A Journal of Practical and Useful Vacuum Technology

From THE VACUUM LAB

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Initial Evacuation of Sealed-Off Devices

Bending the Rules: When the Vacuum Rules Get in the Way, Careful Analysis Allows Rule Bending

Vacuum technology has many fixed rules, but when the application requires the rules to be bent, careful analysis of the rules and application will often allow the rules to be worked around.

Vacuum technology, like all discrete technologies, is replete with rules of one sort or another. They include a long list of basic guidelines in addition to do's and don'ts, rights and wrongs, and dire warnings of imminent disaster. If you believe the old homily that "rules are made to be broken," it's strongly recommended that you'd better think again. Those rules grew out of long years of practical and theoretical experience that was often painful. So, you break the rules only at your peril, but many applications make it virtually impossible to follow all the rules. This dilemma is all too common to ignore. When we consider that vacuum technology is so unforgiving that you can do everything right with only one mistake and that mistake causes total failure, the dilemma deepens. Taken absolutely, this would mean that you cannot break the rules but you cannot follow them. What you can do is bend them, but you must bend them very carefully.

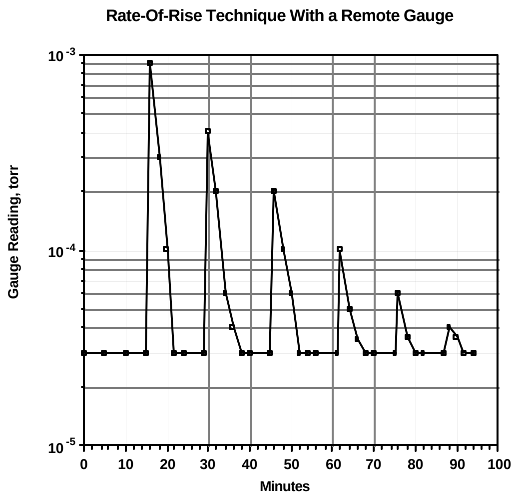
Bending the Rules

Bending the rules is a very tricky proposition, and it requires a full measure of knowledge and thought before doing so because of the fact that a change in one area will have an effect in another. Consider that the complexity of a vacuum system is greater than the sum of the complexity of its parts. if, for example, the rules say that you shouldn't use a particular material within a chamber because it presents too high a gas load, but the application requires its use, you have to find a way to work around the rule. Plastics with high outgassing rates shouldn't be used, but what do you do if your application is to coat them? You find a way to deal with the high outgassing rate. This means that the entire system design has to be considered carefully in light of the inescapable fact that you must use this material. These kinds of problems come up constantly in vacuum technology, and the techniques for working with them vary widely from problem to problem. The one constant, though, is the analysis of the system, and acceptance of the fact that being forced to break or bend one rule doesn't cancel all the rest. One particular type of application that is common is the evacuation of devices that are to be sealed off under vacuum following initial evacuation. This would include cathode ray tubes, CCD cameras, IR sensors, and dewars among a seemingly endless list. A good way of learning the analytical part of the rule bending technique is to work through one of these applications.

Encountering Dilemmas

Taking a good look at the subject of dewar flask pre-evacuation is particularly useful because the family includes devices that span a wide range and share most of the problems of all the other sealed-off devices. Here, then, we include devices to be permanently sealed-off such as thermos bottles at one end of the family and demountable cryostats at the other end. In general, they need to be evacuated to high vacuum in order to remove enough gas molecules to ensure low heat transfer and the requirement to do so as quickly and easily as possible is obvious.

The rules of vacuum system design tell us that we need to provide a large-as-possible pumping port with the pump directly mounted to the port or to an equally large valve. Right away, a problem emerges. In many cases, the dewar is to be tipped-off if it's made of glass or pinched-off if it's made of metal. This requires a small diameter pumping port and line, and this results is a low conductance port which, in turn, results in a low effective pumping speed. Being forced, by physical necessity, to bend a rule requires a penalty, and that penalty is pumping time. The question is how much time?



The pressure within a dewar can be estimated when a remote gauge is necessary by using a Rate-of-Rise technique. When the gauge reading stabilizes, a valve between the gauge tube and dewar is closed for 5 minutes to allow the pressure to rise in the dewar, and then a pressure spike is seen when the valve is opened. This cycle can be repeated until a small enough spike is observed.

The rules also dictate that a high vacuum gauge be mounted directly on a vacuum chamber in order to achieve an accurate and reliable pressure reading, and here we encounter another problem. It's both economically unfeasible and physically impossible to include a permanently mounted appendage gauge tube on each dewar. Since we still need to know when the dewar has been evacuated to the right pressure, we have to provide another work-around solution that will, in turn, require another penalty; convenience and uncertainty. The gauge tube, then, will need to be mounted between the pump and the low conductance pumpout line. The gas laws, which can never be ignored, tell us that the effective pumping speed at the gauge tube will be higher than the speed at the chamber, and this, in turn, tells us that the pressure within the chamber will not be the same as read by the gauge. In fact, it will probably be a couple of orders of magnitude higher than the gauge reading. So, how do we know when the dewar has been pumped down to an acceptable pressure?

The Work-Around

We now have a multiple set of dilemmas to work around. The low conductance of the pumpout tube has forced us to sacrifice pumping speed and pay a price in time, and the relatively remote gauge tube will only provide a reading that is somewhat proportional to the pressure within the dewar. We have been forced to bend the rules by the reality of the application, but we can analyze the situation in light of the rules to find a possible solution. In this case, we can utilize our knowledge and understanding of the technology to defeat the dilemmas.

If we are attempting to achieve high vacuum within the dewar, we will be in the drydown zone below 10^{-3} torr, and this means that water vapor will not only be the dominant gas within the dewar, but will still be desorbing steadily. If we provide a valve between the pumpout tube and the pump-valve pair, we can close the valve and allow the pressure to rise within the dewar in a classic rate-of-rise test. When we close the valve, the gauge pressure will drop quickly to some equilibrium pressure, but when we open the valve after some pre-determined time, the gauge will quickly respond to the pressure increase within the dewar and stabilize at some reading. By repeating this test during the pumpdown cycle, you can gain a measure of the conditions within the dewar as the pressure spike encountered upon opening the valve decreases with each test. You still won’t know the pressure within the dewar with any direct certainty, but you’ll have an analog measure to work from.

The Rules Remain

Although we have just seen one practical solution to a need to bend the rules, the rules won’t go away. In fact, it’s often necessary to go deeper into our thinking when bending the rules. In the case of dewars, for example, they often contain internal physical (molecular sieve) or chemical (active metal) getters to help maintain the vacuum after final isolation from the pumping system. Both types can serve as a source of gas unless that gas is pumped away. Physical getters will emanate water vapor and chemical getters can contribute large amounts of hydrogen that’s released during activation. In either case, this gas must be removed before isolation, and the same rate-of-rise test can be used to ensure its removal.

The rules, then, can be bent or even broken when an application requires it, but a long and careful analysis is required while all the trade-offs and interactions are probed. We must always remember that a simple change in one part of a process is likely to have an impact, and maybe an important one, on the rest of the process. Taking the easy way out is often a clear path to a fool's paradise.

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