

# THE VACUUM CHRONICLES

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## The Phototron<sup>™</sup> and Residual Gas Composition

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Although the Phototron is primarily a device for desorbing water vapor, it is often possible to reduce the partial pressures of the other residual gases commonly found in vacuum systems as well as the water. The key to understanding the behavior of residual gases within a chamber is to understand the points of origin of those residual gases. In this case, we need to consider the matrix bed of water vapor that forms on all of the inner surfaces when the vacuum chamber is exposed to ambient air.

### WATER BED FORMATION

When a vacuum chamber has reached its ultimate vacuum levels, the inner surfaces will probably be still coated with at least a few monolayers of sorbed water vapor but the thickness of the bed will be hundreds of monolayers thinner than it was at the start of the pumpdown cycle. This is likely to be true to some variable extent whether it is a high vacuum system or an ultrahigh vacuum system, since a surface that is totally clean of sorbed water is seldom to be found.

As the system is let up to air or exposed to air, the water vapor making up the air's humidity will begin to make random molecular impacts with the system's inner surfaces. The polar nature of the water molecule allows the molecules to bond together with weak bonds. As the time that the chamber is exposed to air increases, the number of random water molecule to water molecule impacts also increases; and as these impacts continue, the resulting bed of weakly bonded water molecules continues to thicken. Even with only a few minutes exposure, bed thicknesses of several hundred monolayers are common. As the thickness of the bed increases, the monolayers become more and more disordered causing variations in water to water bond strength.

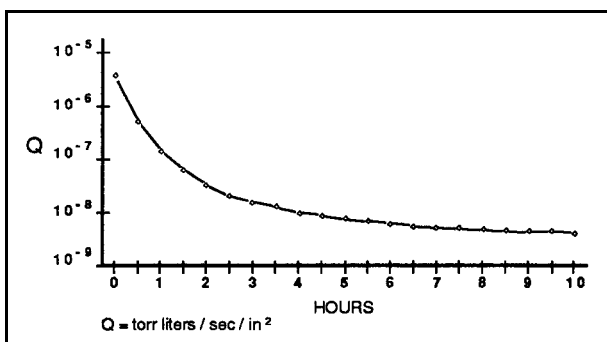


Figure 1. Natural Desorption Rate of Water Vapor without Phototron Treatment.

### BOND STRENGTH IN THE WATER BED

The bonds between the system's actual walls and the first several monolayers are the strongest to be found in the bed. These conditions prevail whether the material is metal, glass, or ceramic. This is why a surface that is completely clean of sorbed water vapor is so rare in working vacuum systems. These initial layers are highly ordered, and the subsequent water-to-water bonds formed are also highly ordered which results in relatively strong bonds. As more and more monolayers are formed, the order begins to fail and disorder increases continuously to the surface of the bed. As the disorder increases, bond strengths become lower and lower.

The gradient in water-to-water bond strength through the bed is evidenced by the desorption rate of water from the inner surfaces during a pumpdown. The desorption rate shown in Figure 1 indicates an initial high desorption rate that steadily decreases with time. Desorption occurs as enough thermal energy penetrates through the bed to the bed's inner surfaces where the water molecules absorb enough energy to overcome the energy of the weak bonds holding them to the bed.

As each molecule desorbs, it takes its desorption energy with it and more energy is required to desorb the next monolayer. As the bed erodes, the bonds become ever stronger and more energy and time to transfer that energy are required for further desorption. Desorption rates, then, can only be increased by somehow getting more energy to the sorbed molecules so they can overcome their bonding energy. Heat applied by bakeout or ultraviolet light from a Phototron will apply this energy.

### THE WATER BED AS A MATRIX TRAP

As the water bed forms from continuous impacts of water molecules in the air (Figure 2), the other gases present in the air also impact the forming bed. Some of these molecules will stick to the bed for a short time; and as the water continues to deposit, a number of these molecules will become trapped in the forming water molecule matrix. This will be true of the gases normally thought of as making up air such as nitrogen, oxygen, carbon dioxide, etc. Additionally, any "foreign" gases such as hydrocarbons that are present in the air will also be trapped in the matrices of water. These non-water molecules will be literally "plastered over" and will be present in the water bed as the system is pumped down again.

### RESIDUAL GASES DURING PUMPDOWN

It's generally accepted that the residual gases within a vacuum system are dominated by water vapor below, say, 10<sup>-4</sup> torr, and that water vapor is the gas to be most concerned about at these

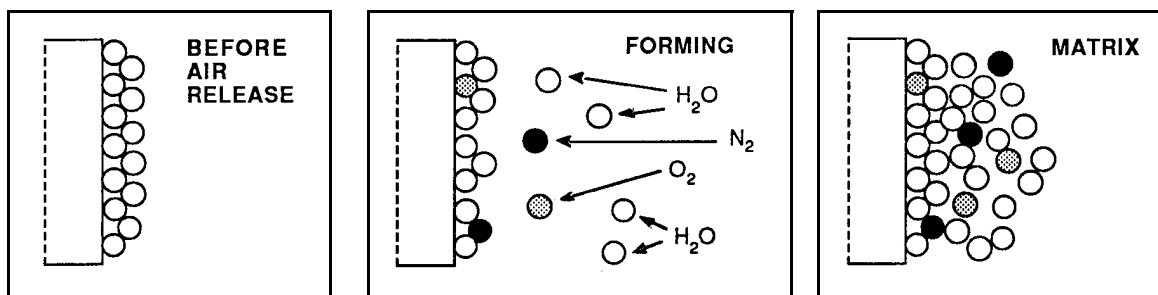


Figure 2. Water Matrix Trapping Gases.

pressures. This is, of course, true; but we must also consider that small amounts of the various air gases remain in the residual gas makeup. These components are often missed in an RGA spectra because they are so much smaller in magnitude than the water peak that they don't show up when the RGA sensitivity is adjusted to keep the water peak on scale.

Obviously, these gases are still within the chamber, but it is difficult to understand why they haven't been completely removed from the chamber. They are permanent gases, so they'll remain in the gas phase where they are available to be pumped by the same pumps that have already pumped away larger quantities of these same gases. They should be entirely gone unless there is some other source of these gases within the chamber.

If the slopes of the various gas concentrations including water are carefully plotted, it can be seen that they are essentially parallel in most cases. It becomes impossible to rationalize a relationship between water vapor that is slowly desorbing from the internal surfaces and air residuals that just happen to be still bouncing around within the chamber.

The parallel relationship becomes clear, however, when we realize that the low levels of the air gases are actually emanating from the water bed. As the water desorbs, the entrapped gases are released from the matrix so that all the gases tend to be in proportional levels. As the desorption rate of the water becomes lower and lower due to the increasingly strong water bonds, the amount of other gases released from the matrix becomes lower as well. As long as any substantial amount of water remains on the surfaces, the other gases will slowly desorb along with the water. When Phototron treatment is used to lower the levels of water vapor in the residual gases

by forcing enhanced desorption from the inner surfaces, it is common to find that lower levels of the other gases are also present after treatment. Typical results are shown in Table 1.

|              | H <sub>2</sub><br>2 | H <sub>2</sub> O<br>18 | CO/N <sub>2</sub><br>28 | O <sub>2</sub><br>32 |
|--------------|---------------------|------------------------|-------------------------|----------------------|
| No Phototron | 3x10 <sup>-8</sup>  | 5x10 <sup>-8</sup>     | 5x10 <sup>-9</sup>      | 4x10 <sup>-8</sup>   |
| Phototron    | 8x10 <sup>-10</sup> | 7x10 <sup>-9</sup>     | 6x10 <sup>-10</sup>     | 4x10 <sup>-10</sup>  |
|              | torr                |                        |                         |                      |

Table 1. MRC Eclipse Machine at Ultimate Pressure.

## CONCLUSIONS

Phototron treatment can be used to lower the levels of other gases in the chamber even though the Phototron's UV wavelengths are not specific to any gas other than water vapor. Low levels of these gases cannot be attained unless a large portion of the water bed is removed by Phototron treatment, bakeout, or extended pumping.

This is a simplified view of a single phenomenon that affects residual gas makeup. This is a complex subject that includes a number of other phenomena such as chemical reactions on hot filaments, etc., but it can be taken as a working technique to help understand the processes that occur within vacuum systems.

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