TECHNICAL GUIDE

PAPYEX®

FLEXIBLE GRAPHITE

MERSEN

Sealing applications

MARKETS

Mersen is one of the oldest manufacturers of flexible graphite in the world. **Papyex®** quality is demanded, through technical specifications, by many end users engaged in the chemical, nuclear, aeronautical, refining sectors, etc.

Through **Papyex®**, **Mersen** guarantees for its partners, experts in sealing products, reliability, service and performance, in particular in terms of resistance to oxidation.

STATIC GASKETS

Papyex®, by virtue of its chemical, physical and mechanical characteristics, is an excellent material for flange gaskets.

Spiral wound gasket

Papyex® flange gaskets have the following advantages:

- Excellent properties for use under pressure and temperature.
- Insensitivity to thermal shocks.
- No ageing: neither shrinkage, nor hardening, nor hot creep.
- Practically unlimited chemical resistance.
- Non-polluting (asbestos-free).
- Easy to cut and shape.

The main fields of use are: chemical and petrochemical industries, refineries, and the energy, engineering and automotive sectors.

DYNAMIC GASKETS

Seals produced from **Papyex®** are self-lubricating. They resist high temperatures, high pressures and chemical agents. Regular inspection and periodic replacements are not necessary.

Papyex® is a flexible, pure, homogeneous material without binder or asbestos. It is characterised by its qualities of thermal conductivity, elastic recovery, capacity for compacting, friction even when dry, and chemical inertness.

Papyex® seals, by virtue of the absence of ageing and relaxation, avoid retightening and eliminate wear on rods and shafts.

Papyex® is used as a stuffing-box material for valves, pumps, mixers and stirrers in the chemical, refrigeration, oil, petrochemical and food industries.

This material guarantees long service life: a **Papyex®** seal means 35,000 operations, and several years of use without leakage and without maintenance.

Die formed rings

Die formed ring with metallic yarn

Die formed gasket with anti-extrusion ring

Thermal applications

MERSEN IN FURNACE INDUSTRIES

- Heat-treatment furnaces under vacuum or controlled atmosphere.
  - Furnaces for passing through controlled atmosphere.
  - Vacuum brazing furnaces.

Mersen offers a complete range of high-performance materials for industrial furnaces:

- **Calcarb®**: rigid carbon felt insulation.
- Graphite for refractory application
- Carbon/carbon composite.
- **Papyex®**: flexible graphite.

Associated with other Mersen's materials Papyex® has become the essential material for overcoming numerous technical difficulties at the best cost for industrial furnace users.

WHY PAPYEX® IN FURNACES?

- **As a screen:** thanks to its reflecting capacity, it reduces energy loss. The anisotropy of its thermal conductivity ensures a better homogenisation of the temperature in the chamber.
- **As a thermal insulation element:** it can be used alone, in multiple screens, or in addition to commonplace insulating materials: carbon felt, rigid felt, graphite foam.
- **As a sealing material:** in plants functioning at high temperatures and in a corrosive environment, it is impermeable to hot gas and can be used as a static gasket or impervious packing.

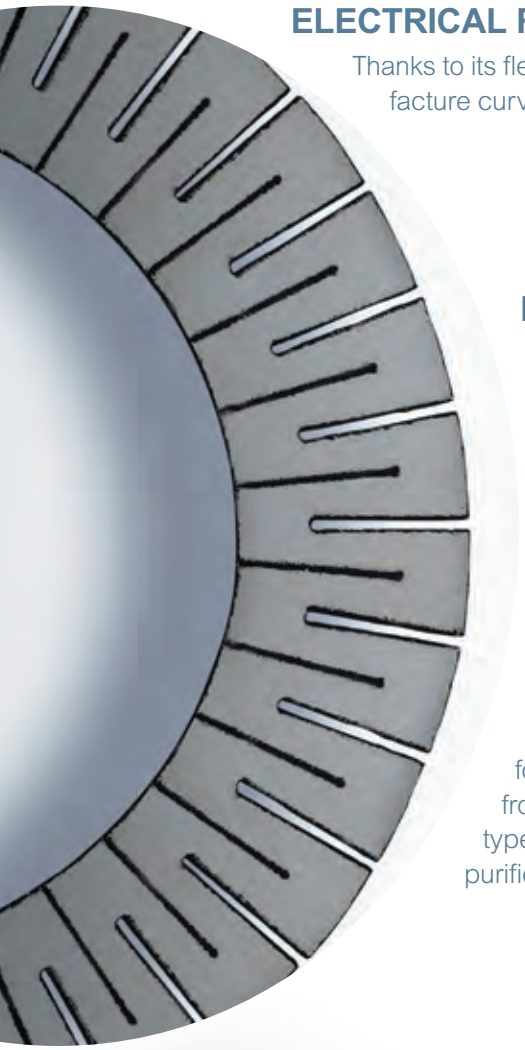
ASSEMBLIES WITH INSULATORS

Papyex® is used in combination with insulators for limiting hot spots and for its heat-reflecting capacity.
The assemblies can be produced on rigid insulators such as **Calcarb®** or on flexible felt.
To make these assemblies, **Mersen** uses an adhesive that withstands very high temperatures.

RESISTANCE TO THERMAL SHOCKS

During a rapid rise in temperature, the gases contained in **Papyex®** may cause blisters on the surface of the material. To avoid this inconvenience, **Papyex®** FHT is first treated at high temperature, which eliminates this risk.
Moreover, on request, the surface of **Papyex®** can be perforated to facilitate degassing.

Other applications

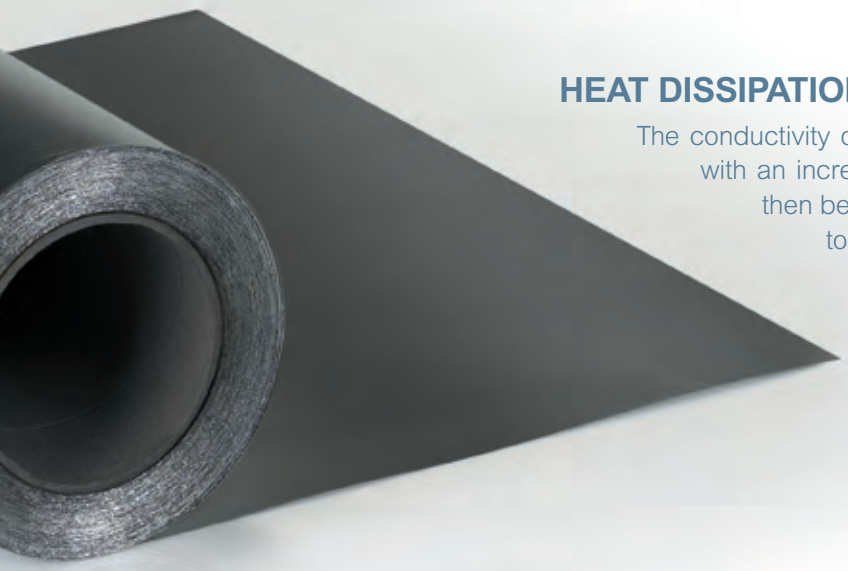


ELECTRICAL RESISTANCE IN FURNACES

Thanks to its flexibility and fineness, **Papyex®** can be cut easily, thereby making it possible to manufacture curved resistors that adapt to non-standard laboratory equipment.

PROTECTIVE INTERFACE

- **For metal casting, Papyex®** provides protection for graphite moulds and ingot moulds preventing the sticking of certain metals and alloys; it prevents a rapid deterioration of expensive equipment and facilitates mould stripping.
- **In the glass industry, Papyex®** is not wet by molten or viscous glass.
- **In hot compression operations** and in particular in the case of sintering, the thinnest **Papyex®** makes it possible to produce inserts that facilitate mould stripping and better temperature distribution.
- **In soldering or brazing,** in particular in the case of work on delicate assemblies, **Papyex®** is used to protect against splashing of adjacent areas that would risk being damaged.
- **In producing ingots, Papyex®** is used for protecting the graphite equipment from reactions with the silicon. For this type of application, **Papyex®** can be purified (less than 5 ppm).



HEAT DISSIPATION PRODUCT

The conductivity of **Papyex®** in the plane of the sheet increases greatly with an increase in density (see graph page 9). This material can then be used for dissipating heat with performances equivalent to conductive metals such as copper. In electronics, it thus serves as a thermal interface and heat sink. Its lightness and reasonable cost, makes it competitive compared to other solutions.

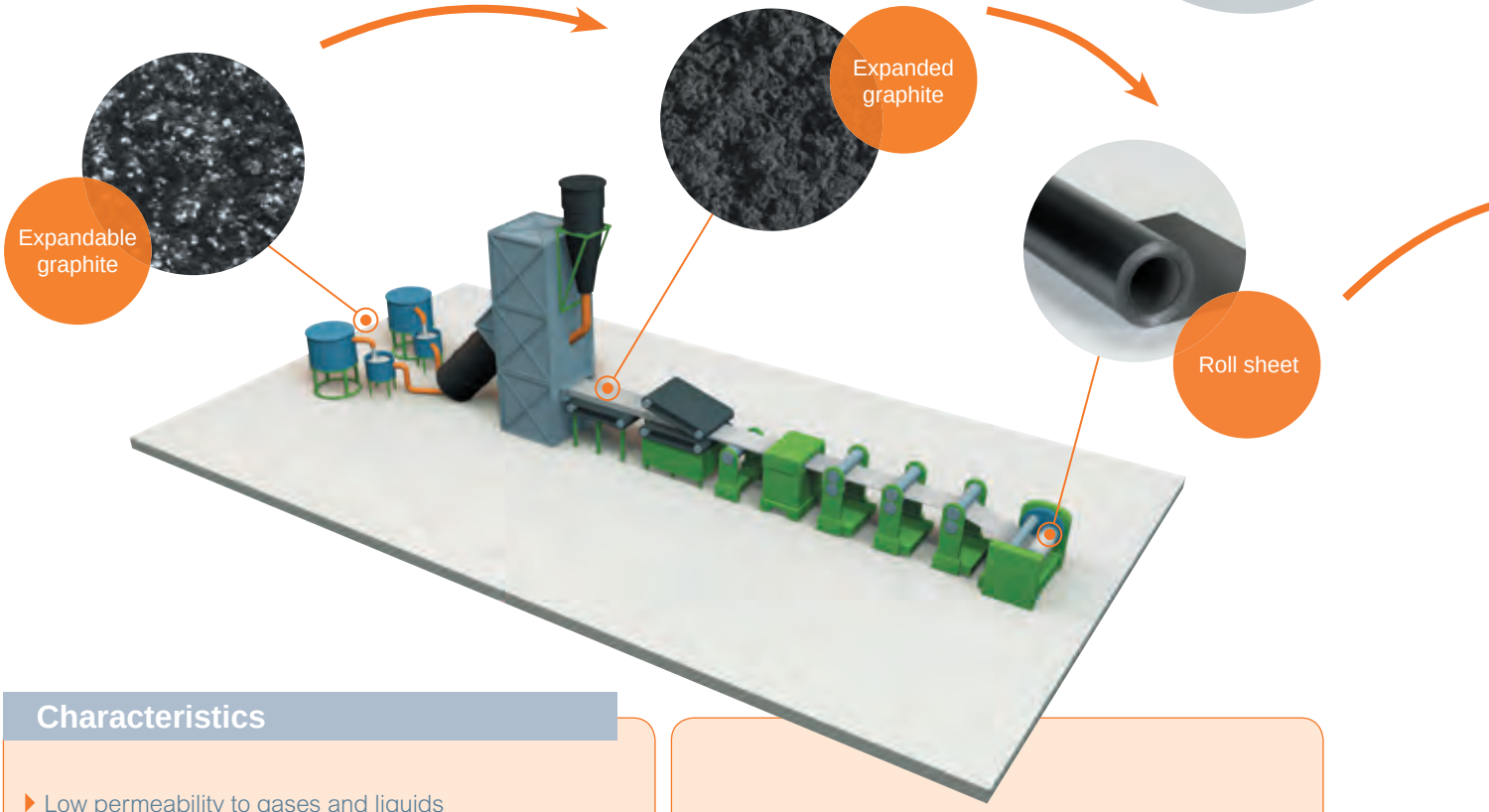
Manufacture

NATURAL GRAPHITE

Flexible graphite is manufactured from purified natural graphite crystallites. The best graphite ores are mainly extracted in China, Canada, India and Madagascar. In order to obtain good-quality flexible graphite, it is necessary to select ores having crystallites with dimensions greater than 180 µm.

EXPANDABLE GRAPHITE

Graphite has the property of forming lamellar compounds by the insertion of atoms or molecules in its structure. This property is used for manufacturing expandable graphite by acid insertion. The inserted compound reacts to a thermal shock at very high temperature: the insertion element vaporises and expands each graphite crystallite.

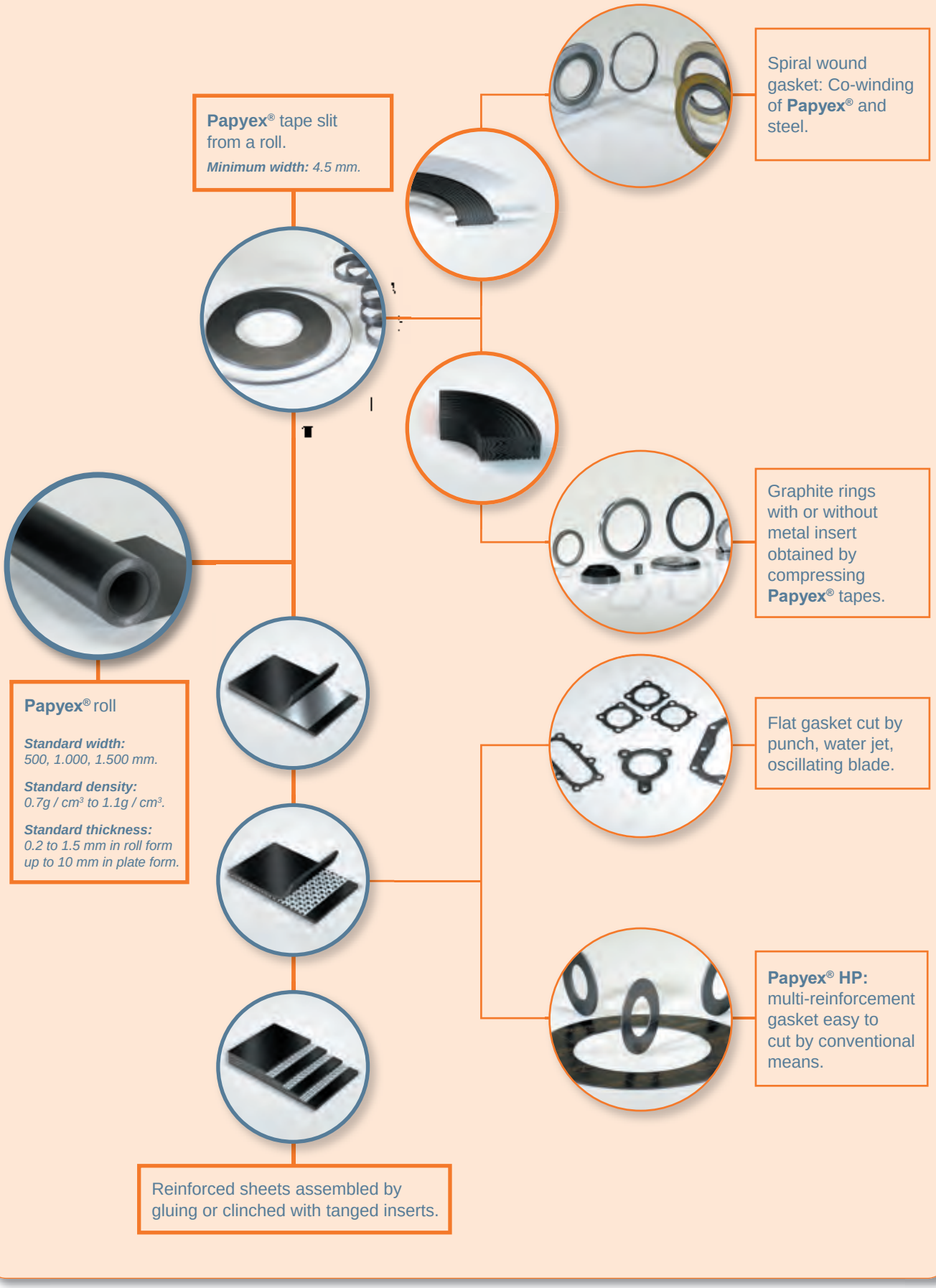


Characteristics

- Low permeability to gases and liquids
- Flexibility, flexible texture
- Resistance to most fluids
- Absence of danger to health; asbestos-free
- No danger to the environment
- Suitable for use at temperatures varying from -250°C to 450°C in air and up to 3000°C in inert atmosphere
- Absence of binders causing neither ageing nor crumbling

- Long-term compressibility stability over a wide range of temperatures
- High elastic recovery
- Anisotropic electrical and thermal conductivity
- Resistance to radiation
- Very good resistance to thermal shock
- Facilitates cutting by punch

Sealing products



Papyex® grades

For more than 30 years, Mersen has been rigorously selecting and processing the best natural graphite ores in order to guarantee its clients compliance with the strictest standards for industrial, nuclear and automotive sealing.
The wide range of Papyex® grades can meet the most advanced requirements for chemical purity in order to minimise risks of corrosion and extend its use beyond 450°C.
Specific anti-corrosion and anti-oxidation treatments further extend its use under extreme conditions.

Flexible graphite meeting sealing requirements

	Chemical, petrochemical industries								Automotive	
	I600		I980		IZ980		IP980		A960	
	Low oxidation rate		Standard purity		With corrosion inhibitor		With oxidation inhibitor		Low purity	
	specification	typical value	specification	typical value	specification	typical value	specification	typical value	specification	typical value
Carbon rate	> 99%	99.40%	> 98%	99.25%	> 92%	96.25%	> 95%	97.90%	> 96%	98.45%
Ash content	< 1%	0.60%	< 2%	0.75%	< 2%	0.75%	< 2%	0.75%	< 4%	2%
Inhibitor rate	-		-		2% to 6%	3%	1% to 3%	1.35%	-	
Sulfur content	< 700 ppm	500 ppm	< 1.400 ppm	700 ppm	< 1.400 ppm	650 ppm	< 800 ppm	650 ppm	1.400 ppm	1.000 ppm
Total chlorine content	< 50 ppm	25 ppm	< 50 ppm	25 ppm	< 50 ppm	25 ppm	< 50 ppm	25 ppm	80 ppm	50 ppm
Mass loss (500°C / 24h)	< 0.5%	0.10%	< 4%	1.50%	< 4%	1.50%	< 0.5%	0.20%	< 10%	5%
Mass loss (670°C / 4h)	< 4%/h	3%	-		-		-		-	
Maximum operating temperature:										
• to air	550 °C		450 °C		450 °C		550 °C		450 °C	
• under an inert atmoshere	2.700 °C		2.700 °C		2.700 °C		2.700 °C		2.700 °C	

General properties

	specification	typical value
Tensile strength (D=1g / cm^3)	> 4 Mpa	4.5 Mpa
Compressibility	45% to 52%	45% to 52%
Elastic recovery	10% to 15%	10% to 15%
Area weight distribution (g / m^2)	+ / -5%	3.50%

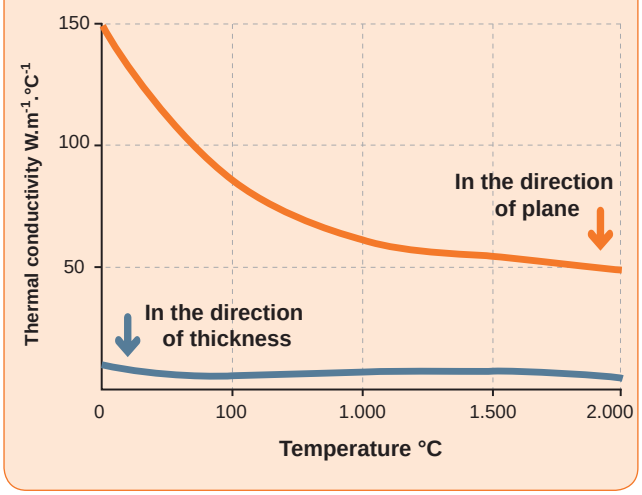
Physical properties

	unit	in plane	through thickness
Permeability	$cm^2.s^{-1}.atm^{-1}$	-	10^{-5}
Shore hardness	C^2	25	25
Coefficient of thermal expansion	10^{-6} . $°C^{-1}$	zero	25 to 28
	10^{-6} . $°F^{-1}$	zero	14 to 15
Electrical resistivity	Ω.cm	0.001	0.05
	Ω.inch	0.0004	0.02
Emissivity coefficient			
at 400°C	-	0.4	0.4
at 1 000°C	-	0.6	0.6

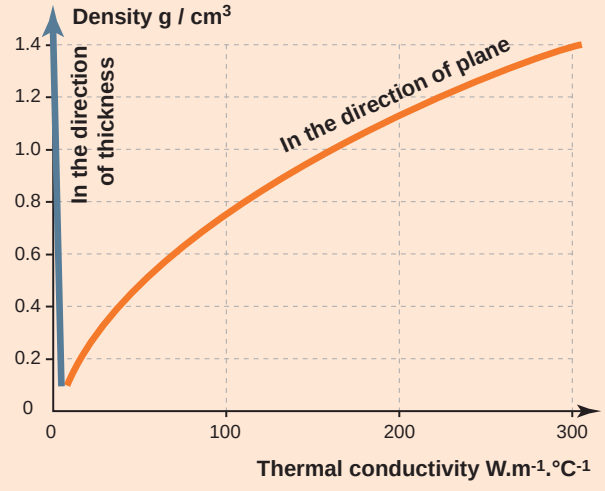
Flexible graphite meeting sealing requirements

	Nuclear											
	N9985		NS200		NSZ200		N998		NZ998		NP998	
	The highest purity without additive		Very low sulfur		Very low sulfur, active protection against corrosion		High purity without additive		High purity, active protection against corrosion		High purity with oxidation inhibitor	
	specification	typical value	specification	typical value	specification	typical value	specification	typical value	specification	typical value	specification	typical value
Carbon rate	> 99.85%	99.90%	> 99.5%	99.55%	> 93.5%	96.55%	> 99.8%	99.85%	> 93.8%	96.85%	> 95%	98.50%
Ash content	< 0.15%	0.10%	< 0.5%	0.45%	< 0.5%	0.45%	< 0.2%	0.15%	< 0.2%	0.15%	< 0.2%	0.15%
Inhibitor rate	-		-		2% to 6%	3%	-		2% to 6%	3%	1% to 3%	1.35%
Sulfur content	< 600 ppm	500 ppm	< 200 ppm	120 ppm	< 200 ppm	120 ppm	< 600 ppm	450 ppm	< 600 ppm	450 ppm	< 600 ppm	450 ppm
Total chlorine content	< 30 ppm	20 ppm	< 30 ppm	20 ppm	< 30 ppm	20 ppm	< 30 ppm	20 ppm	< 30 ppm	20 ppm	< 30 ppm	20 ppm
Leachable chlorine content	< 20 ppm	10 ppm	-		-		< 30 ppm	20 ppm	-		-	
Halogen content (F, Br, I)	-		< 50 ppm	30 ppm	< 50 ppm	30 ppm	-		-		-	
Mass loss (500°C / 24h)	< 1%	0.50%	1%		1%		< 1%	0.60%	-		< 0.50%	0.10%
Maximum operating temperature :												
• to air	500 °C		500 °C		500 °C		500 °C		450 °C		550 °C	
• under an inert atmoshere	2.700 °C		2.700 °C		2.700 °C		2.700 °C		2.700 °C		2.700 °C	

Thermal conductivity according to temperature



Thermal conductivity according to density



Grades of sheets

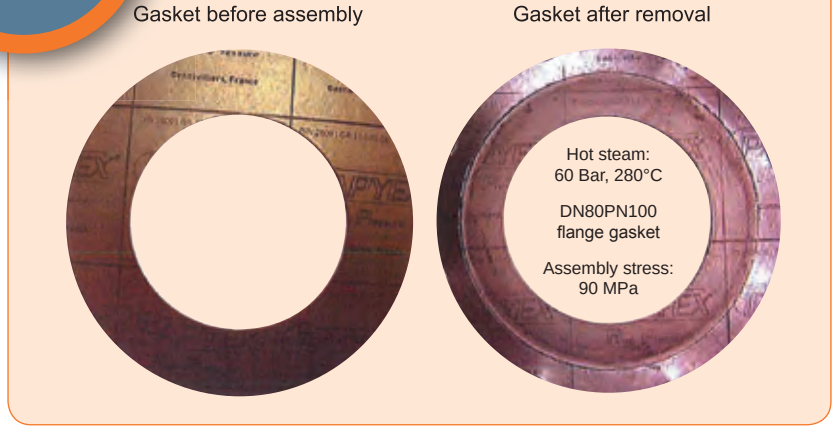
IN PARTNERSHIP WITH SPECIALISTS IN STATIC SEALING, MERSEN HAS DEVELOPED A COMPLETE RANGE OF FLEXIBLE GRAPHITE SHEETS ALLOWING CUSTOMERS TO CUT FLAT GASKETS FOR THEIR SPECIFIC APPLICATIONS.

They are available in all grades suited to purity specifications for the chemical, petrochemical, refining, and nuclear or aeronautics industries. **Mersen** checks the purity of its materials in its analysis and measuring laboratories on a daily basis in order to guarantee its customers compliance with chemical specifications for materials.

ANTI-STICKING COATING FOR FACILITATING GASKET REMOVAL

Mersen has developed a surface impregnation that forms an anti-adhesion coating effective up to 350°C in application. This AS “Anti-Stick” coating meets the technical specifications of leading chemical firms in Germany. It is an option that is particularly recommended for tanged reinforced products.

Non-stick coating TEST

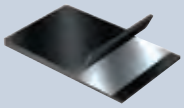
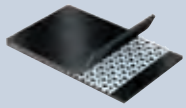


A UNIQUE SERVICE FOR PROMOTING YOUR BRAND

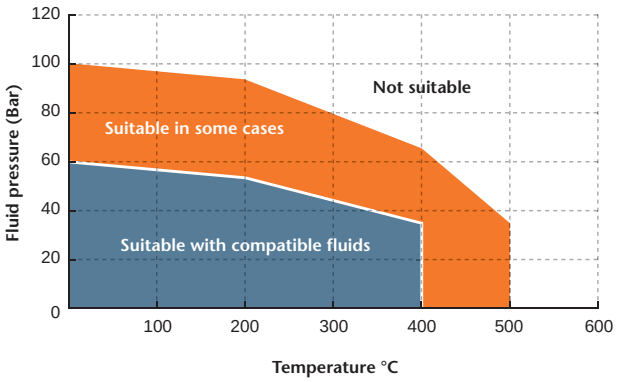
Mersen - sealing specialists - offers its customers the option of promoting or customizing their own brand, by means of a service marking the sheets by screen printing. We can print your sheets in the colour and model of your choice.

The largest format is up to 1.500 x 2.000 mm.

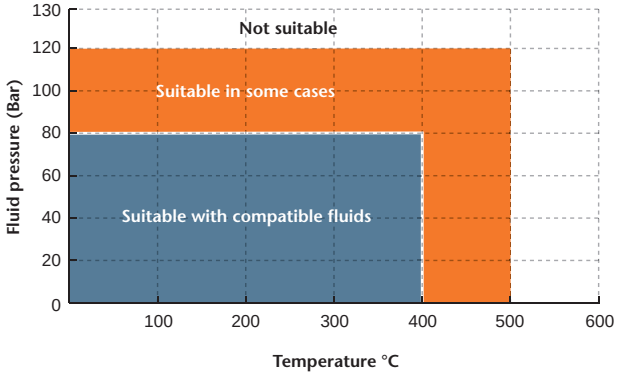
Technical data of Papyex® sheets

		PAPYEX® SR				PAPYEX® RI					PAPYEX® RN						PAPYEX® PI			
																				
		Flexible graphite sheet without reinforcement.				Flexible graphite sheet reinforced with a 50 µm glued flat stainless steel insert. It is used in flange connections for chemical, petrochemical industries.					Flexible graphite sheet reinforced with a 13 µm glued flat nickel insert. Easy cutting and resistant to very corrosive fluids, in particular chlorine.						Flexible graphite sheet reinforced with a tanged 100 µm stainless steel insert, without adhesive. Suitable for manufacturing pipe gaskets & reactors seals in chemical and petrochemical industries.			
	Unit / standard	technical data				technical data					technical data						technical data			
Sheet size	m	1 x 1 / 1.5 x 1.5				1 x 1 / 1.5 x 1.5					0.5 x 1 / 1 x 1 / 1.5 x 1.5						1 x 1 / 1.5 x 1.5			
Insert material	DIN / ASTM	without insert				1.4401 / SS316 (flat)					Nickel						1.4401 / SS316 (perforated)			
Insert thickness	µm					50					13						100			
Nomenclature	DIN 28 091-4	GR-10				GR-10-O-1 K-Cr					GR-10-I K-Ni						GR-10-O-1 M-Cr			
Flexible graphite density	g / cm³ + / -10%	0.7 to 1.3				0.7 or 1					1						1			
Standard thicknesses	mm + / -10%	1	1.5	2	3	0.75	1.0	1.5	2.0	3.0	0.4	0.8	1.0	1.5	2.0	3.0	1.0	1.5	2.0	3.0
Amount of inserts	nb	0				1			1 or 2		1			1 or 2			1			1 or 2
Gas permeability (helium)	cm³/ min	< 0.30	< 0.60	< 0.80	< 0.85	< 0.60					< 0.85						< 0.60	< 0.60	< 0.80	< 1.0
Specific leakage rate L	mg / s / m	< 0.05	< 0.08	< 0.1	< 0.15	< 0.06					< 0.1						< 0.06	< 0.06	< 0.08	< 0.1
σ_{vo}	N / mm²	160	140	120	100	100					110						180	160	140	120
σ_{Bo} at 300°C	N / mm²	140	120	100	80	70					90						160	140	120	100
Gasket coefficient (bD = 20 mm) :																				
• σ_{vu} DIN E 2505	N / mm²	20				10					10						20			
• m DIN E 2505	DIN coefficient	1.3				1.3					1.3						1.3			
• m coefficient ASTM		2				2					2.5						3		2.5	
• y coefficient ASTM	psi	1.500				900					1.000						9.000		4.000	
• Compressibility ASTM F36A-66	%	40-50				40-50					40-50						30-35		30-40	
• Elastic recovery ASTM F6A-66	%	10-15				10-15					10-15						15-20			
• Residual stress DIN 52913, 16h / 300°C	N / mm²	> 47				> 45					> 45						> 48	> 48	> 48	> 45
• Ash content DIN 51903	%	< 2.0				< 2.0					< 2.0						< 2.0			
• Sulfur content	ppm	< 50				< 50					< 50						< 50			
• Anti-sticking treatment		Yes, upon request				No					No						Yes, upon request			

Papyex® RI / Papyex® RN - Pressure / temperature

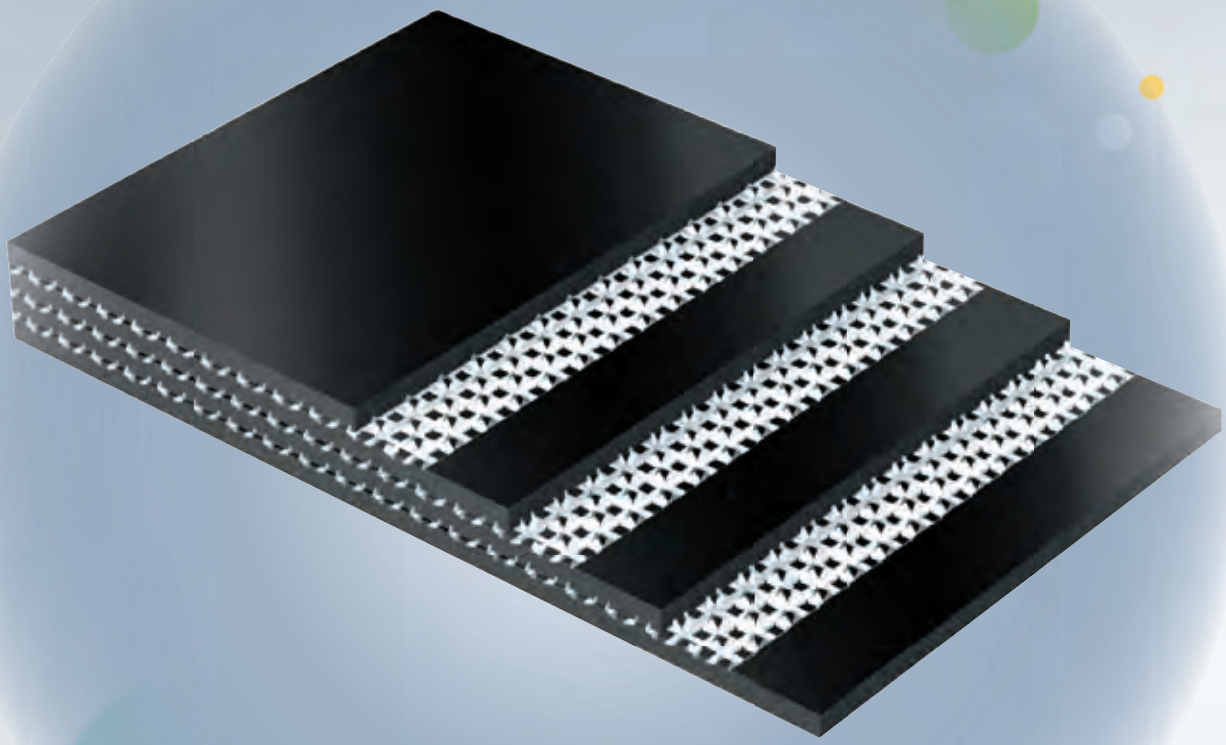


Papyex® PI - Pressure / temperature



TECHNICAL GUIDE

PAPYEX® HP

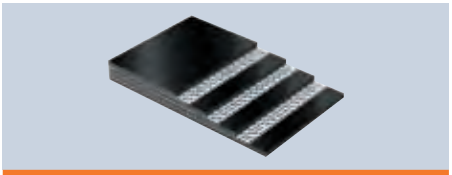


The structure patented by Mersen pushes back the boundaries of flexible graphite in the field of sealing:

- Very high pressure.
- No adhesive, simple mechanical assembly for very high temperatures.
- Easy cutting by conventional means by virtue of fine reinforcements.
- Easy dismantling because of the anti-sticking treatment.

MERSEN

High-performance Papyex® HP multi-reinforcement sheet

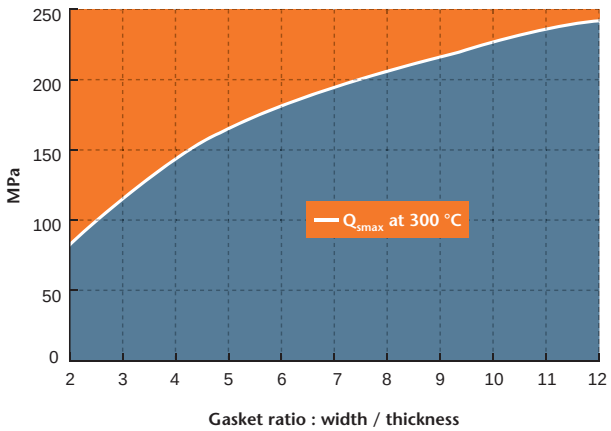


PAPYEX® HP

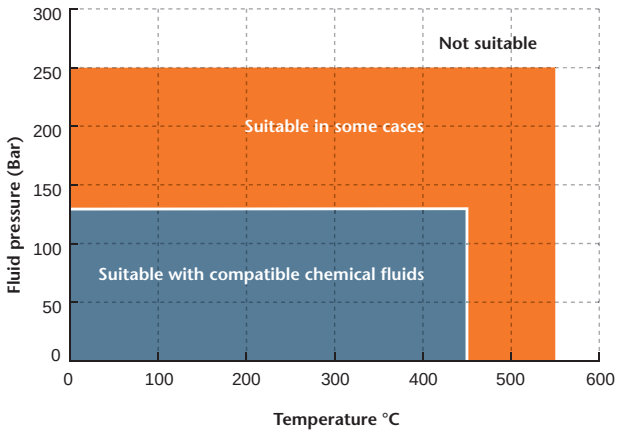
Multi-reinforced flexible graphite sheet designed to resist very high pressures and mechanical stresses even the highest temperatures. Suitable for high pressure steam in generator, pump seals and high pressure vessels.

	Unit / standard	technical data				
Sheet size	m	1 x 1 / 1.5 x 1.5				
Insert material	DIN / ASTM	1.4401 / SS316 (L) (tanged)				
Insert thickness	µm	50				
Nomenclature	DIN 28 091-4	GR-11-I-3-Cr				
Flexible graphite density	g / cm³ + / -10 %	1.1				
Standard thicknesses	mm + / -10 %	1	1.5	2	3	4
Amount of inserts	nb	1	2	3	5	7
"Anti-sticking" treatment		yes				
Tightness		Ta-Luft certification, optional				
Mechanical tests: • EN 13555 - Gasket width 20 mm	T°C	20°C		300°C		400°C
• Q_{smax}	N / mm²	> 220		> 220		200
• PQr (50 Mpa)		0.99		0.94		0.92
• Compressibility ASTM F36A-66	%	30-40				
• Elastic recovery ASTM F36A-66	%	4-5				
• Residual stress DIN 52913, 16h / 300°C	N / mm²	> 48				
Gasket coefficient (bD = 20 mm):						
• σ_{vu} DIN E 2505	N / mm²	20				
• m DIN E 2505	DIN coefficient	1.3				
• m coefficient ASTM		2.5				
• y coefficient ASTM	psi	3.000				
Papyex® **grades available:**		I600		N9985		NS200
• Ash content DIN 51903	%	< 1		< 0.15		< 0.5
• Sulfur content	ppm	< 700		< 500		< 200
• Chlorine content	ppm	< 25		< 20		< 20

Maximal seat pressure on the gasket



Pressure / temperature



MERSEN

Expertise, our source of energy

A WORLD EXPERT
in materials and solutions
for high temperature processes

A GLOBAL PLAYER

Global expert in materials and solutions for extreme environments as well as in the safety and reliability of electrical equipment Mersen designs innovative solutions to address its clients specific needs to enable them to optimize their manufacturing process in sectors such as energy, transportation, electronics, chemical, pharmaceutical and process industries.

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