THE VACUUM CHRONICLES

Volume 3, Number 3

Pumpdown Curves and Rate of Rise Measurements

by Phil Danielson

Vacuum technology is always in need of new diagnostic tricks to help check out system performance. Here's a couple that are so old that they're probably new. They're quick and simple, and will give you an incredible amount of information if you use them a lot. In fact, they're the same trick. You do one forwards and you do one backwards. Pumpdown curves and rate of rise measurements. That's all.

WHY BOTHER?

Why indeed? The industry has all kinds of residual gas analyzers with data collection and data handling goodies that can tell you everything you want to know. In fact, they're so great that you can get buried in data without even trying. This kind of information is invaluable and important. There's no question about that.

What we're looking at here is an additional technique that provides a quick check of system performance and that can be used at pressures too high for RGA operation. Additionally, it provides a diagnostic tool for systems that don't have an RGA installed.

This technique, then, is not intended to replace RGA's, but is intended to provide a quick and easy check or warning of system performance or non-performance. Why spend a lot of time, effort, and energy digging around in RGA data until you know you have to?

KNOW YOUR SYSTEM

Every system performs differently. Even identical systems from the same manufacturer will have subtle, and sometimes not so subtle, differences in performance. You just have to characterize each and every system.

With any vacuum system, and especially with production systems, you'd like to detect the onset of possible problems before they occur. If you can see a possible problem on its way, you can often react appropriately before the problem gets out of hand and requires a lot more time and work to clean up. If you collect enough simple performance data and constantly check for changes in performance, it gets easy. The problem is what data to collect and how to collect it. Too much data can be worse than no data at all if there's so much data that you bog down in it. Here's a proven technique.

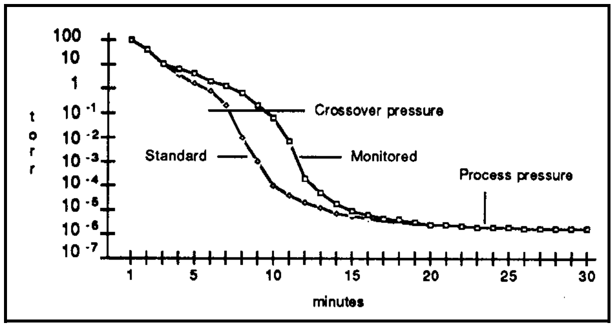

Figure 1. Diagnostic pumpdown curve.

PUMPDOWN CURVES

Pumpdown curves can tell you a lot about how your system is performing. What's happening during the pumpdown cycle is generally ignored because it's just a time consuming thing you have to get through before you can get on with the process, and it's the process that's the most interesting. So, the pumpdown is often looked as something that takes as long as it takes. If you look at a pumpdown cycle as something that "ain't over till the fat lady sings," you'll tend to just wait until you hear the singing. Monitoring the time to reach a given pressure will tell you something, but there's a whole lot more information to be garnered from the SHAPE of the curve.

Figure 1 shows an example from a cryopumped system that would never be apparent from RGA or total pumpdown time data. The shape of the curve shows a slightly longer time to reach cryopump crossover pressure even though the total time to reach process pressure was about the same. The cause of the fall-off in roughing performance was traced to the build-up of condensed water vapor in the oil-sealed roughing pump. The water in the roughing pump was easily removed by gas ballasting, but the water in the pump was only a symptom of a bigger potential problem. The roughing pump was fitted with a molecular sieve foreline trap to stop the oil from backstreaming into the chamber. Since molecular sieve absorbs both oil and water, it turned out that the sieve was already saturated with water to the point where water vapor was passing right through it into the roughing pump. Since a trap that's already saturated with water can't trap any oil, it was apparent that oil vapor was about to start backstreaming into the chamber. By the time the oil was detected by an RGA, it would have been too late to avoid a complete cleanup with the downtime expected with a full system shutdown.

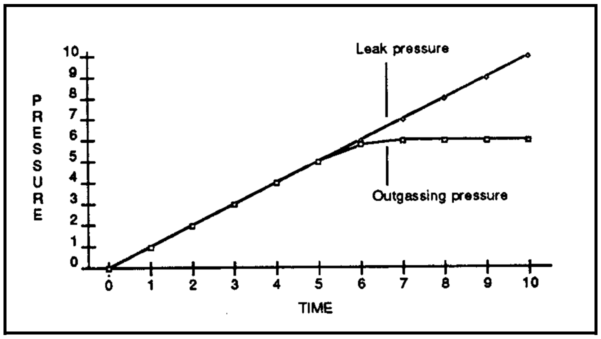

Figure 2. Diagnostic rate of rise curve.

This example shows what kinds of benefits can be gained from monitoring the pumpdown curves all the way from atmospheric pressure. In observing the curves shown in Figure 1, it would seem that a great deal of data point measurements would be required on a routine basis; but this need not be true. Once the "normal" or "standard" curve is obtained, there is no necessity to take a lot of data. Depending upon the complexity of the curve, only a few points near important regions, such as crossover in the example, would be necessary. It's a judgement call.

The important consideration is getting the comparison in realtime or close to realtime at the very least. Obviously, a strip chart analog recording or a print out would be ideal. Just as obviously, an automatic comparison from a computer system controller would be a little more than ideal. But, we've only covered half of the total technique.

RATE OF RISE MEASUREMENTS

A pumpdown curve can reveal a good deal about a system's performance under the conditions of gas removal and quasi equilibration, but a "rate of rise" measurement can reveal further subtleties under differing circumstances.

Rate of rise measurements are made by closing the valve to whatever pump is in service and graphing the pressure rise with time. The semi-erroneous term "leak up rate" has been with us for a long time, and it is often used to describe rate of rise measurements. In fact, system specifications of leak up rate in microns/minute were fairly common some years ago instead of RGA specs or actual system total leak rates. Rate of rise is a more accurate term because the pressure rise observed in a valved off system can be attributed to more than leakage. Gas loads from water or contaminant desorption, virtual leaks, and gas diffusion and permeation will cause pressure rises. In fact, all of these effects were once lumped under the broad term "outgassing" at one time and sometimes still are.

Figure 2 shows an old but still useful technique to tell whether the source of an unsatisfactory system performance is due to leaks or "outgassing." If the system is leaking, the pressure will continue to rise, but any other form of gas load will tend to equilibrate or tail off due to such effects as vapor pressure equilibrium or reduction of pressure differentials.

Rate of rise measurements can and should be made at various points in the pumpdown cycle. There is such a great variation in systems that there is no real rules of thumb that can be applied. The acceptable rates of rise will have to be worked out for each system; but once they are determined, there should be little variation unless a problem occurs. In most systems, the rate of rise slope will be controlled by the desorption rate of the water vapor left on the walls at the various pressures where the measurement might start. Common variations that might occur will probably be traceable to variations in humidity or in the amount of time a system is exposed to air of varying humidity.

Rate of rise slopes can be programmed into a system controller so that a GO/NO GO test is performed at one or several points in every pumpdown. This technique can be extremely useful to provide early detection of leaks, contamination, or any other variable that might affect the process to be carried out following the pumpdown cycle.

CONCLUSIONS

The technique(s) described can be extremely valuable in that they can provide a good deal of early detection. Their basic simplicity will then make it easy to decide whether or not you'll need to go further in diagnostic testing. At the very least, they'll help avoid the bogging down in data that can easily occur when a large amount of RGA data is available but possibly not presently relevant.

V3, #3/1992, "Pumpdown Curves and Rate of Rise Measurements"

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