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RATE-OF-RISE CURVES AS A DIAGNOSTIC TOOL

One of the simplest tools to help monitor the health and well being of your vacuum system is to measure the rate-of-rise in the chamber after pumpdown. This technique can be considered as the second half of an overall surveillance/diagnostic program that includes measuring and comparing pumpdown curves as the first part.

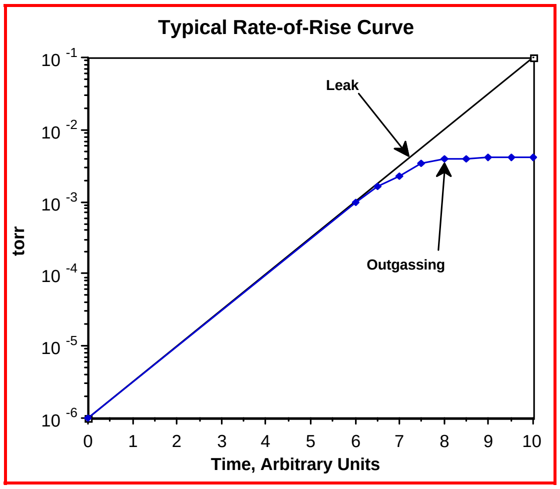
Taking a rate-of-rise curve is simplicity itself. Once you've pumped the system down to some pre-selected pressure, you merely close the high vacuum valve and monitor the pressure as a function of time. These curves are often erroneously called leak-up curves, but a pressure rise that occurs when the pump is valved off need not result from a leak. Any and all gas loads can cause a pressure rise. Rate-of-rise curves will help provide a measure of those gas loads that can be easily compared to a "standard" previously obtained curve for a given system.

Leak or Outgassing?

If you've already done a pumpdown curve, you have only half of the performance picture. Let's say that you've pumped your chamber down and the pressure is a little higher than usual for a given pumping time. The first suspicion is usually a leak. If the slower-than-usual pumpdown isn't caused by a leak, you can spend a lot of time and energy hunting for a non-existent leak. A rate-of-rise curve, however, can give you a quick and easy go/no-go indication of the presence of a leak. If the pressure continues to rise at a steady rate over time, you've got a leak, and it's time to go into leak detection mode in order to find and fix the leak.

If the rate of pressure rise begins to slowly tail off, though, the cause of the deviation from normal in the pumpdown curve is an internal gas load that would fall under the broad heading of "outgassing." Outgassing is a term often erroneously applied to any and all non-leak gas loads. Used in this way, the term includes surface desorption, true outgassing from the bulk of materials of construction, permeation, and virtual leaks along with various and assorted contamination-related gas sources.

The figure shows a typical rate-of-rise curve difference with both types of gas loads. As the curve labeled outgassing begins to flatten out, the vapor sources within the system are approaching an equilibrium condition where little or no further pressure rise will be observed. This could be a vapor pressure equilibrium or merely the total amount of gas from virtual gas



pockets having totally escaped into the chamber proper. A leak, though, will continue to allow gas into the chamber from the atmosphere.

In general, permeation gas loads, say through elastomer O-rings, will be small enough to be easily differentiated from a real leak. Large numbers of O-rings on a small volume chamber can occasionally confound this technique due to the large amount of gas permeating in from the atmosphere. The time-base for differentiating between leaks and outgassing is too variable from system to system to determine any time specs as a universally acceptable test parameter, but taking a few curves with a specific system will quickly allow a spec for a given system and process to be established. There's no real substitute for explicit experience with a system and its process.

The practical power of this technique is obvious when you consider the time saved in avoiding a fruitless session of leak checking when the reason for an unacceptable pumpdown curve lies elsewhere. As with pumpdown curves, experience will provide some further useful clues as to the source of a problem by comparing today's rate-of-rise curve shape with yesterday's. For example, a curve with sudden spikes or variations is often caused by virtual leaks where the gas leaves a trapped volume in spurts. Additionally, the rate-of-rise due to various types of contamination will differ with the source of the contamination. A fingerprint will have a different effect than a trace of mechanical pump oil, but this will vary from system to system. Each process will have its own peculiarities, but the clues can be invaluable in saving time in trouble-shooting a system that appears to be performing outside of its normal envelope.

Beyond a Pumpdown Curve

There's no question that monitoring pumpdown curves will give you invaluable insight to your system's performance. These curves can also give you early warning of impending problems, but subtle variations can be easily hidden if your monitoring stops with just pumpdown curves and omits rate-of-rise curves.

A common example is found in systems with higher pumping speeds than are absolutely necessary. Most modern vacuum systems fall into this category. "You can't have too much pumping speed" thinking often makes a lot of sense. This is especially true in cryopumped systems where the cryopump provides very high water vapor pumping speeds. If we consider the fundamental performance relationship

$$Q = SP$$
$$\text{Gas Load} = \text{Pumping Speed} \times \text{Pressure},$$

we can see that a higher pumping speed will produce a lower pressure with a given gas load. This also means that a slight increase in gas load might well be hidden within the normally expected day-to-day variation in the ionization gauge's reading if the pumping speed is high enough.

Here's a specific example. If you compare today's pumpdown curve with yesterday's, and they're pretty much the same, you could easily go ahead and assume that you're within spec and start the process. However, the amount of water vapor on the internal surfaces of the chamber might well be different than usual because there was a wide variation in humidity from yesterday to today. If today was more humid, the internal surfaces would have sorbed a thicker bed of water vapor when the system was open, and this would result in a higher water desorption rate. A high water vapor pumping speed could easily deal with the higher desorption rate and provide an acceptable pumpdown curve. An apparently acceptable pumpdown curve, then, could lead you to erroneously assume that your process parameters were also acceptable.

A process that is susceptible to water vapor contamination, as are many thin film processes, isn't really based on a pressure spec as much as it is in number of molecules that might enter or collide with the process. A higher pumping speed, then, will certainly give you a low enough pressure, but the higher desorption rate will allow more water molecules to interact with the process as they leave the surfaces, pass through the process volume, and are pumped away.

The effect of the increased desorption rate will be hidden in the pumpdown curve because of the high pumping speed, but a rate-of-rise curve will quickly show a steeper increase in pressure than is normal. Therefore, a combination of pumpdown curve and rate-of-rise curve together could and would catch a problem before the process was initiated.

Full or Partial Curve?

Once a system is well established in terms of performance, a rate-of-rise curve taken for only a few minutes can be used to detect variations in slope that can serve as an early warning of impending or present problems. This short-term technique can be considered as a system performance surveillance step. Any deviation from the norm would then call for a full rate-of-rise curve to be taken by extending the time-base to allow for a full diagnostic check. Such short-term surveillance steps are often built into a routine system pumpdown cycle.

Qualifying or Requalifying a System?

Both pumpdown curves and rate-of-rise curves are useful in qualifying a system for performance following maintenance or any other changes, such as replacing a leaking O-ring or some other simple but process-crucial operation. Once an acceptable pressure is achieved, a rate-of-rise curve that is compared to a previously determined acceptable curve will be an important indicator that the system has been pumped on enough to be back into qualification parameters for further process work.

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