A Journal of
Practical and Useful
Vacuum Technology

By Phil Danielson

From THE VACUUM LAB

RECENT ADVANCES IN VACUUM SEALING TECHNIQUES

Vacuum technology, like all complex and evolving technologies, seems to advance in fits and starts with long and apparently static periods in between. This cyclic behavior gives rise to the chicken or egg question of whether new process requirements drive innovation or whether innovation enables new processes. Years of observation tends to indicate that it works both ways in a push/pull process. In fact, large leaps in pumps, hardware, etc. tend to be followed by years of steady but incremental improvements that finally settle into a state of technological stagnation.

A condition of relative stagnation has been reigning for some time in vacuum sealing. Following the flange wars of the 60’s and 70's, vacuum sealing mainly embraced two acceptable and successful standards. Bakeable or ultrahigh sealing applications settled within the Conflat[1] (CF) standard with copper gaskets and multiple flange bolts. High vacuum and generally unbaked applications became concordantly dominated by the ISO (International Standards Organization)-KF (KleinFlansch/little flange) using split clamps and MF (Multi-Fastener) using either C-clamps or bolts along with elastomer gaskets. The preponderance and acceptance of these two standards is exemplified by the verbal reference to sealing being a “done deal.” Further, a comparison of the contents of vacuum books written in the past few years with earlier books shows that seals are presently only covered in a fairly perfunctory fashion.

As might be expected, process needs are changing again, and technological change is alive and well. A number of new developments in sealing technology have appeared recently, and they represent the two major vectors for innovation: adapting to existing technology and going back to a clean board.

Adapting to Existing Technology

The inherent outgassing and permeation rates of elastomer O-rings have long been recognized. Vacuum pre-baking of Viton[2] O-rings will substantially reduce the outgassing rate, but that’s only a part of the problem of gas loads from Viton. The degree of permeation of atmospheric gases through the O-rings has begun to militate against their use in new processes with increasingly more stringent ultimate vacuum requirements. In some cases, the ability to make up flange pairs quickly and easily drops out of the equation when the need for lower ultimate pressures are required. Additionally, the growing need to operate many pumping lines at elevated temperatures to prevent condensation of process gases on room temperature surfaces becomes important. Even if these temperatures are not high enough to damage the O-ring material, the permeation rate increases asymptotically with increasing temperature. Since large numbers of these flanges are of the ISO standard and already on existing equipment, the economic burden of grinding off the existing ISO flanges and replacing them with copper-gasketed Conflat flanges is heavy indeed.

The most obvious fix for such a condition is to find a gasketing material that does not exhibit the same relatively high permeation rate as elastomers that are presently used. A partial fix has been applied with mixed success by using aluminum or aluminum alloy gaskets with either a diamond-shaped or coined cross section. Although softer than the stainless-steel flanges themselves, the aluminum requires a great deal more compression force than an elastomer O-ring to achieve a leak-tight seal. This means that the “normal” split clamp used with an ISO-KF flange has to be replaced by a chain-type clamp with a nut tightening system to provide enough force to deform the aluminum gasket sufficiently to force it to flow into the flange imperfections as required for a leak-tight seal. Additionally, high temperatures will cause the aluminum to stick or bond to the stainless steel flange surfaces and usually destroy those sealing surfaces sufficiently to prevent re-sealing. The aluminum gaskets can also be considered to be a single-use gasket that requires replacement every time the flange pair is disassembled.

Although the use of aluminum gaskets can be considered as a partial solution, and certainly an improvement over elastomers in terms of permeability, a new gasket has recently been introduced that exemplifies the concept of adapting existing technology with new improvements. This seal is formed from a thin inconel ring coated with a thick tin electroplate. The combination of the springiness of the inconel to maintain pressure against the flanges and the soft tin coating that will easily allow the tin to flow into flange imperfections together form an ingenious solution to the permeation problem. Leak-free seals can easily be made using the standard split clamp with wing nut tightening with no more force required than is used for the usual elastomer O-ring.

Pumpdown curve and rate-of-rise measurements carried out at The Vacuum Lab, Inc., comparing the room temperature performance of Viton and inconel/tin on ISO-KF flanges and copper-gasketed Conflat flanges showed that the permeation rate of the new gaskets was 2.3-2.5 times lower than Viton and essentially the same as copper. Thus, the ingenuity of combining several different technologies together to form a new sealing material or gasket allows a truly important performance upgrade to existing flanges. The total impact of this new sealing technology will be interesting to follow in the future. For example, a bakeable valve could easily be built without the need for the massive and expensive sealing drive mechanism usually required for metal-sealed valves.

The Clean Board Solution

The same performance needs that drove the inconel/tin seals has fostered another development that probably began with the "what are we trying to do?" question. If the gasketing material is the source of the permeation problem, then the obvious solution is to get rid of the gaskets entirely. This is exactly what came out of the clean board approach. A new sealing system is available that provides a metal-to-metal demountable seal without any gaskets at all. In this system, flanges are used to force the ends of stainless steel tubes together sufficiently to achieve a stainless-to-stainless steel that is not only leak-tight but bakeable as well. These seals are reported to vary from small tubes up to about 200 mm, but no performance tests have been undertaken by The Vacuum Lab.

[1] Trademark of Varian Associates
[2] Trademark of Du Pont