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UNDERSTANDING VIRTUAL LEAKS

Virtual leaks are things that will drive you virtually crazy because they aren't really leaks, they just seem to be. Many hours of working with a leak detector and probing with helium will end up with the inevitable conclusion that there aren't any leaks in the system that can be found, but still the system won't give you either the pumpdown curve or final ultimate pressure that was expected. At this point, it's likely that the system contains at least one virtual leak that's slowly dribbling gas into the chamber and making it seem as though there's real leak present. In fact, there are probably a number of small virtual leaks instead of just one big one. So what's a virtual leak?

A virtual leak is a source of gas that's physically trapped within the chamber with only a small, very low conductance, path from the trapped pocket of gas into the chamber proper. An internal weld crack is a good example in that, following an air release, the gas within that tiny crack will leave the crack slowly due to the restriction in easy gas flow into the chamber proper. As the pressure in the chamber drops during the pumpdown cycle, the gas from the crack will become a small but continuous gas load flowing into the chamber. Depending upon the pumpdown specs required by the process, this small amount of gas might or might not be a problem. The point is, though, that it is a gas load and gas loads should usually be reduced to a minimum. This is especially true of water vapor that entered the virtual leak pocket when the chamber was backfilled with air. Water vapor will slowly desorb, but will usually resorb on another surface point. In a virtual leak pocket, the desorbing water vapor molecule can, and probably will, continually desorb and resorb forever because it can't be easily pumped away since it can't easily reach the chamber. Although these small gas sources can be sometimes regarded as minimal, the other end of the virtual leak spectrum is almost always a problem. That is the relatively large pocket of gas trapped in a condition where it's almost impossible to escape quickly. The blind, tapped hole with an inserted screw is a prime and common example such as is shown in the Figure 1. Look at it this way: a 1/4 in.-diameter tapped hole with an inserted screw that leaves 1/16 in. clear at the bottom has a dead volume of 0.049 in^3, and this volume will trap and contain 0.6 torr liters of gas at atmospheric pressure. This amount of gas would be

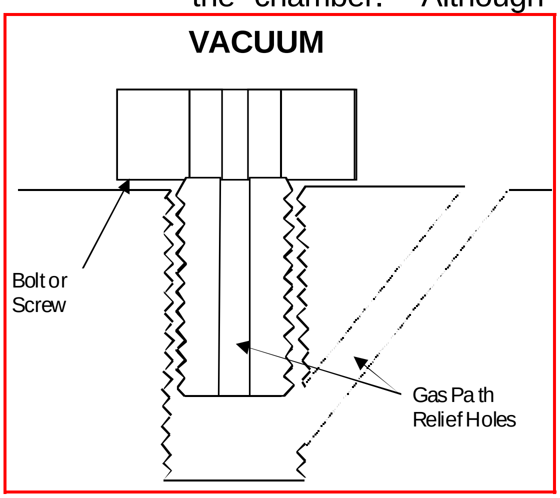

Figure 1. Common Solutions to Trapped Volumes

equivalent to 6 x 10^{-3} torr in a 100 liter chamber. That's a lot of gas. Since there is only an infinitesimal possible gas path through the threads, the time required to remove that much gas from the trapped pocket is likely to either be, or seem to be, infinite. Blind tapped holes are often found in systems and cause process problems. An often reported problem is such virtual leaks in assembled active metal sputtering cathodes where the trapped air slowly bleeds across the target and forms insulating oxide and nitride surface films which can then charge up and arc.

Detecting Virtual Leaks

Keeping in mind that virtual leaks have no discernible virtue, they can be detected by observing a system's misbehavior or lack of virtue. Analog gauges can be used easily since virtual leaks are often evidenced by small pressure bursts as gas trapped in, say a crack, will reach the chamber end of the crack and burst into the system followed by a sudden return to the original pressure. This will tend to occur on a fixed time base over a short time span. If an analog ion gauge is reading 1.2 x 10^{-5} torr steadily and then bursts or spikes up to something like 1.3-1.4 x 10^{-5} torr repeatedly, it's probably a virtual leak. Figure 2 shows this effect schematically.

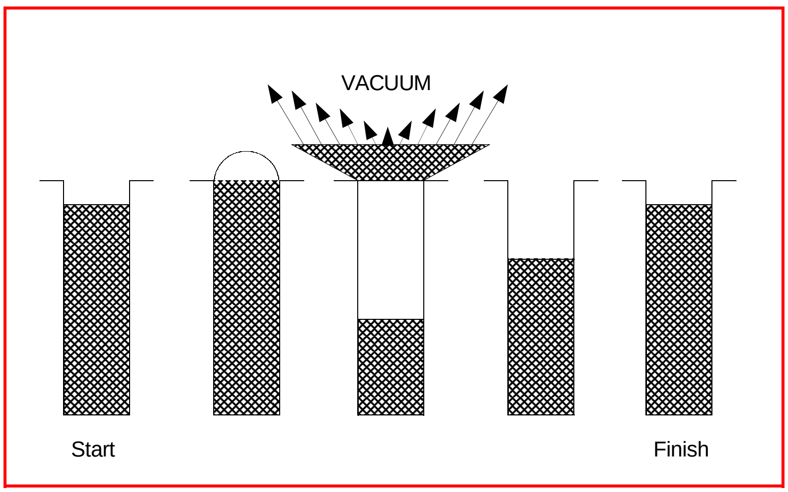

Figure 2. Single Burst Behavior of a Virtual Leak.

A small amount of heat or cold applied to a suspected area will usually adjust the frequency of bursts. Heating the trapped gas will cause the burst frequency to increase while cold will cause the frequency to decrease. In a practical sense, the trick is to keep the head locked in position while observing to avoid parallax effects. This technique is extremely difficult with digital gauges since it's almost impossible to read the digits during a burst. Residual gas analyzers also have a problem in that the bursts are usually composed of air (gas mixture), and the difference in any given peak height of the peaks representing the gas mixture is too small to observe easily during a total pressure burst.

Avoiding Virtual Leaks in the Design Phase

Obviously, the best way to deal with virtual leak problems is to avoid them entirely. This is usually an impossibility since a virtual leak can be something as simple as the gap between flanges or two surfaces in contact. In short, they are sometimes unavoidable. Accepting one, however, does not mean that ten are acceptable. As the design of a new system comes together, the key is to continually pare away the possible virtual leaks. They tend to come in four overall types:

1. Gaps
2. Cracks
3. Surface contacts
4. Trapped pockets.

In most cases, they can be avoided up front by using better assembly techniques for welding, brazing, etc. Other unavoidable virtual leaks can be dealt with by providing a relieved gas path as shown in Figure 1. A good example of design level avoidance is the design of a newly introduced metal gasketing system for the ubiquitous standard ISO-KF-MF flanges in that axial relief holes are provided in the centering ring to allow gas trapped in a space pocket between the centering ring and the seal to be pumped out efficiently. Another common example is the use of bolts with a longitudinal relief hole through the entire bolt as shown in Figure 1. These pre-drilled bolts are commercially available. Solutions, then, can be simple or require some ingenuity, but a flow path must be provided to allow the trapped gas to escape.

Dealing with Existing Virtual Leaks

Once a system is in operation and a single or series of virtual leaks are detected that are inhibiting the best possible operation, it's difficult to do much about them without starting over. Since this is usually economically unfeasible, the only solution is to find some way to relieve gas paths. This can sometimes be done by modifying or rebuilding demountable components or by drilling relief holes in parts of the chamber itself. In general, this means following some of the same techniques that could be used in the original design phase. An additional trick that sometimes works with virtual leaks that cannot be relieved is to release the chamber to argon. This will work in cases where argon is not detrimental to the process. The argon will slowly leak from the virtual leak pocket into the chamber and retard the ultimate pressure, but can be safely ignored. Examples would be sputtering where argon is used in the process or processes where the vacuum is used to protect the process chemically and the presence of an inert gas will do no harm. An example would be many vacuum furnace processes.

In short, avoid virtual leaks, deal with them, or learn to live with them.

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