sgl carbon

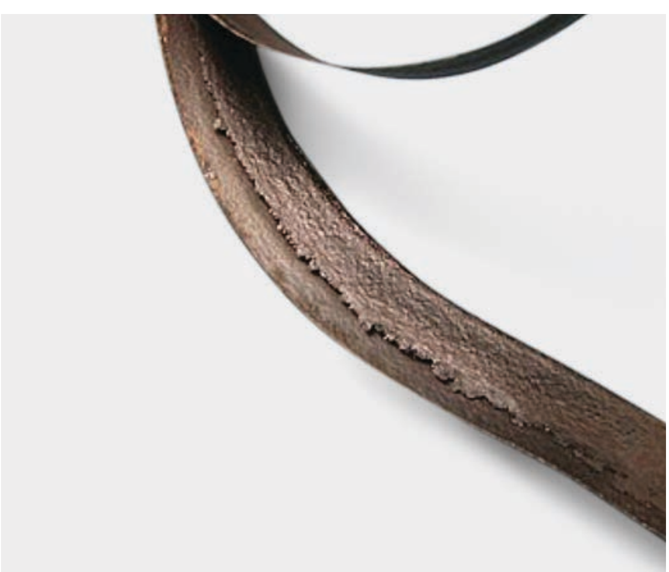
SIGRAFLEX® thermal stability

With most flange and apparatus connections and valve spindle seals, there is a general presence of atmospheric oxygen outside the connection. Most SIGRAFLEX materials remain stable in air for long periods at temperatures up to approx. 400 °C (752 °F). At higher temperatures, the thermal stability is progressively degrading, depending on the installation and service conditions.

With increasing temperature from 300 to 450 °C (572 to 842 °F) and depending on the graphite quality, the graphite undergoes technically relevant oxidative decay in the presence of atmospheric oxygen. This is perceivable by a hardly measurable weight loss, which increases as the temperature rises. Oxygen (O or O_2) starts to form a chemical bond with carbon atoms (C) from the hexagonal graphite lattice, and escapes into the environment as carbon monoxide (CO) or carbon dioxide (CO_2).

If atmospheric oxygen is present in the outer periphery only, the mass of a gasket installed in a flange connection is continuously degrading starting from the outside, as can be clearly observed in the pictures below. Consequently, the surface pressure is decreasing over time up to the complete failure of the sealed joint.

Graphic on page 2 shows the typical weight loss of graphite foils with 0.5 mm (0.02 inch) thickness and a density of around 1.0 or 1.12 g/cm^3 (62.4 or 70 lb/ft^3) measured in hot fresh airflow. When comparing oxidation rates, and thus thermal stability of different products, it is mandatory that always the same measurement parameters are applied, as the test results may diverge therefore by up to a factor of 10. Ideally, a defined reference material is included into the measuring procedure.



↑ Two photos of a graphite gasket that failed after strong oxidative degradation.

For the practical use for the sealing of armature spindles, SIGRAFLEX graphite foil tapes are converted into die formed rings. Assembled as stuffing box packings, the oxidation rate is usually much lower than shown in graphic. The reasons are as follows:

- Higher density of the graphite, usually 1.4 – 1.8 g/cm³ (87 – 112 lb/ft³)
- Larger mass with simultaneously smaller surface area to attack (favorable surface-to-volume ratio)
- Barrier effect of operating medium such as steam, which permeates the seal from within and thereby impedes diffusion of oxygen into the seal from the outside
- Chambered installation
- The stuffing box is usually much cooler than the operating medium.

Flat gaskets are governed by similar laws. The flange temperature is lower than the mean service temperature, too. In the case of non-insulated piping, the difference often amounts to approx. 50 to 80 °C (90 to 144 °F).

A distinction should be made, however, between gaskets operated in non-oxidizing media under elevated internal pressure, or – in a worse scenario – gaskets exposed to atmospheric oxygen in a unit operated under vacuum.

In the case of a steam line operated at 500 °C (932 °F), small amounts of steam diffusing through the gasket produce a "barrier" between gasket and atmospheric oxygen. As a result, the service life of SIGRAFLEX gaskets at high temperatures is increased.

In a petrochemical residue vacuum distillation unit operated at approx. 400 °C (752 °F), however, atmospheric oxygen diffuses into the gasket from the outside as a result of the internal partial vacuum. This actually accelerates oxidation. From experience it is acceptable to use SIGRAFLEX at higher temperatures of e. g. 600 °C (1112 °F), as long as the operating temperature is only elevated short term. In contrast to many other materials used for sealing, graphite does not get damaged at high temperature, there is just a mass loss over time.

Quantitative predictions about precise service life cycles are difficult to make, as they are governed by the individual installation and service conditions, which can vary widely. Thus, the following values for the typical service life may only serve as a very rough estimate for a correctly designed and mounted stuffing box packing made from oxidation-protected SIGRAFLEX graphite foil, or a flat SIGRAFLEX flange gasket which is oxidation-protected. Presupposing that the operating medium is under positive pressure and does not contain oxidizing substances, the following, non-binding guideline values are applicable: Approximately fifty years at 400 °C (752 °F), approx. ten years at 450 °C (842 °F), approx. two years at 500 °C (932 °F), approx. half a year at 550 °C (1022 °F) and approx. one month at 600 °C (1112 °F). It is indispensable that an individual estimation is performed for each case!

In general, considering the above mentioned limitations, service live can be increased by a factor of around two to three compared to the above by using the best oxidation resistant flexible graphite foil available, SIGRAFLEX APX2®.

Caution:
Competitor material available on the market often exhibits a significantly lower service life. As a general rule, caution has to be exercised with manufacturer's specification for maximum operating temperatures. While the specifications of SGL Carbon often refer to safe operation of five to ten years, other manufacturers confine themselves to the specification of short-term temperatures.

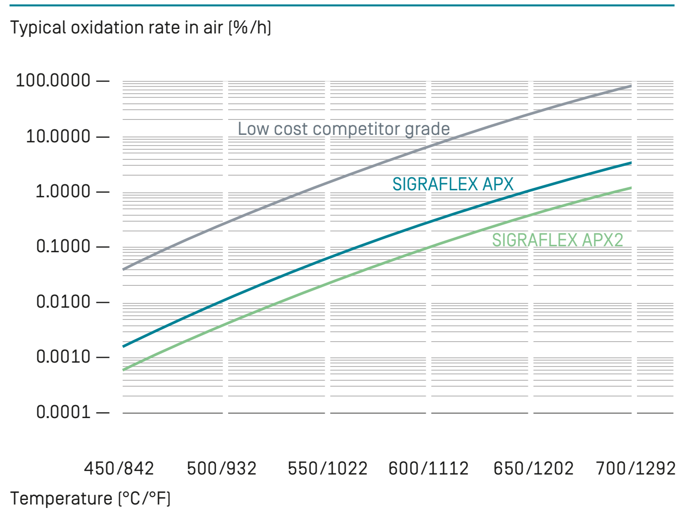
To a certain degree, flange gaskets are protected from attack of atmospheric oxygen by the flange surfaces. Slightly longer service life can be achieved if the cut edges of the gasket, which are exposed to oxidizing media or atmospheric oxygen, are additionally protected by a stainless steel eyelet. To fully unfold its protective effect, the eyelet must be completely compressed within the flange surfaces.

Besides temperature, surface area of attack by atmospheric oxygen and density, the oxidization rate is primarily influenced by the graphite quality. It is predominately determined by the elemental composition of the raw material natural graphite and the production process of the graphite foil.

Statements made in the past saying oxidization rates increase over-proportionally with increasing ash content are only partially correct. On average, the tendency of increasing burn rates with higher impurity levels still holds true for the majority of material available on the market, as a low level of impurities often translates into a low level of elements having a catalyzing effect to oxidization.

However, the type of impurity and the applied production process have a much stronger influence on the product longevity than the ash content itself. High-purity graphite foil with an ash content of approx. 0.15 % can be found on the market which was measured at a 20 times higher oxidization rate than high quality graphite foil with an ash content of 2 %. The following illustration compares the typical mass loss of different graphite foils: Highest oxidation resistant SIGRAFLEX APX2, medium oxidation resistant SIGRAFLEX APX and typical oxidation resistant product where there was no focus on oxidation resistance in raw material selection and production.

Typical oxidation rate of flexible graphite foil in air



In cases of operating temperatures exceeding 400 °C, it is generally recommended to consult the gasket material manufacturer, or even at lower temperatures if low quality material is used.

Suitability of SIGRAFLEX gasket materials for use with oxygen

The Federal Institute for Materials Research and Testing (BAM), Berlin/Germany, tested several SIGRAFLEX products at oxygen pressures up to 160 bar (2320 psi) and temperatures up to 300 °C (572 °F). Test results show that there are no objections on safety grounds to the use of SIGRAFLEX for sealing flange joints made from copper, copper alloys or steel.

This applies equally to flanges with raised faces, projections and recesses or tongue-and-groove structures.

“There are no objections, either, to the use of the listed SIGRAFLEX materials in plants or plant components for liquid oxygen. Since pressure exerted on liquid oxygen causes no appreciable changes in concentration, i.e. has no significant influence on the reactivity of the material, restriction to a specific pressure range is not required.“ (Source: BAM Test report on the suitability of a selected gasket material for use with oxygen)

Stability in other media at temperatures above 400 °C (752 °F)

As a matter of course, the following specifications are only applicable if SIGRAFLEX graphite is not exposed anywhere to atmospheric oxygen. For logical reasons, only inorganic compounds or elements can be discussed here, as nearly all organic compounds – i. e. the operating media – are chemically instable at such high temperatures. The following specifications apply exclusively to SIGRAFLEX graphite; however, they are not applicable to stainless steel reinforcements used in some SIGRAFLEX products. Also, in combination with these metal inserts made from ASTM 316L, the limitation to 800 °C (1472 °F) must be observed.

Inorganic gases

- **Noble gases, e. g. helium (He), argon (Ar), Xenon (Xe):** SIGRAFLEX graphite is fully stable up to around 3000 °C (5432 °F), beyond 2000 °C (3632 °F) gradual embrittlement setting in.
- **Nitrogen (N_2):** Starting from approx. 1600 °C (2912 °F) cyanogen formation sets in under nitrogen atmosphere. In the presence of hydrogen (reduction of water vapor), formation of hydrogen cyanide (HCN) takes place.
- **Carbon dioxide (CO_2):** Starting from approx. 600 °C (1112 °F) a slight attack sets in, which has almost no technical relevance up to 800 °C (1472 °F). At this point, carbon monoxide (CO) starts to form.
- **Water vapor (H_2O):** Starting from approx. 600 °C (1112 °F) a slight attack sets in, which has almost no technical relevance up to 700 °C (1292 °F). Depending on the temperature, carbon monoxide, carbon dioxide, hydrogen and methane (from hydrogen in a secondary reaction) are formed.
- **Hydrogen (H_2):** Starting from approx. 900 °C (1652 °F) methane formation is possible under hydrogen atmosphere.
- **Oxygen (O_2):** Under pure oxygen atmosphere, SIGRAFLEX remains reasonably stable up to approx. 300 °C (572 °F).
- **Ozone (O_3):** Under pure ozone atmosphere, SIGRAFLEX graphite remains reasonably stable up to approx. 150 °C (302 °F).

SIGRAFLEX graphite is not resistant, for example, to sulphur trioxide (SO_3), bromine (Br_2) or fluorine (F_2).

SIGRAFLEX graphite is resistant, for example, to ammonia (NH_3), hydrogen sulphide (H_2S), sulphur dioxide (SO_2), hydrogen chloride (HCl) or carbon monoxide (CO).

If required, the respective operational limits must be determined experimentally for each application.

Please see also our technical information about chemical resistance.

Molten salts

Graphite is not resistant to melts with a strong oxidization potential, e.g. potassium chlorate ($KClO_3$), potassium nitrate (KNO_3) or sodium peroxide (Na_2O_2).

Molten metals

SIGRAFLEX is resistant to molten metals up to the carbide formation level, except for alkali melts.

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