

THE VACUUM CHRONICLES

Volume 4, Number 8

Sources of Water Vapor in Vacuum Systems

by Phil Danielson

Although it's generally accepted that water vapor is the dominant residual gas in most vacuum systems at pressures in the 10^{-4} torr range or below, little thought is often given to how it got there, how much did you start with, and how to control it. You'll often hear vague comments like "humidity," or "it's been up-to-air for a while," but although both of these comments are true, it's not all that hard to be more precise about it.

ATMOSPHERIC AIR

Water vapor is most commonly introduced to a vacuum chamber when it's let up-to-air to change workloads or some such operation. Since all atmospheric air contains at least some water vapor, there will be some water vapor entering your chamber with whatever percentage of water is present. The amount of water vapor (humidity) in the air is usually expressed in % relative humidity (%rh). Figure 1, which shows the partial pressure of water vapor in torr vs % relative humidity at 20°C, puts the units more in line with vacuum thinking and units.

When you see the amount of water vapor in torr, you can begin to really appreciate the amount of water involved. In a subsequent pumpdown, however, we aren't as interested in the remaining amount of water vapor that is in the gas filling the chamber as we are the amount of water vapor clinging to the chamber's internal surfaces.

The source of the water vapor we earlier referred to at pressures of 10^{-4} torr and below is water molecules slowly and painfully desorbing from the internal surfaces.

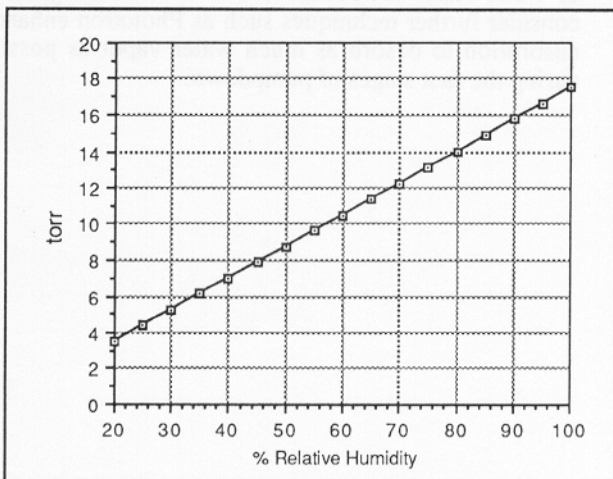


Figure 1. Partial Pressure of Water Vapor vs Relative Humidity.

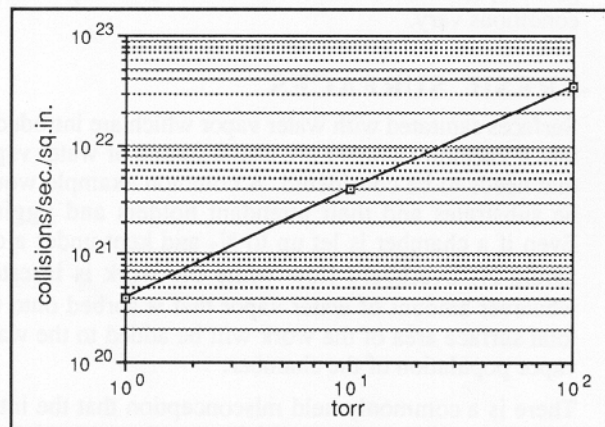


Figure 2. Water Vapor/Wall Impacts vs Atmospheric Partial Pressure.

When the system is let up-to-air, the water vapor in close contact to the internal surfaces will immediately stick to the newly exposed clean surfaces. Then, as the gas molecules move in their continual molecular motion, more water molecules will impact the surfaces and a multi-layer matrix bed of sorbed water molecules will form and continue to become thicker as long as water molecules are available for sorption and the system is exposed to atmospheric air.

Since the water molecules have to impact a surface before they can be sorbed, it's useful to consider the number of impacts that might occur while you've got your system up-to-air.

If you look at Figure 2, you'll see the number of water molecule impacts/sec./in.² that are likely to occur at whatever partial pressure of water vapor is in the atmosphere at that time. If you look at Figure 1, and know the relative humidity, you can see the partial pressure of water vapor. Then, on Figure 2, you can read the number of collisions which you can multiply by the total square inches of internal surface area and the number of seconds of exposure.

For example: If you let a 1,000 in.² chamber up to air for 10 minutes at 50% relative humidity, you can easily figure out the total number of collisions.

1. Figure 1 says that 50% relative humidity is 8.75 torr partial pressure of water vapor.
2. Figure 2 says that 8.75 torr will impact a square inch 3.5×10^{21} times in a second.
3. 1,000 in.² will be impacted $1,000 \times 3.5 \times 10^{21} = 3.5 \times 10^{24}$ times/second
4. 10 minutes is 600 seconds, so 3.5×10^{24} impacts/second \times 600 = 2.1×10^{27} total number of impacts.

This information, by itself, doesn't really tell you much. If, however, you compare a pumpdown curve under these conditions and then compare it to a curve under differing time or humidity conditions; you can begin to relate them to each other in terms of total number of impacts. These numbers, useful as they are, can only be used in a relative sense. There are just too many critical variables such as air motion, system open or closed, ambient temperature, surface temperature, etc., to try to work in an absolute sense. They will, however, give you a useful handle for comparing the pumpdown performance of a given system and installation on a day-to-day basis as conditions vary.

FRESH SURFACES

Surfaces saturated with water vapor which are introduced into a vacuum chamber are also a source of water vapor that needs to be considered. A common example would be substrates and their attendant holders and jigging. Even if a chamber is let up to N_2 and kept under a dynamic N_2 overboard flow while the work is inserted, whatever amount of water vapor that is sorbed onto the total surface area of the work will be added to the water vapor population of the chamber.

There is a commonly held misconception that the introduced water vapor load will be merely pumped away during the pumpdown cycle. This is partially true in that a percentage will be pumped away, and it is probably only a small percentage. Here's what happens. During the pumpdown cycle, a portion of the loosely bound water at the very top of the sorbed water bed will be entrained and pumped away while the chamber is under viscous flow conditions during roughing. Once molecular flow conditions are reached, the remaining water will slowly begin to desorb in any and all directions.

This means that the greater percentage of the desorbing molecules will impact a chamber wall instead of immediately entering the high vacuum pump. The odds are that the molecules impinging on the chamber walls will stick before they bounce into the pump. Since the chamber's surfaces are relatively clean, the sorbed water will form fairly strong bonds that will result in a low re-desorption rate. A low desorption rate means a slow pumpdown to process pressure.

To recap, we have introduced surfaces with a high desorption rate into a chamber with surfaces that are clean

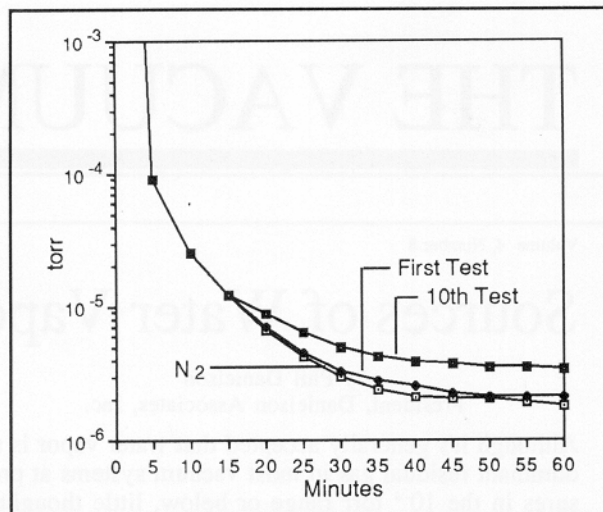


Figure 3. Effect of Fresh Surface Introduction.

enough to have a low desorption rate, so the chamber's surfaces become partial pumps for most of the newly introduced water vapor. In a single process, the build-up of water vapor on the chamber's walls doesn't have a really important effect on a practical process chamber, but the build-up continues with subsequent runs. An example is shown in Figure 3. This shows a system pumping down from an N_2 backfill alone with a second curve showing the same conditions but with the introduction of a fresh surface 0.1 of the chamber's total surface area. The effect on pumpdown time really begins to show up on Figure 3's third curve after the tenth cycle where the amount of water sorbed on the chamber's wall has reached a point where the chamber's desorption rate slows the pumpdown.

CONCLUSIONS

An understanding of the sources of water vapor in vacuum systems can give some clues in terms of techniques of avoiding or reducing the amount of sorbed water vapor the system has to deal with during pumpdown. It is also apparent that it is almost impossible to totally avoid introducing at least some water vapor into a working practical production system. Once the sources of water vapor are reduced, it is still advantageous to consider further techniques such as Phototron enhanced desorption to desorb as much water vapor as possible during the first stages of pumpdown.

V3,#8, Sources of Water Vapor in Vacuum Systems

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