Water Desorption Pressure Relationship

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Note that all references to The Phototron have been replaced with The UVB-100. Otherwise this article is unchanged.

by Phil Danielson

Desorption of the water vapor sorbed onto the inner surfaces of a vacuum system will spontaneously occur during the entire pumpdown process. At relatively high pressures (above 1 torr) the desorption rate will be fairly low, but it will increase slowly as the pressure drops (below 1 torr). Below 100 millitorr, it will increase greatly as the pressure in the system drops into molecular flow conditions. At these pressures, the amount of water vapor in the system will be the predominant gas species. The water vapor will remain the predominant species until the system has been pumped on long enough for the layers of water on the surfaces to erode down to more tightly bound layers where a relatively low desorption rate results. Alternatively, the sorbed water can be subjected to energy input that excites it and increases the desorption rate such that low rates result more quickly. The UV energy from UVB-100 excitation is an efficient method of reducing the amount of water in the residual gases. Operating a UVB-100 to maximize efficiency will result in quicker pumpdowns.

Pressure Relationships

Viscous Flow

The UV energy from the UVB-100 will not result in increased water vapor desorption unless the energy is able to reach the sorbed water molecules in order to energize them. In most cases in practical vacuum systems, energy scattering in the residual gases will stop the UV from reaching the walls. The power is essentially dissipated before it can reach the walls. Around 1 torr or so, the UV will begin to reach the walls. At this point, the desorption efficiency is fairly low, but several mechanisms are occurring that result in a mutually efficient means of water vapor desorption/removal.

Desorbing the water from the walls is useless unless it can be removed from the chamber after it is desorbed. If it is not removed, it will resorb as soon as it impacts onto another sorption site. Obviously, it has to be pumped away. If the UVB-100 is operated during the roughing cycle, it will add to the desorption rate of the water at viscous flow conditions.
As the air is being swept out of the chamber by the roughing pump, water is desorbed by residual gas molecules impacting the walls and transferring mechanical energy to the sorbed water molecules, as shown in Figure
1. This can be viewed as almost a physical erosion process. Once loose in the chamber, the water molecules might impact onto another sorption site and stick again or be pumped away by the roughing pump. At viscous flow pressures where the residual gases behave like fluids, the desorbed water molecule is most likely to be entrained in the flow of gases being pumped much like a windborne particle, as shown in Figure 2. The addition of the UVB-100's UV energy will then add to the already occurring desorption with the additional benefit of efficient removal from the chamber.

Molecular Flow

Since molecular flow is defined as a condition where a residual gas molecule is more likely to impact the chamber wall rather than another molecule, the behavior of a desorbed water molecule in the chamber will differ from its behavior under viscous flow conditions. Once desorbed, it will either find another sorption site or be pumped away by the high vacuum pump, as shown in Figure 3. Since there is only a small statistical chance of the molecule being pumped following desorption, it will most likely impact the chamber wall and resorb. It will then be re-desorbed and re-sorbed continually until it is finally pumped. Although the chances of resorbing are lower if the walls are hot (thermal bakeout) or under constant energy bombardment (UVB-100 UV), the resorption process will still occur to some extent. Accordingly, the amount of water removed from the system during the roughing cycle at viscous flow will be water that doesn't need to be desorbed and pumped away by the high vacuum pump under molecular flow conditions.

Pumpdown Performance

Figure 4 shows a series of pumpdown performance curves of the same system under varying conditions of UVB-100 treatment. It must be remembered that desorption of the water will occur with no additional treatment of any kind, but that UVB-100 treatment is used to increase the desorption efficiency and provide faster pumpdown.
When the UVB-100 is turned on at high pressure, the desorption efficiency will increase as the pressure drops due to less energy loss in the rapidly decreasing residual gases. At high pressure (just below 1 torr), the lower efficiency of desorption is countered by the increased efficiency of water removal from the chamber due to its being entrained in the viscous gas flow into the roughing pump. As entrainment decreases due to pressure drop in the residual gases, the efficiency of desorption increases due to more energy reaching the sorbed water. Hence, the efficiency tradeoff tends to balance during the entire roughing cycle.
The more efficient desorption that occurs when the UVB-100 is turned on at a lower pressure (molecular flow) is counter-balanced by the fact that the water will sorb and desorb continually as described above. As Figure *4* shows, the best total pumpdown performance will be achieved

when the UVB-100 is turned on during the roughing cycle and continued into part of the high vacuum cycle.

Desorption Rate

Under any circumstances, the desorption rate of the water vapor from the system's walls will vary due to how much water vapor has been removed already. The polar nature of the water molecule provides very weak bonds between the layers of water molecules. As the layers of water build up on the inner surfaces while the system is up to air, the bonds become weaker and weaker with each layer that builds up. This means that the desorption rate of the outer (vacuum side) layers will be higher than the lower layers due to the difference in bond strength between the molecules. The outer layers are disordered physically and are bound more loosely than the lower layers so the outer layers will quickly desorb during the energy transfer conditions that occur during the roughing cycle. The more tightly bound layers must be exposed before the full efficiency of the UV from the UVB-100 can become effective, and lower pressures are required before the full energy can reach the walls.

Practical Operation

Each UVB-100 power supply is provided with a remote ON/OFF input that allows the UVB-100 to be turned on from an additional control device. The process control output of a vacuum gauge can be easily used to turn the UVB-100 ON at about 1 torr. Additionally, the UVB-100 can be turned OFF by a gauge when a pre-determined desorption level is reached as indicated by the total pressure in the chamber. In many (most) cases, the UVB-100 can be simply turned ON when the roughing cycle starts, and the control unit's timer used to turn the UVB-100 OFF at a pre-determined time.

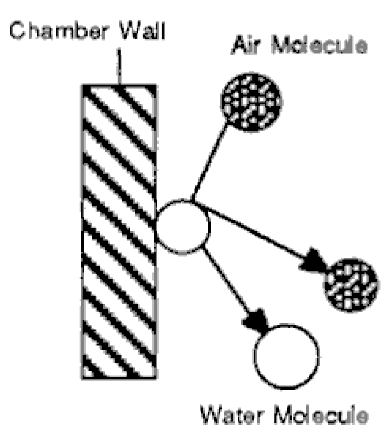

Figure 1 . Water Desorption by Impact with Air Molecule

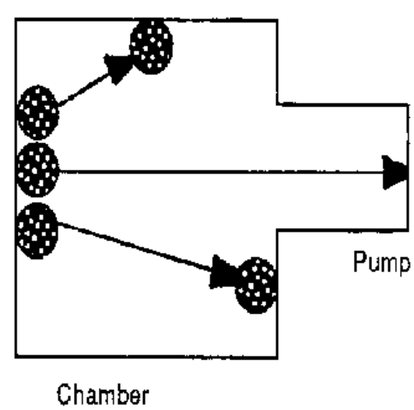

Figure 2. Track of Desorbing Water Molecules

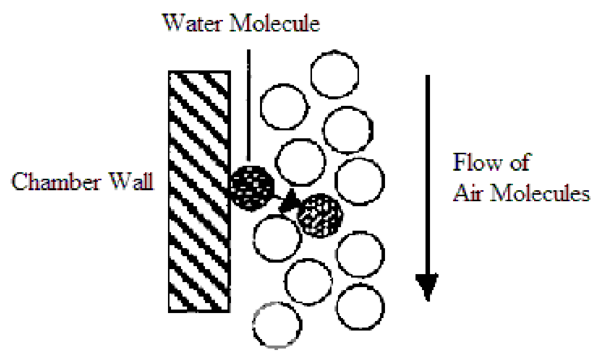

Figure 3. Desorbing Water Molecule Being Entrained in Flow of Air Molecules

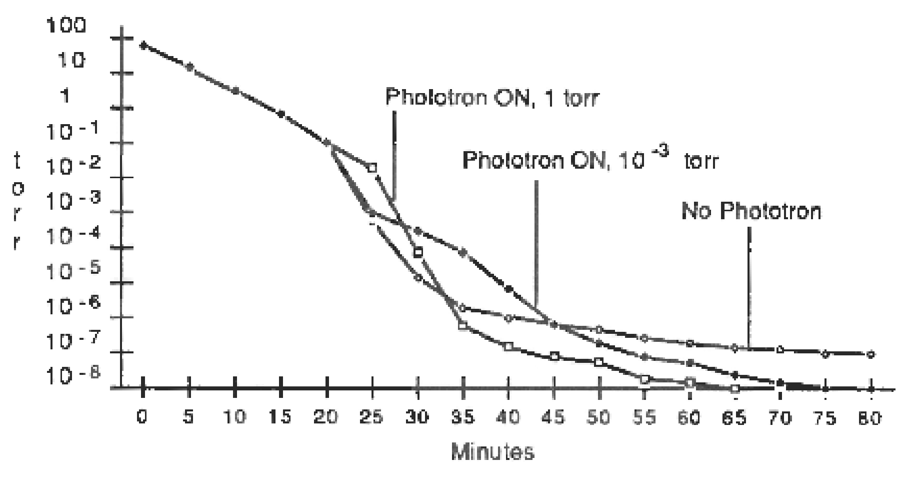

Figure 4. Pumpdown Performance Curves of Same System under Varying Conditions of UVB-100 Treatment.