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From THE VACUUM LAB

By Phil Danielson

Dry Gas Techniques for Reducing Water Vapor in Vacuum Systems

Anyone practicing vacuum technology will encounter pumpdown time or ultimate pressure problems resulting from the slow desorption of water vapor from the system's internal surfaces. Since these surfaces are exposed to water vapor in the air as humidity, some sorption of the water will occur whenever the system is opened to air. This is especially evident with batch systems or load locks that are frequently cycled between air and high vacuum. Although at least some surface sorption will occur any time the system is open, there are a number of techniques to reduce the amount of sorbed water before it becomes a major problem in the latter stages of the pumpdown process.

Dry Gas Release

If, when ready to bring a chamber back up to atmospheric pressure for reloading, the chamber is released with a dry gas such as nitrogen instead of ambient air, the rate of sorption of water vapor from the atmosphere will be slightly reduced. There is a common belief that the nitrogen will form a virtual barrier over the internal surfaces to block airborne water molecules from contacting the surfaces. When the system is opened for loading, the water molecules in the ambient air will very quickly diffuse through the nitrogen and begin to sorb on the surfaces. The rate of sorption, though, will be slightly reduced, so it is necessary to begin another pumpdown as quickly as possible. The total amount of water that is sorbed is directly proportional to the number of collisions of water molecules with the surfaces. The number of collisions is, in turn, proportional to the amount of water in the gas within the chamber and the time of exposure.

Although some reduction of water vapor sorption can be achieved with dry gas release, much greater effects can be realized by continually flushing the chamber with the same dry gas all the while the chamber is open. This dynamic flushing condition will greatly enhance the effect of barring water molecules due to the rate of flow of dry gas pouring out against the atmosphere. This entire technique will depend upon the opening-to-chamber volume ratio. For example, a box coater with a full opening door would require an extremely high wind of dry gas exiting the chamber to provide much effect.

More importantly, though, in most practical systems is that the dry gas release will fill virtual leak voids with dry gas, and this filling will help bar sorption when compared to allowing them to fill with water-bearing air. Subsequent pumpdown will only have the problem of removing a permanent gas from the voids instead of permanent gas plus desorbing water vapor.

Closed Chamber Flushing

Flushing a chamber with dry gas after it has been opened and then re-sealed prior to another pumpdown cycle can produce some practical removal of sorbed water vapor. When the chamber is open to air, the surfaces can sorb monolayers of water that are several hundred layers thick. The first layers that sorb will bond to the surfaces with the strongest bonds even though they are still relatively weak when compared to chemical bonds. As sorption continues, the bonds become weaker and the subsequent layers more and more disordered. These loosely bound upper layers are most often removed during the roughing cycle so that the total bed has been reduced from hundreds to tens of layers or less before a reduction in pumpdown time is apparent. Atmospheric pressure flushing will tend to remove the loosely bound layers by impact followed by entrainment into the overboard flow. The roughing cycle, which follows the flow cycle, can expose some of the more tightly bound desorbing layers.

Even greater effects can be seen if a hot gas is used instead of an ambient temperature gas. A heated gas flow will transfer some thermal energy to the sorbed water molecules and help them desorb by overcoming the weak binding energy. The desorbed water molecules are then easily entrained by the hot gas flow and will not be as liable to resorb as those desorbed by ambient temperature gas. Simple, clean, and non-particle producing gas heaters are available from a number of electric heater element manufacturers.

There are no fixed rules-of-thumb for either time or temperature for the best efficiency of flushing since each chamber and process is different. Performance testing is required in each and every case. Consider, though, that there will be little effect with times much under five minutes with either ambient temperature gas or much less than say 70^{o} C in the case of heated gas. The tradeoff in time saved during a pumpdown needs to be compared to the time and trouble involved in flushing to determine whether or not it would be an economical solution. Flushing can also have a downside in that it will help move already present particles around within the chamber and they can easily end up on the work.

Reduced Pressure Flow

One of the most effective dry gas flow means of desorbing sorbed water molecules is by flowing dry gas through the chamber at a reduced pressure. The idea here is to impart energy to the water molecules by impact with gas molecules. The mechanical energy of the impact gas needs to be sufficient to overcome the bonds binding water molecule to water molecule in the sorbed bed. The important part of this process is not only the ablation of water molecules from the surface of the sorbed bed, but the further need to entrain them in the flowing impact gas. This can only be done under very specific gas flow regime conditions. The mean free path of all the gases involved must be as long as possible, so this means a low pressure. Additionally, The maximum amount of flowing impact gas must be introduced into the chamber to maximize the number of impacts with the sorbed water vapor. The total gas flow must be such that actual entrainment of the desorbed water molecules will result without the total pressure being so high that the desorbed water molecules will impact other molecules in the chamber volume, lose energy, and resorb.

This combination of gas flow conditions can be generally met by pumping the chamber into the low pressure end of the viscous flow regime before adding any impact gas. In most cases, this would be in tens of torr. If the roughing pump is left open for full flow, then impact gas is added until a constant flow in and out of the chamber will maintain the target pressure. A common starting point would be to maintain the chamber at about 1-10 torr for 5-10 minutes for maximum effect. Argon is often used instead of nitrogen since it's a bigger molecule and is likely to have more kinetic energy upon impact. Also keep in mind that the impact gas will be cooled as it expands through the leak valve's orifice and into the chamber.

As in the previous techniques, actual tests need to be run in order to determine the maximum effectiveness of time and pressure for water desorption, and this will be borne out by pumpdown time to some lower pressure under varying desorption conditions.

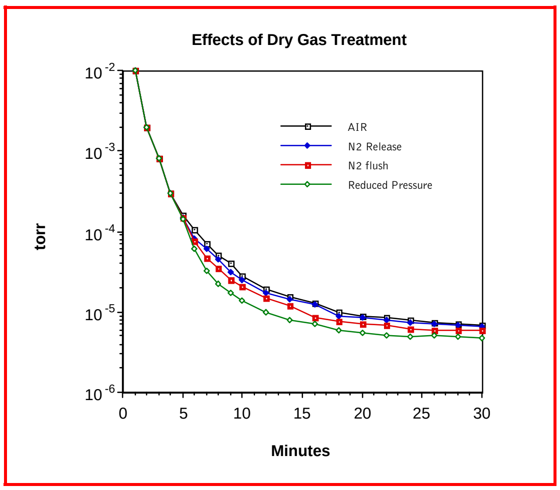

Figure and Conclusions

It must be realized that although these techniques are helpful, they do not reproduce the desorption, pumpdown time, and ultimate pressure results that can be obtained by forced desorption in the molecular flow regime by either bakeout or UV bombardment since these techniques will remove more, if not all, of the more tightly bound molecules in the sorbed bed.

The figure supplies the relative pumpdown performance expectations one might achieve under good-to-best conditions of the gas flow desorption techniques.

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