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How the Phototron Works

by Phil Danielson

Since water vapor is the dominant residual gas in most high vacuum systems; and coupled with the fact that it is an active gas that can interact with most processes, its full or partial removal becomes attractive and sometimes mandatory. Since the source of this residual water vapor is almost always the desorption of molecules from the inner surfaces of the vacuum chamber that were sorbed onto those surfaces while the system was up-to-air, it stands to reason that the removal of the water sorbed on the surfaces will remove it from the chamber's residual gases. The trick is removing it.

When a chamber is open to air, the water vapor in the air will sorb onto the inner surfaces. The first, or early, layers of water molecules will form into a highly ordered matrix bed; but as subsequent layers form, the bed will become more and more disordered. Due to the highly polar nature of the water molecule, the water molecules will cling together in the bed with the more disordered layers clinging together with weaker water-to-water bonds. Thus, there is a gradient of bonds that increase as you delve deeper and deeper into the bed.

This can be seen clearly in Figure 1 where an initially high desorption rate slowly drops with protracted pumping. Note that after hours of pumping, the desorption rate becomes lower and almost fixed. This indicates that you are now pumping on the more tightly bound layers following removal of the more weakly bound layers.

The desorption shown in Figure 1 can be called "natural" desorption in that thermal energy is slowly transferred from the chamber walls, through the bed of sorbed water, and into the innermost layers until enough energy is absorbed to overcome the energy of the weak bonds holding one water molecule to another and allowing the energized molecules to desorb into the chamber.

Externally applied heat has been used traditionally to speed desorption; but while effective, there are some drawbacks that must be taken into consideration in modern process systems. These would include thermal degradation of elastomer o-rings, extended heating and cooling times, and thermal expansion/contraction problems among others. A quick and controllable desorption method that didn't require or provide heat would have obvious attraction.

The Phototron easily fulfills these requirements. Since desorption requires energy of some sort to be transferred to the sorbed water molecules, the goal is to transfer as much energy as possible to the molecules to raise the

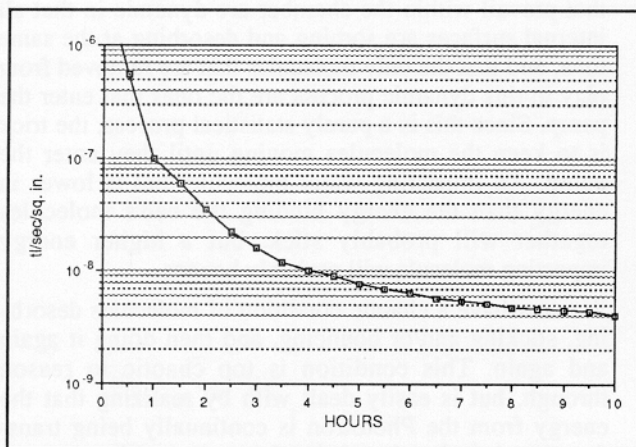


Figure 1. Natural Desorption Rate of Water.

desorption rate during the initial pumpdown to remove as much water as possible from the residual gases. The Phototron accomplishes this by transferring energy directly from a special UV bulb to the water molecules.

Consider spectroscopy where the property of specific molecules to absorb light at specific wavelengths is used as an analytical technique. Another example would be optical filtering where a specific filter material or window is used to absorb specific wavelengths of light. The Phototron uses a special bulb inserted into the vacuum chamber that provides an intense source of a specific wavelength in the UV band that is efficiently and effectively absorbed by water molecules.

When the Phototron is turned ON, the UV leaves the source (bulb) and is transferred through the vacuum directly to the water molecules. As the UV energy is absorbed by a water molecule, the energy level in the molecule rises until that energy level is higher than the energy binding that one molecule to another. At this point, the water molecule will desorb from the bed of sorbed water and enter the volume of the chamber.

In an oversimplified view, the water molecule will desorb, enter the chamber's volume, and be immediately pumped away. In reality, the situation is more complex. The molecule will leave the bed at an entirely random direction and move in a straight line since molecular flow conditions prevail and collision with another molecule is unlikely. This effect is shown in Figure 2.

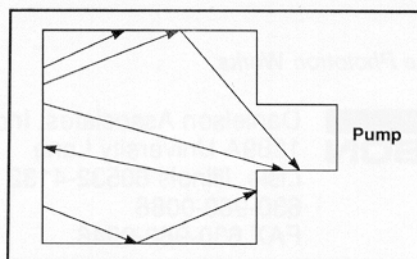


Figure 2. Desorbing Molecules in Play.

The desorbed molecule might enter the pump and be pumped away, or it might impact another surface within the chamber. If it impacts another surface, it might bounce, or it might then stick to the impacted surface.

Whether it sticks or not depends upon two things: the energy of the impacting molecule and the condition of the bed upon which it impacts.

At this point, we need to understand that the conditions that prevail within the chamber are dynamic in that all internal surfaces are sorbing and desorbing at the same time, and that the only molecules that are removed from play in this dynamic process are the ones that enter the pump. Since this is a purely statistical process, the trick is to keep the molecules moving until they enter the pump. An impacting water molecule that is lower in energy than the energy binding the bed's molecules together will probably stick, but a higher energy impacting molecule will probably bounce.

We now have a chaotic condition of molecules desorbing, sticking and/or bouncing, and then doing it again and again. This condition is too chaotic to reason through, but is easily dealt with by realizing that the energy from the Phototron is continually being transferred to the migrating molecules until they finally enter the pump. Energy is pumped into sticking molecules and into molecules in flight between surface impacts.

The chaotic conditions described above obtain in any case where water vapor is present in the chamber or on the inner surfaces. If we look at "natural" desorption, the only difference between it and Phototron induced desorption is that the total number of molecules in motion is greater when the Phototron is being used.

TRY THIS EXPERIMENT

A simple short term experiment will clarify understanding the need to keep molecules in motion until they wander into the pump.

If you take a system that is apparently at equilibrium and apply a torch to a single point, you'll get a sudden pressure burst, much like what you see in Figure 3. You've added enough thermal energy to a single small area to increase the desorption rate enough to increase the pressure three orders of magnitude in a few minutes. That's a lot of desorbed gas. If you then remove the torch, the pressure begins to fall off rapidly until it reaches the original equilibrium pressure you had before applying heat.

The first thought is that the pressure should re-equilibrate to a lower pressure, but it didn't. Where did the gas go? Wasn't it pumped away once you desorbed it?

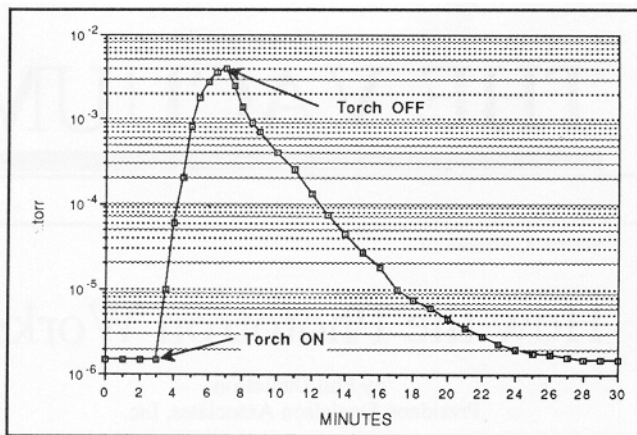


Figure 3. Spot Desorption with Torch

Obviously not. Only a miniscule amount was pumped away, and that amount was too small to show up in the post-experiment pressure reading. Where did it go then?

It went to other parts of the chamber, and a large part of it stuck. Additionally, a lot more of it re-equilibrated on the small clean surface you created by applying heat with the torch. The clean surface acted like a temporary pump until it was again saturated with water vapor. All you did was to move it around a little within the chamber temporarily; and then, as the constant motion of the water molecules within the chamber continued, it spread itself evenly over all of the internal surfaces.

THE PHOTOTRON'S FUNCTION

Obviously, the only way to achieve a permanent reduction of water vapor is to continuously desorb the water vapor from the entire chamber until it has been pumped away. This is exactly what the Phototron does. It stimulates an increased desorption rate and keeps the desorbed molecules at an enhanced energy state whether they are in flight or temporarily sorbed on a surface. This, then, gives us water molecules in three conditions of existence:

1. Still residing in a sorbed condition in the initial bed,
2. Transient molecules in an energetic state re-sorbed loosely on the initial bed, and
3. Molecules in play within the chamber at a condition of enhanced energy.

By keeping the water molecules, once desorbed, in an energetic condition, the odds of their being pumped rise as they stay in play within the chamber more often than if they just desorbed and could only be pumped if they wandered into the pump in a single or double excursion through the chamber. As the pump continually draws down the population of energetic water molecules, the desorption rate of the initial bed drops until either further desorption is required to reach a new and lower desorption rate or an acceptable desorption rate is achieved.

DANIELSON Danielson Vacuum Products, Inc.
1989A University Lane
Lisle, IL 60532-4156

Toll Free (U.S.A. & Canada)
1-877-9DANVAC (1-877-932-6822)
TEL 630-960-0086
FAX 630-960-0546
Email: sales@danvac.com
www.danvac.com