!
+ Graphite has low thermal expansion 4,5 x 10^{-6}.
+ Graphite is lightweight (1/5 of metal).
+ Graphite has a higher thermal unifomity.
+ Graphite does not bond.
+ Graphite has excellent resistance to corrosion and radiation.

HOT ZONE

GRAFSHIELD™ GRI™

THE CARBON BASED INSULATION

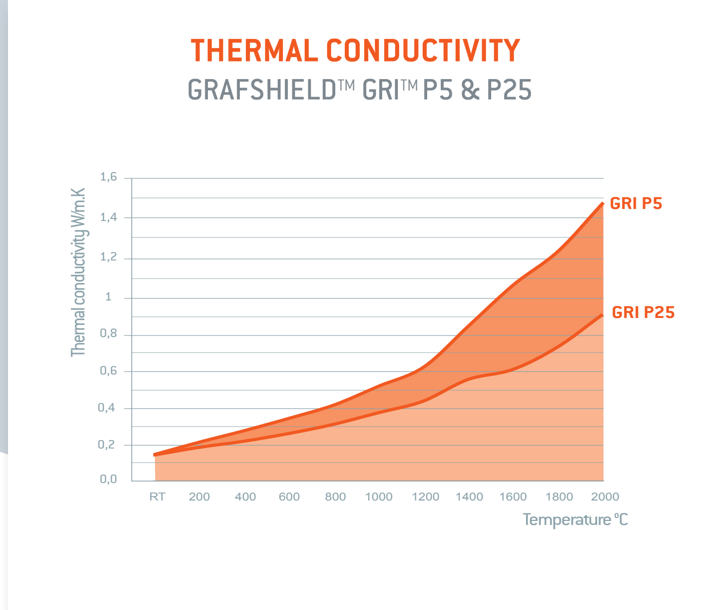
High-velocity gas

At a pressure of 20 bar, a quenching gas such as nitrogen has a weight of 51 kg/m³! Mersen heat treatment experts can help you to identify the right insulation grade for high-velocity gas quenching.

KEY FEATURES OF GRAFSHIELD™ GRI™ INSULATION:

- + oxidation resistance properties.
- + high tensile strength for an improved resistance to gas quenching.
- + appropriate Thermal Conductivity for fast heating and cooling down cycles.
- + robust, lightweight and ease of installation.
- + extented lifetime.
- + competitive solution.

Mersen designs and produces a complete range of carbon insulation solutions to answer to most of the industrial high temperature processes, branded under the name Grafshield™ GRI™ and Calcarb®. Our high temperature experts can help you to select the right material for you.

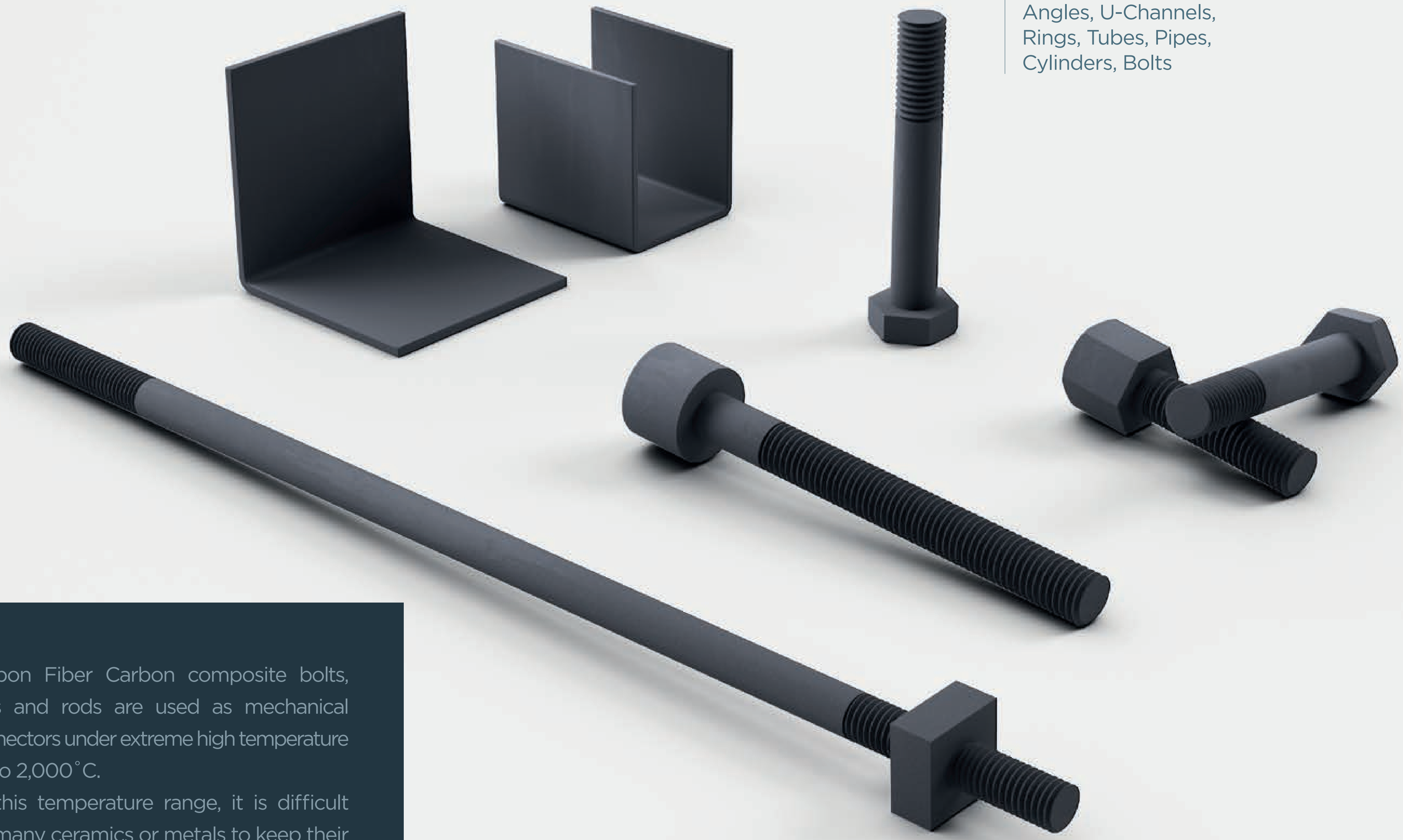


WEAR PROTECT, the Carbon Fibre Composite (CFC) protective layer.

WEAR PROTECT is a flexible 2D composite layer made with continuous carbon strands, woven and densified with a carbon matrix to:

- reinforce insulation boards and strenghten its mechanical properties
- protect insulation boards from abrasion and oxidation
- can be used as a support for soft felt insulation

ACCESSORIES



Standardized design

Fabricated shapes include but are not limited to: Sheets, Angles, U-Channels, Rings, Tubes, Pipes, Cylinders, Bolts

PART 2
Tooling >

Carbon Fiber Carbon composite bolts, nuts and rods are used as mechanical connectors under extreme high temperature up to 2,000˚C.
At this temperature range, it is difficult for many ceramics or metals to keep their physical mechanical strengths. CFC material has the advantage in higher heat resistance and superior strength.

TOOLING

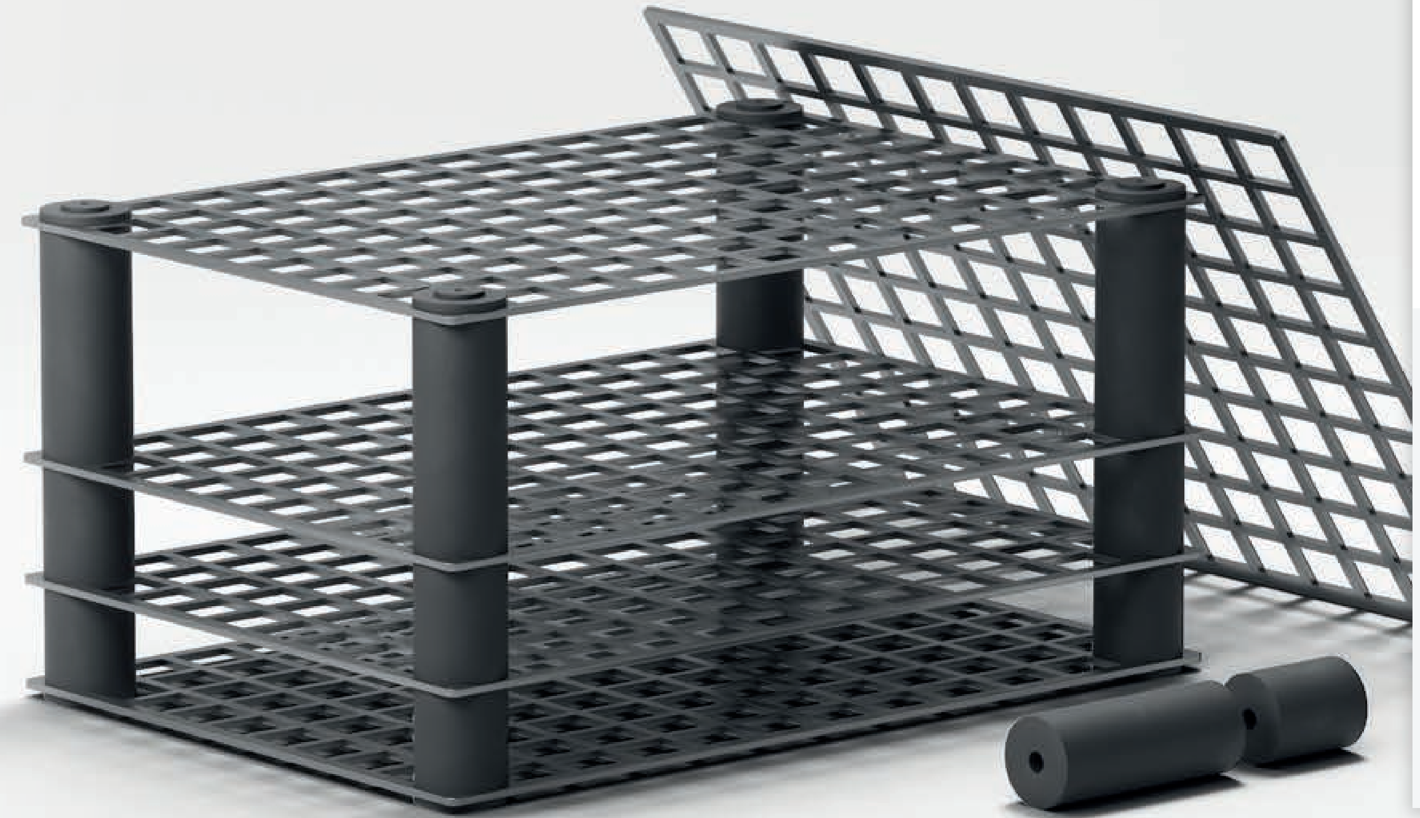
2D CFC LOADING TRAYS

FOR STANDARD HEAT TREATMENT PROCESSES

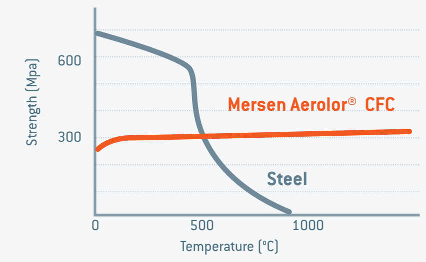
Carbon Fiber Carbon Composite (CFC) also referred to as Carbon Fibre Reinforced Carbon composite (CFRC) is an advanced material that is made of carbon fibres and a carbon matrix. It combines the desirable properties of the two constituent carbon materials. The Carbon matrix (heat resistance, chemical resistance, low thermal expansion coefficient, high-thermal conductivity, low electric resistance) and the Carbon Fiber (high-strength, high elastic modulus) are molded together to form a better combination material.

CFC LOADING TRAYS KEY BENEFITS

- high strength: thermal shock resistance increases with temperature.
- distortion free material, even when subjected to rapid temperature cycles making it the ideal material for automation.
- lightweight: 8 to 10 times lighter than steel racks!
- CFC Composite has a self-lubricating surface. No sticking/brazing of metal parts to rack surface.
- extra long service life time: CFC systems are not susceptible to fatigue.
- faster heating and cooling cycles with less energy needed: with its low density, CFC loading trays do not absorb heat, reducing significantly heat-up and cool down cycles. CFC racks improve your productivity and reduce your energy cost.

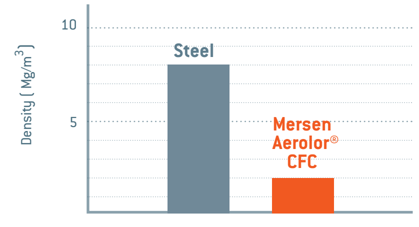


Ultra heat resistance



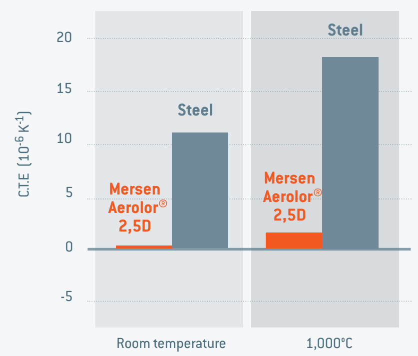
CFC composite has higher stength at high temperatures compared to metallic materials. Mersen Aerolor® can be used even at ultra-high temperatures of 2,000°C or higher in inert atmospheres.

Light-weight and easy to handle



CFC composite has low density compared to metallic materials, and therefore, make light weight designs possible.

Low coefficient of thermal expansion



Absence of any tendency to distort. Whereas metal trays need to be constructed from a solid, heavy and thick structure (room being lost for pieces) and reshaped with a hammer after some months in operation, the CFC material has absolutely no tendency to distort. This makes the material highly suitable for use in automated processes.

STEEL VS AEROLOR® CFC COMPOSITE

EASY TO USE	**-80%** Aerolor® tray is much lighter	**2,000°C** Higher running temperature with Aerolor®	**none** No fixture rework with Aerolor®
COST SAVINGS	**-65%** Less energy needed with Aerolor®	**almost unlimited** Aerolor® tray lifetime is almost unlimited	**-30%** Faster cycles with Aerolor®
EFFICIENCY	**Higher furnace utilization** Much more pieces charged with Aerolor®	**CFC fixtures reduce distortion of parts** Improved product quality with Aerolor®	**-30%** Productivity gains - Faster batches with Aerolor®

TOOLING

2,5D CFC LOADING TRAYS

FOR AGGRESSIVE HEAT TREATMENT PROCESSES

Typical applications: Aluminizing and oil quenching loading trays solutions

Heavy-Duty fixtures made of Aerolor® 2,5D Carbon Fiber Composite.

Mersen R&D team, together with our experts in heat treatment have developed a 2,5D composite with even higher performance than the common 2D Carbon/Carbon material.

2,5D CFC HAS OUTSTANDING PERFORMANCE

- + incredible resistance to delamination and mechanical shocks due the 3-D direction reinforcement.
- + lowest reactivity (among all graphite materials) to oxidizing gases and chemical substances.
- + low micro-porosity giving low oil absorption properties.
- + extra long life for a significant impact on your overall cost of ownership.

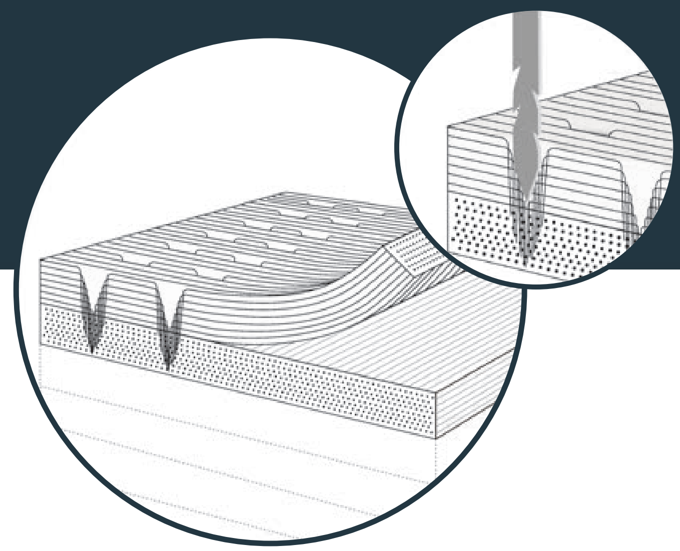
All the CFC components can be purified to 5-20 ppm, which allows them to be used in processes that requires a low purity level.

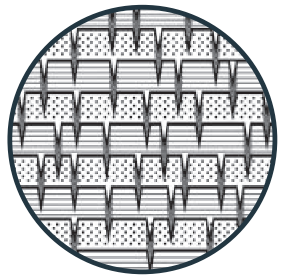
Coating: a wide range of CFC coating technologies and finishes available for anti-dust; anti-oxidation; anti-carburization and ceramic coat.

Alternative solution: with the high charge weights seen in top and bottom loading furnaces, Mersen 2,5D CFC hearth plate is a high strength, cost effective alternative solution to complex CFC structures due to their simple design and minimum machining.

AEROLOR® 2,5D CFC PRODUCTION PROCESS

The needles transport the predominently X-Y (or in-plane) oriented carbon fibers from one layer into the Z direction (or accross plane) into the layer below. These carbon fibers acts as anchoring for the top layers to the ones below.





The needling is randomly applied accross the depth of the preform to make the material fully homogeneous in the three directions.

1,050°C and above?

When the processing temperature is above 1,050°C there is a high risk of carbon transfer from the grids to the product.

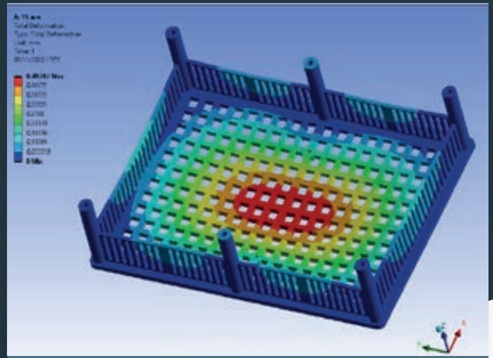
The use of a ceramic barrier, for instance a ceramic coating may be necessary to prevent Carburizing and to avoid an Eutectic reaction. Eutectic melting can occur with CFC materials at temperatures excedding 1,050°C and it is highly dependant on the alloy being run.

The use of tiles is common practice, but if suitable, the coated plate is much more user friendly i.e. no loose components.

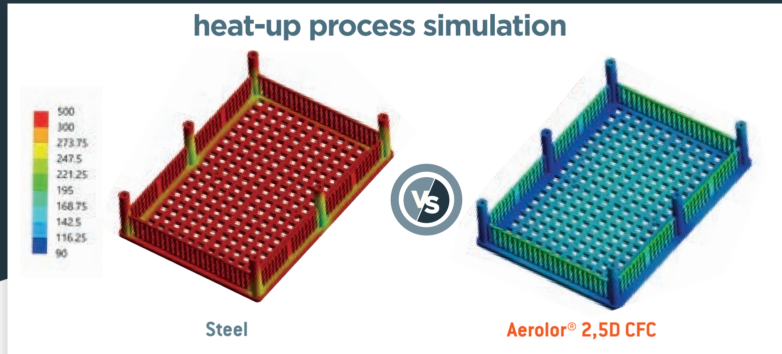
The best coatings are applied by plasma spray and include an intermediate and a top layer. Mersen experts will be pleased to help you select the right configuration for your application.

DESIGN OPTIMIZATION

Mersen designs and produces Carbon Fiber Carbon Composite loading racks. Through comprehensive computer simulations, Mersen can provide you a design with optimized performance. Optimization of the design helps to decrease both the weight and flexion levels of the fixture to achieve the best solution for your process.



CFC fixture distortion simulation under load analysis to optimize the design.



Heat the pieces, not the tray!

With its low density, CFC loading trays do not absorb heat, reducing significantly heat-up and cool down cycles. CFC trays improve your productivity and reduce your energy cost.

RECOMMENDATIONS

		EXTRUDED GRAPHITE	ISOSTATIC GRAPHITE	AEROLOR® CARBON/CARBON COMPOSITE	CARBON INSULATION GRAFSHIELD™GRI™ CALCARB®	PAPYEX® FLEXIBLE GRAPHITE
VACUUM FURNACE CONSTRUCTION / REFURBISHEMENT	HEATING ELEMENTS	6501/ 6502/ 6503	1940	A202 / A015		
	SUPPORTS / OTHER FURNACE ELEMENTS	6501/ 6502/ 6503	1940			
	HOT ZONE	6501/ 6502/ 6503				
	LININGS			A201		1980
	STANDARD INSULATION				Grafshield™ GRI™ P5 Grafshield™ GRI™ P25 Calcarb® soft felt	
	HIGH TEMPERATURE INSULATION (>1500°C)/ PV				Calcarb® CBCF	
LOADING TRAYS	SINTERING PLATES	6501/ 6502/ 6503		A015 / A100		
	LOADING SYSTEMS	6501/ 6502/ 6503		AW252 / A100 / A202		
	HI-LOADED TRAYS / FURNACE BASES (>400 KG)					
FURNACE FURNITURE	BOATS/CRUCIBLES/ PLATES/ DIES	6501/ 6502/ 6503		AW252 / A015		
	BIG CRUCIBLES (DIAM.>500 MM)	6503				

OUR GRADES

		Density		Flexural Strength		Flexural Modulus		Compressive Strength		Coefficient of Thermal Expansion (CTE)		Maximum standard sizes - other sizes on request	
		g/cm³	lbs/ft³	MPa	psi	GPa	psi	MPa	psi	RT - 1300°C	RT - 2,372°F	mm	inch
CFC 2D GRADES	AEROLOR® A015	1,65	103	160	23,200	30	4.4 x 10^6	140	20,300	1,3 x 10^{-6} / C°	0.7 x 10^{-6} / F°	1000 x 2000 mm	39 x 78”
	AEROLOR® A100	1,60	100	135	19,600	35	5.1 x 10^6	90	13,050	0,7 x 10^{-6} / C°	0.39 x 10^{-6} / F°	1000 x 2000 mm	39 x 78”
	AEROLOR® A201	1,35	84	65	19,000	25	3.6 x 10^6	50	7,250	0,5 x 10^{-6} / C°	0.27 x 10^{-6} / F°	1500 x 1500 mm	59 x 59”
	AEROLOR® A202	1,50	93	100	14,500	40	5.8 x 10^6	100	14,500	0,5 x 10^{-6} / C°	0.27 x 10^{-6} / F°	1220 x 2440 mm	48 x 96”

		Density		Flexural Strength		Tensile Strength		Shearing Strength		Coefficient of Thermal Expansion (CTE)		Maximum standard sizes - other sizes on request	
		g/cm³	lbs/ft3	MPa	psi	GPa	psi	MPa	psi	RT - 1300°C	RT - 2,372°F	mm	inch
CFC 2,5D GRADE	AEROLOR® AW252	1,50	93	200	29,000	100	14,500	11	1,600	2,9 x 10^{-6} / C°	1.6 x 10^{-6} / F°	910 x 610 mm	36 x 24”

		Density		Flexural Strength				Young's Modulus				Compressive Strength				Coefficient of Thermal Expansion (CTE)				Maximum standard sizes - other sizes on request	
		g/cm³	lbs/ft³	MPa		psi		GPa		10^6 psi		MPa		psi		RT - 1000°C		RT - 1,832°F		mm	inch
ISOSTATIC GRAPHITE	1940	1,79	112	40		6,300		9,2		1.3		89		13,000		5,2 x 10^{-6} / C°		2.9 x 10^{-6} / F°		508 x 610 x 1830 mm	20 x 24 x 72”
				WG	AG	WG	AG	WG	AG	WG	AG	WG	AG	WG	AG	WG	AG	WG	AG		
VIBRO-MOLDED	6501	1,74	107	18,0	16,8	2,600	2,400	6,9	4,8	1.00	0.70	41	41	5,900	5,900	4 x 10^{-6} / C°	4,4 x 10^{-6} / C°	2,4 x 10^{-6} / °F	4,4 x 10^{-6} / °F	508 x 508 x 1830 mm	20 x 20 x 72”
EXTRUDED GRAPHITE	6502	1,66	104	16,5	13,1	2,400	1,900	6,4	4,6	1.32	0.96	36	37	5,200	5,350	3,6 x 10^{-6} / C°	4,8 x 10^{-6} / C°	2,2 x 10^{-6} / °F	2,4 x 10^{-6} / °F	610 x 760 x 2230 mm	24 x 30 x 88”
	6503	1,74	108	21,0	15,5	3,050	2,250	7,7	5,8	1.59	1.20	45,5	45,5	6,600	6,600	3,6 x 10^{-6} / C°	4,8 x 10^{-6} / C°	2,0 x 10^{-6} / °F	2,6 x 10^{-6} / °F	610 x 760 x 2230 mm	24 x 30 x 88”

WG: With Grain - AG: Against Grain

WG: With Grain - AG: Against Grain

		Density		Flexural Strength		Thermal Conductivity W/m.k (vacuum)		Thermal Conductivity W/m.k (vacuum)		Coefficient of Thermal Expansion (CTE)		Board size max	
		g/cm³	lbs/ft³	MPa	psi	400°C	800°C	1200°C	1600°C	RT - 1000°C	RT - 1,832°F	mm	inch
CARBON INSULATION	GRAFSHIELD™ GRI™ P5	0,17	10.6	1	145	0,23	0,37	0,57	1,01	3,0 x 10^{-6} / C°	1.6 x 10^{-6} / F°	1250 x 1500 mm	49.2 x 59”
	GRAFSHIELD™ GRI™ P25	0,17	10.6	2,09	305	0,17	0,27	0,39	0,56	3,0 x 10^{-6} / C°	1.6 x 10^{-6} / F°	1250 x 1500 mm	49.2 x 59”
	CALCARB® LF7	0,14	8.73	0,80	1,16	0,16	0,25	0,39	0,57	PROVIDED AT REQUEST	PROVIDED AT REQUEST	1000 x 1500 mm	39.3 x 59”

		Density		Flexural Strength		Thermal Conductivity W/m.k (vacuum)		Thermal Conductivity W/m.k (vacuum)		Modulus of Elasticity		Thicknesses	
		g/cm³	lbs/ft³	MPa	psi	400°C	800°C	1200°C	1600°C	GPa	psi	mm	inch
CARBON INSULATION	CALCARB® SOFT FELT	0,075	4.7	0,051	7.4	0,20	0,25	0,33	0,41	0,558	0.08 X 10^6	6 / 8 / 10 / 12	0.2 / 0.3 / 0.4 / 0.5”

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