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From THE VACUUM LAB

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Sealing Materials Require a Careful Choice

Elastomer and metal seals each have their attendant advantages and disadvantages, but it is not always necessary to use either one exclusively. If the application is carefully considered, a mixed installation can be the best decision.

The choice of gasket materials for demountable seals is one of the many crucial decisions that are required in designing a vacuum system. Although system design is always, by necessity, a series of successive critical compromises, a single bad choice can undo the carefully thought out effects of all the good choices.

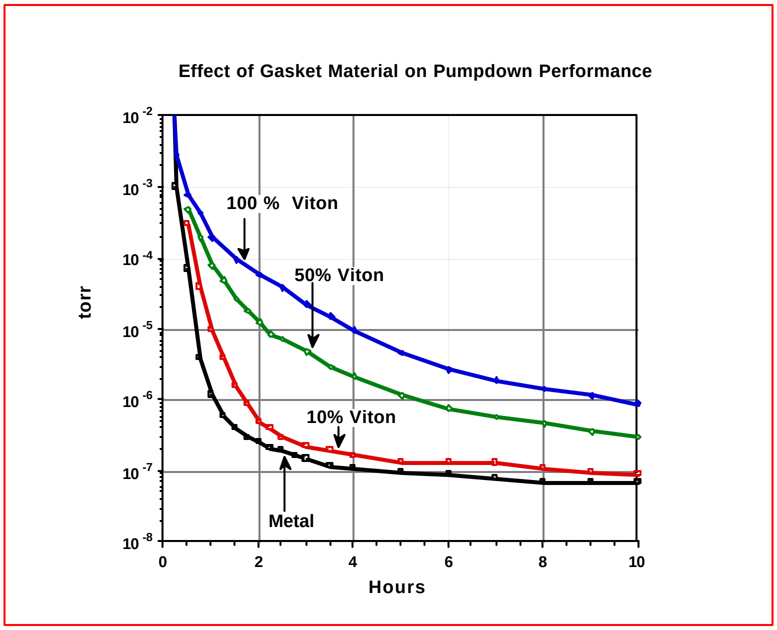
Gas loads and their minimization is one of the key areas where especially critical decisions are required, and that forces us to take careful assessments of the materials used in the system construction. For example, a designer will often choose 304 stainless steel for a chamber material and pay close attention to specifying the surface finish and cleaning procedures to assure that the lowest gas load possible will emanate from the chamber's surfaces and bulk. Then, that same designer will decide to use a gasket material that provides such a high gas load that the diminished gas load from the chamber is no longer of any advantage. That's why the best choice of gasket materials can be a maker or breaker of the system's subsequent performance, so we choose carefully.

There're 2-1/2 Choices

Gasket materials easily break down into two main categories; metal and elastomer. There's also a halfway choice of using a mixture of metal and elastomer seals on a single system. In general, elastomer gaskets add gas loads to the system from outgassing and permeation and metal gaskets don't. Superficially, then, you can make the judgment that it's a mistake to use elastomer gaskets since any gas load that can be avoided should be avoided. That superficial judgment is correct in a purist sense, but engineering is seldom that clear cut. Compromises are inevitable in many cases, but they must be made with care by applying the known pluses and minuses. A comparison of properties and application variables will help.

Elastomer Seals

All elastomer seals are a source of outgassing and atmospheric permeation gas loads, but there are a number of variables to be considered in assessing those particular gas loads. Although there are many materials available, fluoroelastomers such as Viton or Fluorel are arguably the most commonly used in applications where specific needs such as high temperature or chemical resistance aren't required. The outgassing rate of these materials can be reduced by several orders of magnitude by vacuum baking to temperatures above 150°C before installing on a system. They'll still adsorb surface water and absorb water into the near-surface bulk when the system is let up-to-air, but the overall gas load effects will still be much reduced. Standard vacuum practices that are often recommended when better ultimate vacuum pressures are either desired or required is that the system should be baked during pumpdown. Ultrahigh vacuum (UHV) levels are usually achieved only after a 250° C bakeout, but fluoroelastomers start to slowly degrade and break down chemically at temperatures above 150° C.



The pumpdown performance of the same unbaked system with varying linear percentages of metal and elastomer gasketing show that a small percentage of elastomer gasket will only affect the performance marginally.

Permeation of gases from the atmosphere, though, will still provide a gas load large enough to be a problem in some applications, and there's no treatment to make the gasket less permeable. The only reasonable solution to permeation is to use two concentric gaskets with a pumpout space between them. This technique will lower the permeation rate about 3 orders of magnitude. These two "fixes" will improve the gas load performance appreciably, but some gas load(s) are still evident, so why would a vacuum practitioner use them?

The use of elastomer gaskets provides several trade-off compromises that are often appealing enough to allow the unavoidable gas loads to be ignored. In one sense, elastomer gaskets are easier to use. They are resilient enough that a gasket's sealing surfaces can flow into imperfections in a flange or surface and facilitate a seal. This also means that they will only require a modest amount of compression to form a leak-free seal. This translates into only a few flange bolts and reasonable amounts of bolt-torque. In fact, it's often possible to achieve a seal with only atmospheric pressure differential forcing, and holding, surfaces together. A glass bell jar with an L-shaped cross-section gasket on a flat base plate is a good example

The resilience of the elastomer material also allows the gaskets to be re-used continually until the material is damaged physically. Being relatively soft, they are easily nicked or easily damaged by particles being caught on the surface when making a seal.

Metal Seals

Metal gasket materials avoid the gas loads that are always encountered when using elastomers. In general, it's safe to say that they neither outgas nor are they permeable. There are a number of metal materials that can be used as gaskets, and all of them can be baked to some extent. For UHV applications where 250^{o} C bakeouts are required, copper-gasketed Conflat-type flanges where a flat copper gasket is trapped between two knife-edged sealing surfaces are the most commonly applied materials and designs. Metal gaskets are not always used only when high bakeout temperature resistance is required though.

In many applications, the outgassing and permeation gas loads from elastomers are just too high for the application. There are, however, some penalties to pay when using metal gaskets. Metal gaskets are not resilient and they are certainly harder than elastomers. This means that more force is needed to flow the gasket material into the imperfections of the sealing surfaces, and that means more bolts and much higher bolt-torques are required. Flowing the harder gasket materials also means that the sealing surfaces will be less forgiving in terms of imperfections. The need for more force to achieve a seal has another penalty to pay, and that penalty is time. It takes much longer to seal a metal-gasketed set of flange pairs than it does an elastomer-sealed pair. In an application that requires rapid cycling on a continual basis, a metal gasket is a problem. This is especially true for large flanges such as full-opening chamber doors.

There are a number of metals and seal designs that have widely varying sealing parameters, but all of them tend to be more difficult to use than elastomers. Soft metals such as indium or aluminum can be used much more easily than copper, and some gasket designs such as Helicoflex and C-rings can be re-used, but it must be considered that metal gaskets should be considered to be single use, or, at best, limited re-use materials. This adds a cost penalty as well.

Mix and Match

It's not always necessary to seal a system with either elastomer or metal gaskets. A mixed approach will often make more sense when we consider the actual application or process. If we look at vacuum valve designs, we can see some good examples of matching the seals to the application. Vacuum valves usually have three categories of seals within the valve design: the mounting flanges, the bonnet flange where the valve operator and sealing mechanism is joined to the valve body, and the valve seal itself such as the nosepiece in a poppet design or the gate seal in a gate design. This means that a valve might be provided with Conflat flanges, but have an elastomer bonnet seal if a small amount of outgassing and permeation can be allowed. For slightly more stringent requirements, the bonnet might also be metal-sealed, but the valve seal might still be an elastomer gasket. Allowing that single elastomer gasket to remain is a good example of an economic and time tradeoff. A valve seal that is metal requires a much more expensive, strong, and complex mechanism to provide the required seal forces and will usually take longer to make the seal. The single remaining elastomer gasket will not provide a permeation gas load in most applications since, in use, the gasket is kept immersed within the vacuum. In the case of UHV applications, however, the elastomer can be replaced with a metal gasket and the required price in terms of cost and effort is paid.

This same thinking can be applied to the other chamber seals. Flanges that are opened only occasionally can often be metal-sealed while access flanges for loading and unloading can be elastomer-sealed.

It is an exception when a black and white choice must be made. It's usually possible to carefully consider the actual application and make the tradeoffs in terms of gas loads and the time/difficulty ratio to allow a workable and rational mixed choice.