

Durability of expanded graphite in high temperature applications

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Currently, expanded graphite is the most commonly used soft sealing material for high-temperature applications. It is used in the construction of a variety of flat gaskets such as graphite gaskets with reinforced steel inserts, spiral wound gaskets, serrated gaskets and as die pressed rings to seal the stems of many types of valve.

The main application areas for these graphite based seals are the refining, petrochemical, chemical and thermal power industries, all being industries which have a combination of critical operating conditions such as high temperatures, pressure, flammability, risk of explosion and toxicity of media.

Under such conditions the durability and reliability of seals is of paramount concern to seal suppliers and operators alike. The quality of the graphite used is fundamental to its effectiveness and users look for independent verification of performance.

Oxidation of expanded graphite in high temperature applications

Critical to the performance of expanded graphite exposed to high temperatures is its resistance to oxidation. The factors which influence this are:

a) The construction of the joint or housing in which the seal is being installed.

b) The construction of the seal itself.

These two factors determine the level of oxygen in contact with the seal.

c) The media to which the seal is exposed both internally and externally, including their temperature and pressure.

d) The physical nature of the expanded graphite itself. This can vary significantly depending on the geographical origin of graphite, differing technologies and substances used during the production of the expanded graphite, such as inhibitors.

Figure 1 shows a comparison of the oxidation rate of the same expanded graphite under different conditions of exposure (a).

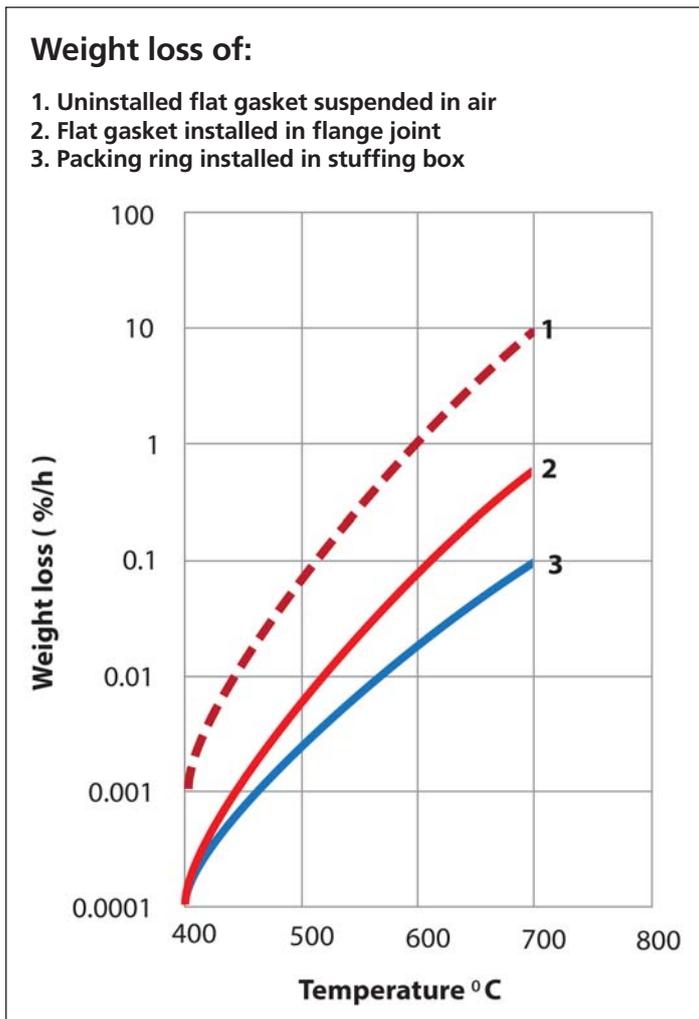


Figure 1

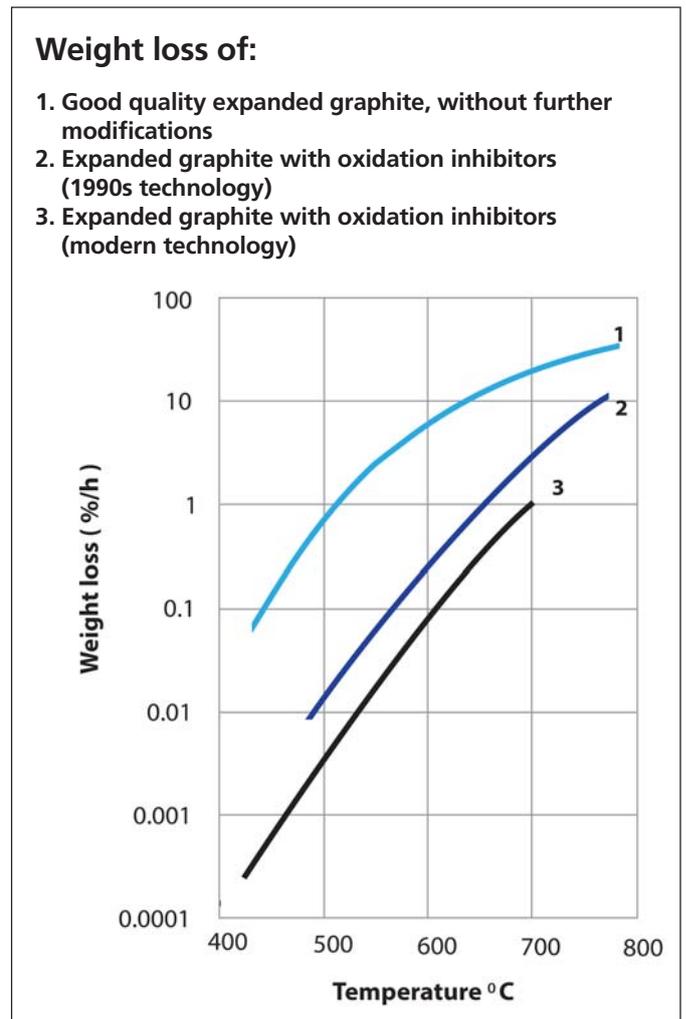


Figure 2



It is evident that the highest losses of mass are observed in the case of samples freely suspended in air where the contact area of the sample with air is the largest and the density of the sample is the lowest increasing the rate of air penetration into the sample.

When a gasket is installed in a flange connection, air penetration is limited to the external edge of the gasket, while at the same time the density of the expanded graphite is higher due to the compression of the gasket, normally in a range of 1.3-1.9 g/cc.

In the case of valve stuffing box packings, the air penetration is lowest, taking place through two cylindrical, relatively long and narrow gaps along the stem and the stuffing box wall. Again with increased density of between 1.3-1.9 g/cc this results in the least mass losses. In operating valves a further factor leading to reduced oxidation is that the actual temperature inside the stuffing box is significantly lower than the working temperature of the medium. In addition to this in high pressure applications, displacement of air from the micro-pores of the expanded graphite by the high pressure medium occurs. This effect is observed particularly in the case of water vapour applications.

Figure 2 compares the oxidation rate of expanded graphite with and without oxidation inhibitors and the differences are significant (note the logarithmic scale). The rate of graphite oxidation is most affected by:

- 'graphite purity' which is measured by the amount of carbon in the graphite. In the highest temperature applications nuclear purity can be requested with a carbon content of >99.85%.
- 'composition of ash' and in particular the content of alkali metal elements within the ash, as these catalyse oxidation significantly.

Standardization

The standards for performance of stuffing box packings in valves include EN ISO 15848 (described in VW March 2015), MSS SP-121 and API 624. In all of these standards, the "wear of packings" in high temperatures is appraised in a way that combines all of the different causes of wear. The key causes which make the largest contribution to this total "wear of packings" are:

- loss of binder - loss of lubricant
- frictional wear of the packing
- mass loss of graphite

In all of these standards the acceptance criterion for any sample tested is to meet the level of tightness described within the standard. Passing the tightness test does not however give any indication of graphite quality and therefore the long term durability of the packing in the application.

A further standard, ASTM F 2168-02 whilst not providing a graphite quality test method does go a little closer to describing key features of expanded graphite and includes the methods for their testing.

True expanded graphite quality testing methods can be found in API 622, FSA-G-604-07 and EN 14772 standards. API 622 (which is specific to stuffing box packings) includes a description of a test method and the acceptance criteria for seals for operation in fittings at temperatures from -29 to 538 °C. FSA-G-604-07 and EN 14772 provide a method allowing for the comparison of the oxidation level of different types of graphite in forms of flat samples at temperatures of 593 and 670 °C (method A) and 593 °C (method B).

In addition to these standard tests, manufacturers and users apply Thermogravimetric Analysis (TGA) techniques which can use a combination of test conditions allowing among other things the control of the environment in which the seal works, the intensity of gas flushing, and many more.

End users face a range of graphite based materials with varying quality in the marketplace. As a result major operators now impose their own testing and acceptance criteria. Some examples are the criteria required by the MESC SPE 85 internal documents of Shell Global Solutions International BV, which are in fact a supplement to the ASTM F 2168 standard, or the EXH-SU-5150 document by Chevron USA Inc.

Summary

Expanded graphite is, and will probably continue to be, the standard soft sealing material used in high temperature applications. Despite concerns regarding oxidation which begins around 400°C – nowadays industrial applications use graphite widely in temperatures significantly higher than this. This is possible because of the continuing development of expanded graphite material: increasing purity, limiting the content of harmful elements in ash and the addition of better oxidation inhibitors. At the same time, new constructions of packings, gaskets and housings are being developed. New designs which result in decreased temperature at the seal face (e.g. elongated stuffing box with cooling fins) create barriers limiting the access of air to the seal. There are now special gaskets and joints which enclose the graphite or in some cases can compensate for the aging process with Live Load spring systems etc. All these ideas mean that usage of high-quality expanded graphite seals cover applications with a working temperature up to 650 °C.

Verification methods of graphite stability in high temperatures are still currently limited. Two standards which provide varying views in this field are: API 622 and EN 14772. Generating a tight seal using expanded graphite material is difficult and needs to take into account the many features of expanded graphite, the application including the construction of the joint to be sealed, operating parameters, surrounding environmental features, existing stresses and system generated stresses or movements acting against seal during plant operation.

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