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From THE VACUUM LAB

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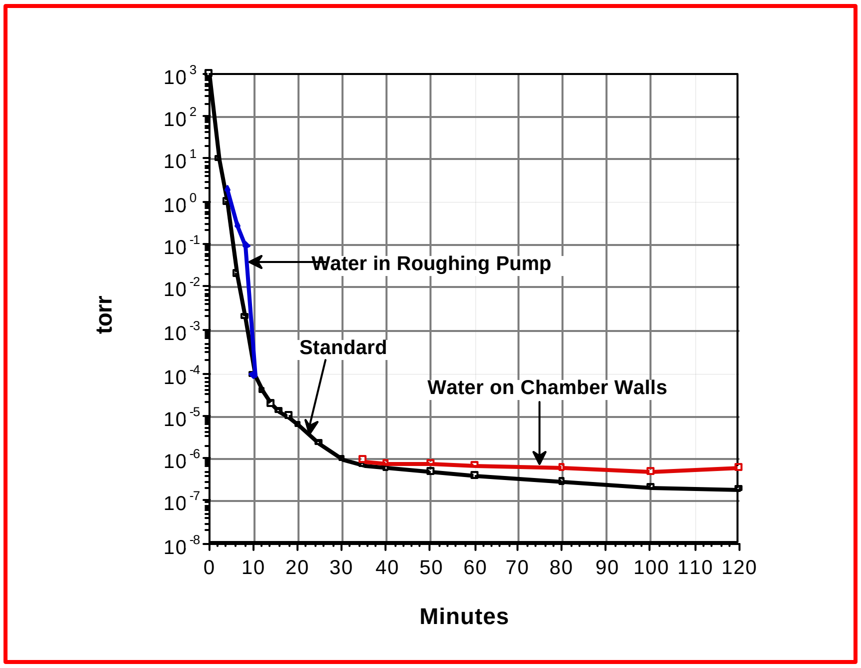
Diagnosing Vacuum Problems with Pumpdown and Rate-of-Rise Curves

If there's one thing you can count on in the practice of vacuum technology, it's that a performance problem will show up at some, usually the worst, time. Why? Well, it's not just that the hardware components or associated electronics will break down, but that the interplay of the process itself with the component parts comes into play during operation. Water vapor can build up within the system and affect pump operation, or process detritus such as spongy deposits can begin to sorb water vapor or hydrocarbon contaminants, The list is endless and highly system and/or process dependent. Although some problems, such as a sudden leak caused by a particle on a loading door O-ring, can appear with no warning, most vacuum problems creep up on the unwary in small, and seemingly insignificant, increments. The wise vacuum practitioner maintains a constant watch and surveillance on the process system's performance and operation in an attempt to spot the onset of a potential problem before it becomes a real problem that will ruin a process run or cause a system shutdown. There are some simple and practical operational tools that will not only help identify incipient problems, but will help diagnose their source and indicate possible solutions.

The residual gas analyzer (RGA) is probably the most ubiquitous and generally accepted tool for monitoring performance and trouble-shooting. As with most instruments, their use is only as valuable as how well they are used. In fact, in many cases, the RGA is considered as a sort of magic talisman to ward off problems. "But I've got an RGA on the system," is a defensive and bewildered comment that can be heard only too often when attempting to point out an application problem. Additionally, it's all too easy for small changes in total pressure to be missed when those changes are distributed over a number of mass peaks. Although most RGA's are fully capable of providing the required precision and accuracy, the handling of the data, either mentally or computer, can allow the advantages to be lost. Pumpdown and rate-of-rise curves are simple tools that can be used in addition to RGA monitoring and for those systems that don't have an RGA installed.

A pumpdown curve is simply a series of pressure vs. pumpdown time observations that can be either graphed or tabled with graphing as the most useful for monitoring and interpreting system performance. In its simplest form, a pumpdown curve is actually used when checking a time-to-ultimate pumpdown process specification. Although this is a common and useful procedure, it can only tell the operator that the system is or isn't behaving the same way it usually does. Graphing the entire pumpdown curve, however, from the onset of roughing to the final process pressure can provide a wealth of useful information. The actual shape of the curve is important. Vacuum gauge controllers that present time vs. pressure curves on their readout are commercially available.



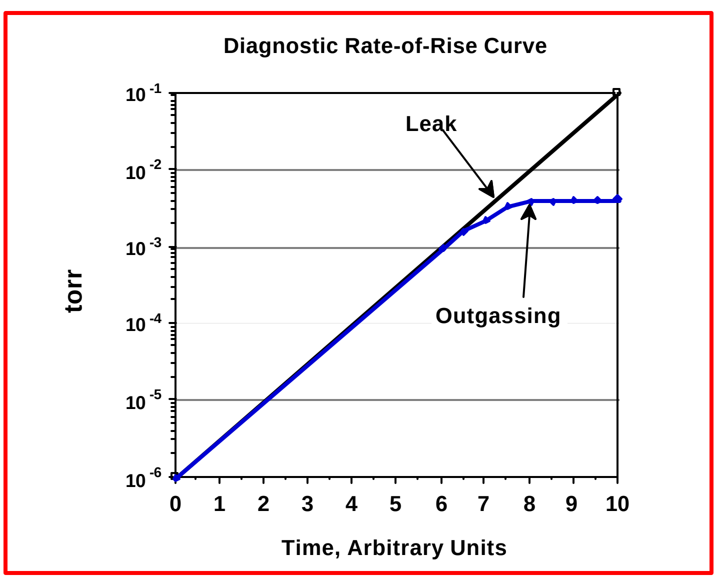
Comparing a pumpdown curve to a standard curve can be used to detect problems such as water vapor condensing in a roughing pump or a build-up of water vapor on chamber surfaces.

Any system should have a detailed pumpdown curve that's been recorded when the system is operating properly. If this curve is used as the "standard", then subsequent curves can be compared to it as a matter of course. If, at any point during a pumpdown, the shape of the curve varies, there's a reason. A single deviation might not be important, but a continuing deviation in the same direction can be a real but early warning of problems building up. A good example would be a slight shifting of the roughing portion of the curve in a cryopumped system with an oil-sealed roughing pump. This effect could easily be a case of condensed water vapor building up within the pump, and that could cause problems in time. The cryopump's high pumping speed for water vapor would probably mask the effects if a full pumpdown curve wasn't observed and/or recorded. Additionally, if nothing was observed until an RGA scan showed a build-up of water vapor at high vacuum, a production run might be lost while the real problem was identified and corrected by merely gas-ballasting the roughing pump. Caught early on, this would never have been a production-halting problem.

Although it's difficult to diagnose a performance problem from just a pumpdown curve alone, it's important to maintain some kind of surveillance on the total curve until a good deal of experience is assembled on the system's overall performance. Each system and process is different enough that specific experience will often allow the early warning signs to be easily interpreted.

Rate-of-rise curves can be even more important than pumpdown curves. Taken together, they can be extremely effective. If, at some time during the pumpdown cycle, the pump is valved off the pressure within the chamber will begin to rise. Since the pumping speed is now zero, any gas entering the chamber will be accumulated. Graphing or recording the pressure vs. time with a zero pumping speed will provide a rate-of-rise curve. These curves are often referred to as "leak-up curves" or "leak-up rate." This is one of those ubiquitous cases where nomenclature and terminology become important since one of the main applications of the rate-of-rise curve is to determine whether the system is leaking or not. It's always a mistake to assume that any gas load into a chamber that's higher than usual is a leak. The amount of time and effort expended in setting up a leak detector and searching for a non-existent leak can be extremely wasteful.

Contamination resulting in additional partial pressure (CRAPP) is often the gas load source. This can be desorbing water vapor building up in porous and hygroscopic wall deposits, oil vapors from backstreaming, or process related contamination. This would also include any of the other common sources of gas loads that fall under the overall heading of outgassing such as atmospheric permeation and diffusion. Taking rate-of-rise curves can help sort out leaks from CRAPP when it isn't immediately obvious from the RGA display. If the rising pressure begins to level out with time, it's probably CRAPP, but if the pressure continues to rise, it's probably a leak. This technique will often resolve the source of a problem when the pressure is too high to use an RGA. Since vacuum problems are often a combination of several small problems instead of a single problem, a combination of a small leak and a small amount of CRAPP will result in a curve that falls somewhere between the curves resulting from one problem alone.



A standard rate-of-rise curve should be established, as with a pumpdown curve, for any system when it is performing properly. The best way of handling them together will depend upon they type of system control and instrumentation provided. A manually operated system can have the operator compare the pumpdown and rate-of-rise readings with a graph mounted on or near the system in real time. If the system is computer-controlled, the data points can be constantly compared to a stored set of curves as the system observes them. The total time base for a rate-of-rise curve will depend upon the system and its inherent gas loads, but a full curve that is taken for a long enough time to differentiate between CRAPP and a leak is only necessary when it's already been determined that a problem might exist and the curve is to be used as a trouble-shooting tool instead of a surveillance tool. In general, a curve taken for only a few minutes can provide a numerical rate-of-rise that can suffice. A rate-of-rise calculation in torr/second or some other convenient units made from a short zero pumping speed condition is usually enough to spot a potential problem.

Another important application of both pumpdown and rate-of-rise curves is in qualifying a system for production following maintenance or cleaning. Any procedure carried out on the system is likely to change its overall sources of gas loads, and that will be reflected in both types of curves. For example, if an O-ring was changed for some reason, a higher than usual rate-of-rise might result due to water vapor or solvent diffusing out of the O-ring's bulk. This might be either a long-term problem requiring re-replacement of the O-ring or it might only require additional pumping time followed by re-testing to bring the total gas load into the required parameters. Obviously, until the system provides curves matching the standard set, it isn't yet ready to be put back into a production status. This can be even more important for a new system where initial qualification curves can be used for acceptance.

These simple procedures can provide extremely useful tools for monitoring system performance and for diagnosing performance problems. They can be used on virtually any vacuum system operating at almost any ultimate pressure, and they can utilize whatever gauges are normally in use on the system. Heading off an incipient problem is always preferable to waiting until the problem becomes extreme.