Tip of the Month/No. 7

Vacuum Grease and O-Rings

Question:
The O-ring in my vacuum chamber is not 100 % leak-proof after long use. Tightening the screws doesn't help. I was advised to lubricate the O-ring with vacuum grease. This trick should make the vacuum better. Should I do it?

Answer:
Grease should be used with caution. With O-ring seals, a thin layer can help to improve impermeability to air. It should be remembered however that "a little goes a long way". A better vacuum is shown on a vacuum gauge. In leak tests, a lower leak rate is measured. This improvement comes at the price of higher background in heavy masses. Such contamination is difficult to remove out of the chamber. In case of doubt, one should avoid using grease.

If a thin layer of grease is not recommended, the seal surfaces as well as the O-ring should be checked. If there is damage, a seal surface can be re-polished if necessary or the O-ring can be replaced.

Reasons:
Tightening the screws:
In an O-ring seal, the elastomer fills and balances out all unevennesses in the metal sealing surfaces. Flat surfaces and compression set of ~15 to 25 % are needed for this. If the compression is too low, the connection is not sealed. If the compression is too high, the O-ring is "squashed". This compression is precisely defined by the centering ring or by an O-ring groove. It doesn't help to tighten the screws even more if the flanges are already resting on the centering ring, or there is contact with the groove.

O-rings for high vacuum connections are durable under normal circumstances. In particular, the standard FKM material barely ages. Leaks are often due to contamination during installation. Opening, cleaning and resealing the connection could be the solution.

Although O-ring compounds are quite robust to handle, the seal or the seal surfaces can be damaged or scratched if opened frequently. Through baking out near the maximum temperature, O-rings are pressed over time into an oval shape, but can still remain sealed for a long period of time. Whether chemical, radiation or plasma attacks occur, for instance, depends upon the respective application.

Figure 1: In case of ISO-KF and ISO-K up to DN 250 size, the centering ring is specified, so that the O-ring is compressed from about 5 mm to exactly 3.9 mm.

Vacuum grease:
Greases and oils in vacuums offer some benefits, but can also have serious disadvantages. We will first list some of the benefits, and then show why it is better to avoid grease in case of doubt.

First the benefits of grease:
Greases and oils can reduce friction for moving parts such as ball or slide bearings. In screws, "chewing up" the threads can be avoided, and the tightness of the connection can be improved. In rotary vane pumps, oil is used to seal gaps, and enables a very good final pressure to be attained.

In static seals, grease can fill in unevennesses of the surface, and contribute to a significantly lower leak rate. Grease in this case allows one to work with significantly lower contact pressure or lower compression of the elastomer. The requirements for surface roughness of the sealing surfaces can be less stringent. An extreme example of this is sealing ground glass joints with silicone grease, as is used for chemical structures such as "standard-" or "taper-ground-joint". The highly viscous silicone lubricant is used without any elastomer seal.

Depending upon the material combination, grease can also diffuse into the elastomer surface and cause a slight swelling in the top layer. This in turn can contribute to filling irregularities.

The rule for O-rings in vacuum technology is: "Less is more."
The applied layer should be very thin and look almost dry.

Now the disadvantages:
When handling components grease can be transferred to other components. Dust and contamination can be held by the grease layer. Extreme amounts of grease can overfill the O-ring groove. There is then no more space for thermal expansion of the elastomer, which is often 10 times greater than the expansion of the surrounding metal.

Grease is a highly viscous liquid, and always has high steam pressure. Therefore one cannot prevent small amounts from evaporating and dispersing in a vacuum. These small amounts can also be detected in a mass spectrometer. It is clear in the mass spectrum that grease is not a molecule with a defined mass; rather it is always a mix of various chain lengths. Fragments of these chains in different lengths can provide for a widely smeared, periodic background signal for masses greater than 45 amu. One must analyze in each case whether these traces can have a harmful influence on the process or the user's planned experiments.

Each grease has a limited temperature range. Often the limit given in the data sheet is the limit for thermal decomposition. The viscosity also changes significantly with temperature, grease characteristics change, and the grease can "flow out".

This is not the greatest problem in a vacuum. But vapor pressure rises exponentially with temperature. It rises even with small increases in temperature – between 20 and 100 deg. C, typically about three orders of magnitude. Smaller amounts of grease evaporate, distribute throughout the equipment and tend to condense at the coldest parts of the chamber.

The steam pressure should not be confused with "operating pressure" for this grease. It presents at most a lower limit for the achievable partial pressure of the grease.

What greases are available?

■ Silicone grease

These synthetic greases consist of siloxane chains, or Si atoms with oxygen atom bridges. They are very chemically inert, and resistant to many specified media, especially to polar solvents such as water and water vapor.

Silicone grease is also quite inexpensive. In any case, even a very thin layer of a few molecules can reduce surface tension. In coating equipment, silicone compounds are therefore extremely inappropriate, as adhesion is affected.

■ Mineral grease

These consist mainly of hydrocarbon chains which, through multiple distillation, the volatile components have been removed.

These chains are destroyed by UV and X-rays, leading to carbon layers. When used with thin-film mirrors for these wavelengths, these C deposits considerably affect the efficiency of optics. Applications in the areas of XUV radiation are therefore particularly sensitive to all hydrocarbon contamination. This includes, for example, space simulators for X-ray telescopes, but also measurement devices for surface investigations or lithography.

■ Perfluoro Grease

The hydrogen atoms are practically completely replaced by fluorine atoms around the carbon chains. In perfluoropolyether, some oxygen bridges are retained in the carbon chains. These compounds are very stable and chemically inert. For instance they are used in high oxygen partial pressure environments. Therefore these compounds are generally biologically inert, and not poisonous. They have a very wide temperature range. Only at very high temperatures of several hundred degrees decomposition take place, which can release toxic and corrosive compounds due to the fluorine.

Before using vacuum grease as a sealant for O-rings, one should therefore first ask: How clean must the vacuum be? For example, in the fore-vacuum area with high gas flows and low temperatures, one can think about using grease – especially if oil-sealed rotary vane pumps are used. If one uses diffusion pumps in high vacuum, a couple of additional hydrocarbons normally don't pose a problem. In layering with high deposition rates or fast flows, there is no time for a significant deposit, and a thin grease layer can increase the life of a seal.

Grease is absolutely taboo for processes with high cleanliness standards. Such processes are usually sealed with CF flanges; however, for loading, an elastomer-sealed flange is almost always included. If you have any doubt at this point, you should plan for a double O-ring groove with an interstage pumping or even a locking chamber.

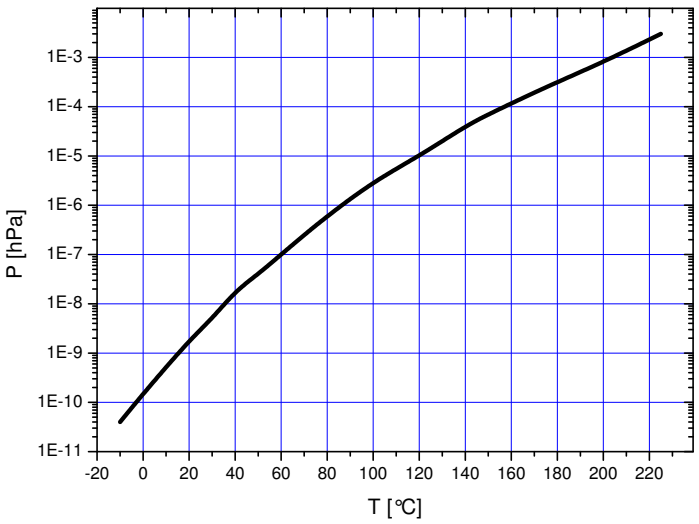

Figure 2: Example of vapor pressure of high-temperature grease versus temperature

At Pfeiffer Vacuum, when O-rings are installed for especially clean UHV applications they are mounted not only “dry” (grease-free), but also additionally degassed in a vacuum furnace before installation. Volatile residues from the production process or the operation are removed in advance, and do not have to be removed through baking in the clean vacuum chamber.

We would be happy to assist you in optimizing your vacuum solutions for specific applications – go ahead and ask us:

http://www.pfeiffer-vacuum.com/contact