A Journal of
Practical and Useful
Vacuum Technology

By Phil Danielson

From THE VACUUM LAB

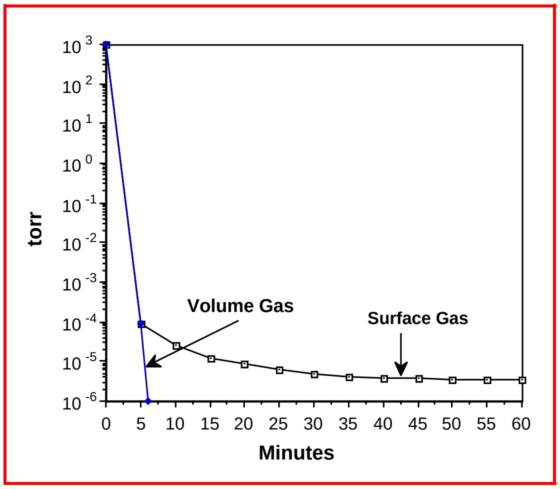
THE VACUUM CHAMBER: VOLUME OR SURFACE AREA?

When assessing the vacuum performance of an existing chamber, the mental eye has a tendency to focus on either of two possible parameters that are both crucial to performance but not necessarily entwined. These are chamber volume and internal surface area. The same can be said for the design stage of a new system in that it is all too easy to focus on either parameter to the possible detriment of the other. Well then, which of the two is most important? As usual, that depends on what you're trying to do. Since each parameter represents a different kind of gas load, it's important to consider them in light of the process and pumpdown requirements. In general, it is always important to reduce gas loads as much as possible.

Chamber Volume

The volume of the chamber is usually only a major factor in cases where pumpdown time is critical from atmospheric to some pressure no lower than a few millitorr (microns). In these cases, the gas being pumped is usually called *volume gas.* This is the amount of gas trapped within the chamber prior to the pumpdown cycle. Pumping volume gas a fairly simple concept that can be compared to emptying a water bucket with a spoon, in which each spoonful is equal in volume until the level in the bucket drops low enough that you can no longer get a spoon to fill by dipping it into the water. So, each spoon cycle removes less water and the level drops slower. A vacuum pump, such as an oil-sealed mechanical pump, that exhibits a lowering in pumping speed as the pressure drops can be mentally substituted for the spoon.

Unless a chamber is being designed to utilize an existing pump, the chamber volume is merely one item in a formula to calculate the required pumping speed to reach a given pressure in the specified or desired time. In other words, the chamber volume is not all that important a consideration, assuming that the proper pump can be supplied. The concept of chamber size, though, can easily lead to some misconceptions due to incompletely applied logic. At first blush, the thought can occur that a larger chamber will require a lot more process gas to flow through to complete a process utilizing a dynamic flow of gas. Although there's a grain of truth to that thought, the practical actuality is that once an insignificant amount of gas is used to reach the specified pressure, the flow rate will equilibrate to the same amount regardless of chamber volume. The same misconception is often applied to leak detection where it is assumed that the response time on a helium leak detector will be slower on a large chamber than on a small one. It will, but it will also be too small to measure since helium equilibrium will establish itself almost immediately. In short, don't worry about the chamber volume.



Surface Area

The figure shows a typical pumpdown curve that follows the pressure reduction in a system vs. pumping time. The pumpdown through the pressure regime where volume gas obtains is either a straight line or close to it. Then, as the pressure drops lower, it appears that the pressure reduction rate hits a wall and slows up markedly. The pumpdown process has literally hit a wall in terms of the source of the predominant gas load. As the volume gas is pumped away, the water molecules that have been loosely bound to the chamber's inner surfaces are slowly desorbing. This gas load is called *surface gas or wall gas.* These water molecules are now not only predominant in the residual gas makeup but are almost the entire gas load. The reduction in pumpdown rate is due to the fact that these polar molecules are held to the inner surfaces with weak bonds and they can only escape when they have absorbed enough energy to overcome those bonding forces. In the absence of directly applied desorption energy, the energy source will be thermal energy slowly absorbed from the chamber. This is a very slow and inefficient energy transfer process, but the water molecules cannot be pumped away until they desorb from the surfaces. Barring forced desorption by bakeout or UV treatment, the pumpdown will take as long as it takes to reach the pressure required by the process specs.

A simple increase in pumping speed will have a small but relatively minuscule effect on the pumpdown time. Since it is impossible to reach out and pull the molecules off the surfaces by adding pumping speed, the time penalty must be paid. Each and every square inch of internal surface area has a finite desorption rate for water vapor that slowly decreases as further pumping occurs. At some point in time, enough water will have desorbed and been pumped away to allow the pumps to achieve the pressure required by the process. The obvious connection, then, is to limit the total number of square inches of surface area within the chamber. The smaller the total surface area, the smaller the gas load from desorbing water molecules. All this adds up to the fact that the internal surface area is the important parameter when pressures below about 1 millitorr (microns) are required.

Chamber Design

Designing a chamber for a minimum of volume will not necessarily ensure that the chamber also has a minimum surface area. For example, a cube and a sphere of equal volume will have very different surface areas. Additionally, most processes require at least some internal arrays that will have their own total surface areas. These will add the same desorption rates per square whatever as the internal surfaces of the chamber. The actual effective surface area is also a function of the surfaces' finish. Consider the state of Colorado. It has a very convenient shape to calculate the total geographic area, but when the Rocky Mountains are added into the equation, the surface area goes up significantly. The same applies to the chamber's total internal surfaces. A polished surface will desorb much less than a rough surface due to internal total surface area.

The whole secret of improving and understanding pumpdown time lies with the gas loads. Whenever possible, gas loads should be reduced or kept to a minimum.

From The Vacuum Lab of Phil Danielson, 630-983-2674
pdanielson@vacuumlab.com www.vacuumlab.com