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Pumping Desorbed Water

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Although UV radiation from a Phototron has proven to be an effective technique for desorbing water from the inner surfaces of a vacuum system in order to achieve quicker pumpdown cycles or lower ultimate pressures, the desorbed water vapor must be effectively removed from the system to realize any advantage from the Phototron technique. The type of high vacuum pump and its speed/throughput performance parameters must be carefully considered if the maximum benefits of Phototron treatment is to be expected.

PUMPING SPEED CONSIDERATIONS

Pumping speed requirements must be considered in a multi-role fashion. When the high vacuum pump is put into operation by turning on or valving in, it will see a high gas load that it is required to meet. As it meets that gas load, the pressure will drop since it is probably pumping away "volume" gas which is atmospheric gas remaining after the roughing cycle. When this gas load has been removed, the pump is expected to remove the "wall" gas which is usually water vapor desorbing from the inner surfaces.

The pump, then, is expected to meet and overcome a dynamic gas load, but also to meet a relatively static gas load that only changes very slowly. This expectation can be described as being able to pump a chamber down and maintain a low pressure. Addi-tionally, the pump must be able to handle gas loads that arise from process requirements. Examples might be additional desorption under thermal conditions or gas loads from hot filaments.

Since the predominant gas in the residual gases is water vapor for an untreated system under high vacuum, the pumpdown performance of the system will depend upon the pumping of the water vapor. Under untreated conditions, the desorption rate of the water molecules from the inner surfaces of the system will follow the curve shown in Figure 1. The desorption rate becomes lower with time as the system is pumped upon. Barring large numbers of virtual leaks or porous materials, the water vapor load in the system is entirely from surface desorption. Increasing the desorption rate temporarily can result in quicker pumpdowns or lower ultimates, but enough pumping speed must be available.

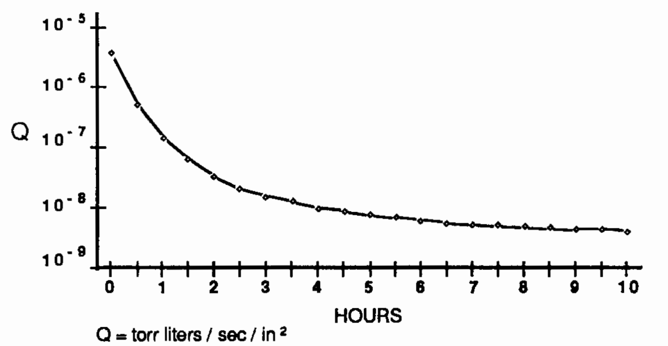

Figure 1. Water Desorption Rate

TOO MUCH PUMPING SPEED

The condition of having a higher pumping speed than is required is a non-problem problem. The required pumping speed to match the desorption load can be calculated by:

Q=SP
Gas Load = Pumping Speed x Pressure
torr liters/sec. = liters/second x torr

This formula can be used to calculate the pressure that will be produced with a given pumping speed at any point in time on the desorption rate curve. A higher pumping speed will produce a lower pressure within the chamber, but will not reduce the desorption rate of the water vapor. This means that the total number of water molecules traversing the volume of the chamber will be the same regardless of total pressure readings or pumping speed. The process being carried out in the chamber will be exposed to those molecules. The only way to reduce the number of molecules exposed to the process is to reduce the desorption rate. The only ways to reduce the desorption rate is to continue to pump on the water layers long enough for the desorption rate to drop or to temporarily raise the desorption rate to remove the required amount of water vapor quicker. If the desorption rate is raised, adequate pumping speed to remove the desorbed water must be available.

TOO LITTLE PUMPING SPEED

If the available pumping speed is too low, the desorbed water will not be removed quickly enough from the chamber. Desorbed water vapor that is not pumped away at the same rate it desorbs will bounce around within the chamber until it finds another sorption site where it will resorb. This condition can be considered to be a pseudo-equilibrium that is pumping speed controlled. If the pumping speed is too low to remove the water when the desorption rate is high early in the pumpdown cycle, the subsequent pumpdown will require much more time than it would if adequate pumping speed were available. In such cases, it is relatively futile to attempt to increase the desorption rate temporarily since the desorbed water could not be removed at the rate at which it is being desorbed.

PREDICTING PUMPDOWN PERFORMANCE

The prediction of actual pumpdown performance can be very tricky in that the number of variables and unknowns can be very large. For example, it is possible to calculate the amount of surface area of the inside of a chamber in the geographical sense, but it is almost impossible to calculate the topographical surface area since the actual roughness, porosity, etc. will have a very large effect on the "real" surface area. Since the rates for water desorption shown in Figure 1 are "averages," actual rates can vary wildly. It is much more reasonable to base predictions on comparative known or measured performances.

If a leak tight system is pumped down to a constant (equilibrium) pressure, the gas load (Q) can be easily calculated since pumping speed and pressure are known. The measured desorption rate/sq. in. can then be compared with the rate shown in Fig. 1. For example, if it is higher; a higher wattage of Phototron UV would be recommended than that for an equal calculated surface area.

PUMPING SPEED REQUIREMENTS

The pumping speed required to efficiently deal with the gas load (Q) encountered when using a Phototron with a recommended wattage of 2.5 mw/sq. in. can be easily calculated by assuming that the gas load will be approximately one order of magnitude higher than shown in Figure 1 at equivalent time periods. For example:

Untreated $Q=6 \times 10^{-6}$ *torr liters/sec./sq. in.*
$Q=SP$
$6 \times 10^{-6}=S \times 10^{-5}$ *torr*
$S= 0.6$ *l/sec./ sq. in. to handle the untreated desorption load*

But,

Phototron treated $Q= 6 \times 10^{-5}$ *torr liters/sec./sq. in.*
$Q = SP$
$6 \times 10^{-5}= S \times 10^{-5}$ *torr*
$S=6$ *l/sec./sq. in. to handle Phototron induced desorption load*

PUMP TYPE CONSIDERATIONS

CRYOPUMPS

Cryopumps are a prime example the "too much" speed. In most installations, they have higher water pumping speeds than the desorption rate of the system at equilibrium. This means that they have more speed and throughput than they are able to use in an untreated system. They are then easily able to handle the higher gas load from Phototron induced desorption of water vapor. In practical experience, the speeds are so high that little pressure rise will be noted when the usually recommended UV wattage of 2.5 mw/sq. in. is used since they are easily able to meet the additional gas loads. Higher wattages can often be used with cryopumps.

DIFFUSION PUMPS

Diffusion pumps are easily able to handle the high gas loads generated by Phototron treatment. This is especially true for pumps that are trapped with liquid nitrogen-cooled baffles. The surfaces of the trap that are at liquid nitrogen temperature provide extremely high water pumping speeds. 100 l/sec./sq. in. is a good rule of thumb.

TURBOMOLECULAR PUMPS

Turbos are usually able to handle the high gas loads, but they present a particular application problem that must be dealt with. A turbo of any size has an extremely high internal surface area due to the many stages of rotor and stator they contain. Large water loads can easily, and often, result in sorption of the water vapor entering the pump onto these surfaces. This results in a condition resembling that of the internal surfaces of the system prior to Phototron desorption. As the system approaches equilibrium following desorption, some of the water vapor will begin to desorb from the inside of the turbo. Some of the water will be pumped away, and some of the water will re-enter the chamber. In some cases, there seems to be no improvement of ultimate pressure following Phototron treatment. This potential problem can be easily dealt with by warming the first few stages of the turbo during desorption. This warming will keep the water from sorbing on the surfaces of the pump. Warming can be easily accomplished with a heating tape on the pump throat or by using the bakeout heater commonly sold by the turbo's manufacturer.

TRIBODYN PUMPS

Tribodyn pumps behave much the same as turbos when pumping large amounts of water vapor. In some cases they are not able to reach their usual ultimate of 1 to 2 x 10^{-6} torr following the pumping of large amounts of water vapor due to their low (as compared to a turbo) pumping speed at low pressures. This potential problem can be dealt with by heating as described for turbos. A special configuration of Tribodyn is available for pumping large water loads where the Tribodyn's lowest ultimate is necessary. The molecular drag module is remotely mounted directly to the chamber and the throat is heated. All Tribodyn models are available in this configuration and are referred to as the "W" (water) option.

SPUTTER-ION PUMPS

These pumps have several potential problems. Because they are low throughput pumps with lower pumping speeds at high pressure, they can often be overwhelmed with gas load when used with a Phototron. Lower wattages than the normal 2.5 mw/sq. in. can be used to limit desorption rate, or short ON/OFF cycles can be applied early in the desorption cycle until pressures are low enough for them to reach their highest pumping speed.

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