

# THE VACUUM CHRONICLES

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## Load Lock to Chamber Water Transfer

### Part 1: The Problem

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As load locks continue to proliferate in modern process applications, and concerns about the presence of water vapor in process chambers become more prevalent; the next step in tracking water vapor is to evaluate its transfer from the load lock into the chamber. Whether the work comes from the load lock directly into the process chamber or whether it first goes into a transfer chamber in a cluster tool, water vapor can be introduced on the surface of the work. This, in turn, can lead to a complex series of transfer of water vapor from surface to surface throughout the process chamber(s) and the process itself.

### THE LOAD LOCK

When work is placed in the load lock, it is likely to have its surfaces saturated with sorbed water vapor. Even though the load lock might be pumped down to a low enough pressure<sup>1,2</sup> before the work is cycled into the next chamber, most of that sorbed water will still be on the work's surfaces.

When the load lock is opened to air for reloading, the lock's internal surfaces will become covered with sorbed water vapor. When the pumpdown commences, some of the sorbed water will leave the work's surfaces and some of the sorbed water will leave the lock's surfaces. A small percentage of the desorbing water vapor molecules will be pumped away, but most of them will impact any and all of the surfaces within the load lock; and most of those molecules will stick, at least, temporarily to be desorbed later.<sup>3,4</sup>

In most applications, the load lock will be pumped down to some pre-selected ultimate pressure as quickly as possible, and this will probably mean relatively large pumps. A quick as possible pumpdown time will be reflected in pumping time measured in minutes and not hours. Figure 1 shows the desorption rate of water vapor in both  $\text{tl/sec/in}^2$  and numbers of molecules/ $\text{sec/in}^2$  with time, and you can easily see that all of the surfaces will still be desorbing heavily within a pumpdown period of 1/2-1 hour.

The total pressure might be low enough within the load lock to allow the valve to be opened between the load lock and the chamber at this point, but the work will still be desorbing<sup>5</sup>, and additional water pumping speed won't help enough to matter much in a practical sense.

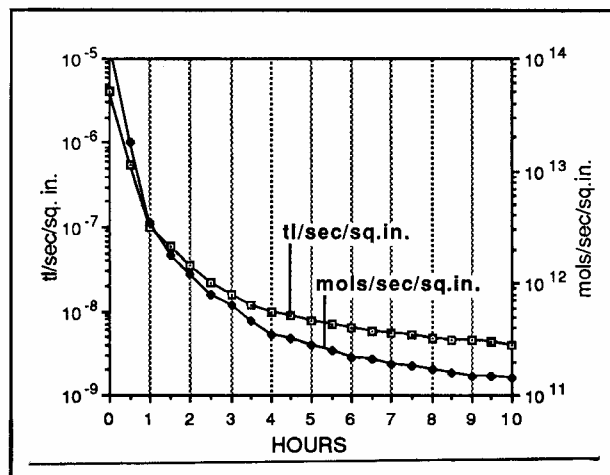


Figure 1. Natural Desorption Rate of Water.

The surfaces will still be desorbing at whatever rate is shown in Figure 1 for that pumping time.

For example; if the pumpdown took about 1/2 hour, the work would be desorbing water vapor at a rate of about  $5 \times 10^{-7}$  torr liters/sec./ $\text{in}^2$  or  $2 \times 10^{13}$  molecules/sec./ $\text{in}^2$ , and this would mean that this desorption rate would be introduced into the process or transfer chamber if the lock were to be cycled at this point.

### CYCLING THE LOCK

When the fresh work is cycled into the chamber, the molecules desorbing from the work's surface will instantly begin the spread through the chamber. The quasi-equilibrium that had previously existed between the chamber's walls and the pump will be disturbed until a new condition is reached. That condition might or might not be a quasi-equilibrium. This will depend on the chamber itself and the amount of time the newly inserted work is within the chamber.

### THE CHAMBER

If the chamber is at a pressure of  $1 \times 10^{-7}$  torr prior to introduction of the work, the internal surfaces will be desorbing water vapor. Using the molecular method,<sup>6</sup> we can see on Figure 2 that the surfaces are also being impacted with  $7 \times 10^{13}$  molecules/sec./ $\text{in}^2$ , and this means that any additional surface will receive molecular impacts at the same rate. This establishes a molecular accounting of:

1. Molecules leaving the introduced surface =  $2 \times 10^{13}$  molecules/sec./in<sup>2</sup>, and
2. Molecules impacting the introduced surface =  $7 \times 10^{13}$  molecules/sec./in<sup>2</sup>.

This accounting of molecules leaving and impacting means that the surface of the introduced work is not going to change over the short term. When the process begins or the surface is subsequently transferred into a process chamber, the amount of water on the work's surface will be about the same as when it left the load lock.

By looking at the accounting presented above, we can also see the interaction of the surfaces and the amount of molecules within the chamber. This condition is occurring all the time with the only changes being the amount of molecules being removed by the pump and the amount of new molecules introduced from the new surfaces being brought into the chamber. The condition of the fresh surface, however, is only one part of the story.

Although there is a large and constant total flux of molecules from the chamber's internal surfaces, the desorption rate per square inch is much lower than that of the new surface. This means that the chamber's surfaces will acquire many of the new water vapor molecules and the total desorption rate of the chamber will rise.

As the chamber's desorption rate rises, there will be a small increase in the partial pressure of water vapor within the chamber. Some of the new water will stick on the walls and some of it will be pumped away. Consequently, the partial pressure rise will not be dramatic or even noticeable at this point. It is always tempting to assume that no changes are occurring if the pressure doesn't rise and seems to be "pumped down all the way." Although the pressure increase will appear to be small, the enrichment of the sorbed water bed on the chamber's walls will provide an increase in desorption rate that is proportional to the amount of water introduced.

Figure 2 shows the increase in the number of impacts that will occur as the pressure rises only slightly. Over time, the number of impacts will rise dramatically even though it might not be readily apparent based on the pressure measurement alone.

The amount of water build-up on the chamber's surfaces will be dependent upon the total surface area of the chamber, the surface area of the work being introduced,

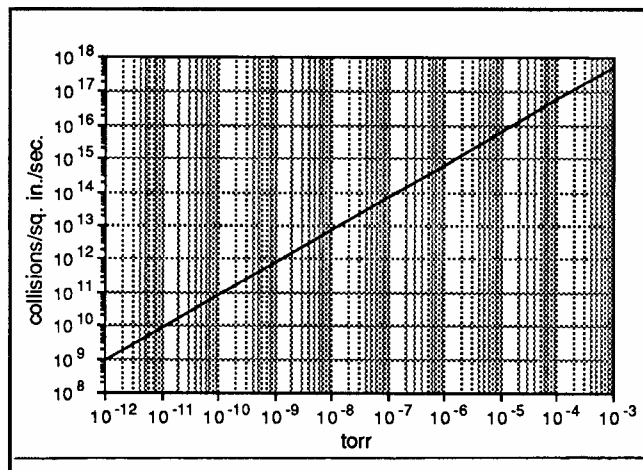


Figure 2. Molecular collisions/sec./in<sup>2</sup> vs Pressure

and the exposure time within the chamber. The pumping speed will not be all that important,<sup>5</sup> assuming that it is already adequate to produce an acceptable ultimate pressure within the chamber.

## SOLUTIONS

There are only two possibilities in attempting to reduce the amount of water on the work and on the chamber:

1. Extended pumping/desorption times, or
2. Energy applied to the surfaces to manage desorption rates.

Since pumping/desorption time is often fixed by the system's production throughput rate, energy application is often the only workable solution.

## REFERENCES

- 1 "Understanding Load Locks, Part 1," *The Vacuum Chronicles*, Volume 1, Number 11
- 2 "Understanding Load Locks, Part 2," *The Vacuum Chronicles*, Volume 1, Number 12
- 3 "Understanding Water Desorption," *The Vacuum Chronicles*, Volume 4, Number 12
- 4 "Sources of Water Vapor in Vacuum Systems," *The Vacuum Chronicles*, Volume 4, Number 8
- 5 "Critical Pumping Speed and Water Vapor in Production Systems," *The Vacuum Chronicles*, Volume 4, Number 9
- 6 "The Molecular Method for Understanding Vacuum Technology," *The Vacuum Chronicles*, Special Edition, 1996