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equipment selection

Flexible graphite seals

A. ENGELMANN G. HOCHEGGER H. EICHER

The authors report on a new material of construction

PROCESSED CARBON COMPOUNDS and graphite have been made use of in the field of dynamic sealing for a considerable time; processed carbon for use in sealing rings, slip rings, packing rings or armoured rings—graphite powder and carbon fibre as aids for soft packings. But for a long time processed carbon or graphite could not be used in the field of static seals. Recently a new constructional material of pure graphite has become available which is suitable not only for dynamic seals but also for static seals where difficult sealing problems have been solved.

This construction material is manufactured in West Germany by Sigri under the trade name *Sigraflex* and is available in the form of flexible sheet, laminates and other pressed items such as rings.

Manufacture

The starting material for the manufacture of the new graphite product is pure, properly orientated graphite. The distances between the planes are increased by chemical and heat treatment to a multiple of its normal value 3·35 Å. A very soft loose material consisting of worm-shaped particles results, which can subsequently be compressed into the final product by means of calenders or presses. The layers of the graphite crystal and the individual particles of the loose, bulk material can only be bound firmly together again by the application of mechanical pressure. No binding materials or fillers are added. Moreover, in this initial pressing process the crystallographic *a*-axes of the individual crystal plates normally align themselves to the direction of pressure, i.e. parallel to the surface of the sheet or laminate. In this connection the directional-independence of the characteristic properties of the microscopic graphite crystal becomes effective in the new materials, as the characteristic properties in Table 1 show.

Table 1.—Physical properties of flexible graphite

		Sigraflex F (Sheet)	*Sigraflex L (Laminate)*
Density	g/cm³	0·9–1·1	0·9–1·1
Specific electrical resistance			
In the direction of the surface	ohm/mm²/m	8	8
At right angles (perpendicular) to the surface	ohm/mm²/m	1·2×10³	6×10²
Anisotropic coefficient		150	75
Heat conductivity (20°C)			
In the direction of the surface	kcal/mh°C	190	190
Perpendicular to the surface	kcal/mh°C	6	6
Anisotropic coefficient		30	30
Gas permeability (air)	cm³/sec	$<10^{-4}$	$<10^{-4}$
Ash content	per cent	<0·02	<0·02

Properties

The material is permeable to gases and liquids. Its resistance to ageing and corrosion is excellent. It does not embrittle even under arduous working conditions. It is not attacked by most inorganic and organic chemicals. It is, for instance, resistant to hydrofluoric, hydrochloric and phosphoric acids, to sodium hydroxide solution and molten sodium hydroxide as well as to all the usual organic solvents and also to hot oils and waxes. Its use is critical in the presence of strong oxidizing agents and of substances which can react with graphite through the development of intercalation compounds; such agents as concentrated nitric acid, highly concentrated sulphuric acid, chromium solutions, chloric acid and permanganate as well as alkali and alkali earth metals. In air it can be used up to 400°C and under a blanketing gas up to 3000°C. The material also has excellent resistance to variation in temperature and pressure.

The graphite sheet and laminate have a smooth, relatively soft lubricating surface. As a result of this they mould excellently into seating surface defects such as scratched or pitted areas. It should be emphasized that the material does not flow under either heat or cold, and remains completely stable in shape under constant loading. Its good self-lubricating properties are excellent for its application as dry-running, dynamic seals. The coefficient of friction for dry running is very low with values between 0·08 and 0·10. The resultant friction heat is quickly dissipated due to the material's high thermal conductivity.

Table 2.—Sealing characteristics for flexible graphite and a few common seal materials for gases

Sealing material	$K_s \cdot K_D$ *(kg/mm)*	K_1 *(mm)*
Rubber	$0{\cdot}2 \cdot b_D$	$0{\cdot}5 \cdot b_D$
Sigraflex F		
0·5 g/cm³	$0{\cdot}45 \cdot b_D$	$0{\cdot}56 \cdot b_D$
1·0 g/cm³	$0{\cdot}6 \cdot b_D$	$0{\cdot}9 \cdot b_D$
PTFE, armoured	$0{\cdot}8 \cdot b_D$	$0{\cdot}75 \cdot b_D$
PTFE	$2{\cdot}5 \cdot b_D$	$1{\cdot}1 \cdot b_D$
IT	$20 \cdot \frac{b_D}{h_D}$	$1{\cdot}3 \cdot d_D$

Flat seals

The characteristic sealing values of Sigraflex F and other common sealing materials are set out in Table 2. Compressibility and the ability to return to its original shape (elasticity) are independent of nominal density. This relationship is shown again in Fig. 1. For normal applica-

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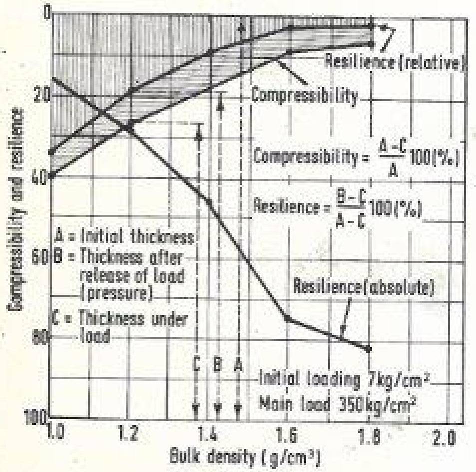

Fig. 1—Compressibility and elasticity to ASTM F 36-61 to standard A

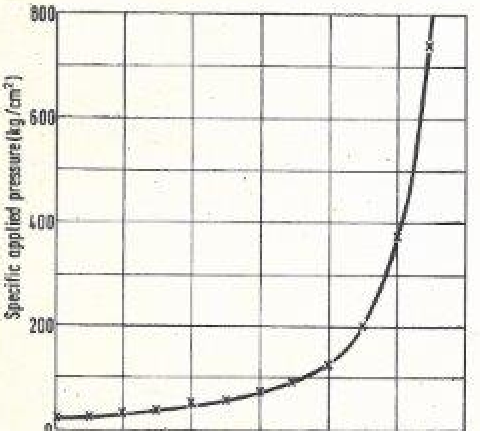

Fig. 2—Showing the degree of independance of the nominal density to applied pressure

tions the nominal density works out at 1·0 g/cm³. Under pressure from the flange the desired final density is reached. Under a compression of 1·6 g/cm³, for example, sealing against an interior pressure up to 200 atm.g is achieved. Figure 2 shows the degree of independence of the nominal density to specific applied pressures. The nominal density of Sigraflex can be regulated within wide limits according to the application. The high degree of compressibility for a low nominal density allows its use for two special applications which could formerly be performed only with difficulty or not at all.

Case 1. *The sealing of uneven flanges*

The sealing of flanges with uneven surfaces, such as enamelled parts or sealing surfaces which have become damaged through extreme notching or erosion. For this purpose a sealing ring of lower nominal density is used e.g., from 0·3 g/cm³. This is compressed sufficiently by pressure of the flange on the nominal density of the sealing ring, to achieve suitable sealing for the operational working pressure.

Case 2. *Sealing larger diameter flanges*

For the sealing of larger diameter flanges Sigraflex of thinner initial density in the form of segments is so laid on the seal seating that the ends of the segments overlap one another by about 10 mm. When the flange is tightened up the segments are neatly compressed into one another at the abutment points. The abutment points are in no way weak spots. This technique can be applied to the replacement of leaking seals on large units of chemical equipment, especially axial installations such as heat exchangers and stirred vessels. Full dismantling is no longer necessary. The upper part of the unit is lifted, the defective seal is removed, the new seal in the form of segments is inserted, the upper part of the equipment is lowered and the joint is tightened. The foregoing technique can be achieved for vertical joints using point by point fixing with a conventional adhesive.

Dynamic seals

When used for dynamic sealing the flexible graphite is applied in the form of gland sealing packing rings. Packings comprising these rings are designed specifically for incorporation under difficult working conditions. They have high cross-sectional consistency of density, good self-lubricating properties and are resistant to most chemicals. The friction coefficient for dry operation lies between 0·08 and 0·10. There is practically no shaft wear. They have very low heat expansion, but high thermal conductivity. The last-named properties together with self-lubrication, markedly decrease the danger of overheating the packing with all its special attendant problems. The material is suitable for application at high temperatures. In the assembly of gland packings, rings with a density of 0·4 to 0·6 g/cm³ are usually so packed that there is little shaft play. In use the nominal density increases by between 30 and 60 per cent.

Very good operating experience has been achieved with, e.g., pumps for hot oils and waxes and in applications in the petrochemical industry.

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