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GAS LOADS FROM ELASTOMER AND METAL SEALS

Although metal seals are inherently better than elastomer seals in terms of cleanliness, bakeability, outgassing rate, and atmospheric permeation, they have disadvantages in terms of both ease of use and cost. This disparity fosters a tendency to want to make compromises that are driven more by human needs than by process requirements. The correct choice is often the difference between a system that fulfills process requirements or one that does not. The major performance difference between the two often comes down to a consideration of gas loads from each, so a rational decision requires an understanding of the gas loads that are inherent with elastomer seals.

There are two major gas load considerations:
1. Bulk outgassing, and
2. Atmospheric permeation.

Bulk Outgassing

Gas emanating from within the bulk of the elastomer material itself can be a major residual gas constituent. This is especially true from new material that has not been vacuum treated by previous use or special treatment. If a new O-ring is used to seal a flange on a vacuum chamber, it is usually obvious, from observing either pumpdown performance or ultimate pressure, that the new seal is adding a greater gas load to the system than had been observed by the older O-ring it had replaced. This gas load will decline slowly over hours, days, or weeks. Initial gas loads from fresh materials are usually from water vapor emanating from within the bulk and contamination from either surface handling (finger grease and oils) or trapped and unreacted volatiles from the manufacturing process.

Cleaning the O-rings with solvents should be scrupulously avoided because the material will absorb large amounts of solvent that will need to be slowly pumped away after the O-ring is installed. If the material is suspected to be contaminated with hydrocarbons already, it will have to be cleaned. One way of handling this is to bake the O-ring in a vacuum oven. Vacuum baked O-rings are commercially available.

If a vacuum oven isn't available, an air bake is a reasonable compromise, but baking times of days are usually required as opposed to hours under vacuum. Either of two thermal treatments will drive off a good deal of the water or other volatile vapors from within the bulk. A simple air bake with an infrared bulb works well and is economical, but beware of placing the

O-rings on, or within a wrapping of, household aluminum foil. The foil usually has a thin residual coating of manufacturing lubricants such as peanut oil which puts contamination right back on the O-ring. Aluminum foil that has been cleaned to UHV standards is commercially available. Handle the material with gloved fingers. Thermally treated O-rings should be immediately installed or stored in a desiccator to prevent them from re-absorbing large amounts of water vapor from the atmosphere.

Pre-conditioning the O-ring will help a great deal in removing gases that will otherwise require extended pumping to remove them and “outgas” the material, but always remember that they will continue to emanate small quantities of gas ad infinitum. There is no such thing as a totally gas-free elastomer when compared to the cleanliness of a metal gasket.

Permeation

All vacuum materials are permeable to atmospheric gases to some extent. A commonly observed example of permeation occurs during long-term helium probing or bagging during leak detection where the leak detector's helium signal slowly increases due to helium permeation instead of the sharp signal increase expected from a real leak. Most O-ring materials are more permeable to helium than they are to air.

Elastomers are, in general, much more permeable than metals. The degree of permeability and the effect of the permeating gases to the process have to be carefully considered before making an elastomer or metal decision. Additionally, a decision on the elastomer material is required since permeation rates vary. The effects of O-ring permeation become increasingly important as the material becomes “outgassed” by extended pumping time or baking.

The two most common materials in present use are Buna-N and Viton.[1] Although Viton is the most commonly used today due to its lower permeability and higher temperature tolerance, Buna-N is still used and available in most catalogs. It’s almost impossible to tell the difference between Viton and Buna-N by looking at them, but they can be identified by tapping them gently with something like a wrench or screwdriver handle. If it bounces, it’s buna-N, but if it goes thunk, it’s Viton.

Both of these materials are permeable to gases. Although the permeation rates are small compared to a leak, they can have an effect upon the ultimate pressure that can be achieved in a system. In a dynamically pumped system such as a process system, it is intended that the high vacuum pump will deal with the amount of gas permeating from atmosphere into the chamber through the elastomer seals. In a sealed-off system where no pumping is provided, the gas permeating into the system will allow a slow, but steady, increase in pressure. To gain an appreciation for permeation, consider this pressure rise. A single ISO/KF-16 Viton

O-ring on a one liter chamber will rise, if the pump valve is closed, at 1 x 10^{-6} torr to 1 x 10^{-3} torr in 222 minutes (3.7 hours) by air permeation alone.

Permeation Rates for Air

BUNA-N 2.5 X 10^{-7} torr liters/sec./ linear inch

VITON 2.5 X 10^{-8} torr liters/sec./linear inch

The fact that Viton has an air permeation rate that is one order of magnitude lower than Buna-N shows one reason why it is used more and more often in high vacuum systems even though Buna-N's resiliency, as evidenced by the bounce test, makes it easier to achieve a leak-free seal. The rates given above are averages since permeation rates will vary from lot to lot and from manufacturer to manufacturer. However, these average rates are repeatable enough to allow performance calculations to be made that are reliable enough for most applications.

Note that the permeation rates are given in terms of linear inches. This is because the relative thickness of the O-rings in most vacuum systems have little effect on the total permeation rate compared to the total exposed length. The permeating air flows slowly and continuously through the bulk of the O-ring in an equilibrium fashion so there is no real depletion gradient through the cross-section that would have much effect.

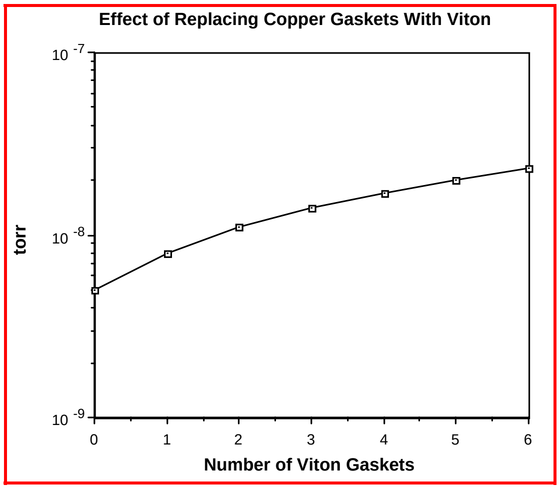
The fundamental relationship,

$$Q=SP$$

Gas Load = Pumping Speed x Pressure,

can be used to calculate performance expectations when elastomer seals are used or not used.

Q= total linear inches of O-ring x permeation rate/linear inch = Total torr liters/sec. gas load from elastomer permeation alone.



In a practical sense, consider a small system with a 50 liter/sec. effective pumping speed and six, 2-3/4 in od Conflat[2] flanges with a gasket length of 6 inches/gasket. The figure shows the performance effects as each Viton gasket is replaced with copper. As shown in the figure, the inclusion or exclusion of each elastomer gasket's permeation gas load can have a dramatic effect on a system's performance. These effects help explain why many modern systems use a combination of copper and elastomer gaskets where the ratio of copper-to-elastomer is a well thought out compromise. If, for example, a flange is to be installed and left in place for long periods, the extra trouble of using copper with its requirement of a lot of bolts, high bolt torque, and installation time is negligible. If, though, a flange is to be opened and closed frequently, the ease and speed of using an elastomer gasket is often a good trade-off against the higher permeation rate.

In cases where a large seal must be used such as on a sputtering target or a fully opening system door, it is usually impractical to use a metal gasket, but the high permeation rate of an O-ring gasket must be avoided. A simple way to solve this is to use two concentric elastomer O-rings with a channel between them that can be pumped down to a medium pressure (10 torr) with an auxiliary pump. This technique limits the amount of gas available for permeation through the inner O-ring.

[1] Viton, du Pont Trademark
[2] Conflat, Varian Trademark