A Journal of Practical and Useful Vacuum Technology

From

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Gas Purge Solutions to Oil and Water Contamination Problems

Contamination problems can be solved or avoided by special gas purging of the system and/or pumping lines during operation.

Contamination is the constant bugaboo that haunts practitioners of vacuum technology. If we define contamination as anything that is likely, or even liable, to interfere with the process or activity being carried out, we can easily understand that the avoidance of contamination and contaminants is the whole ball game.

Virtually every process has its own unique contamination problems that need to be taken into account when attempting to understand or troubleshoot a particular process or vacuum system, and there a only a few that affect most processes.

For example, a higher than usual helium (He) background will have no real affect within a thermal evaporation system due to its inert nature, but it can be a big problem in a He leak detector since it can cause problems in sensitivity and/or response time. A contaminant can be defined as anything that interferes with the vacuum process or operation of the device being built. This means that there are so many possible sources of contamination that it is impossible to generalize upon sources and solutions, but there are some particular problems that can be associated with particular pumping systems and generally accepted contaminants that can be focused upon.

Momentum Transfer Pumps

In general, we can divide high vacuum pumps into capture and momentum transfer pumps. Capture pumps, such as sputter-ion, getter, and cryo, pump the gas by taking it into a “garbage can” and holding it either temporarily or permanently.

Momentum transfer pumps, on the other hand, pump the gas by allowing it to enter the pump inlet, compressing it by some form of mechanical impact, and exhausting it at a higher pressure into another volume at a pressure lower than atmospheric. This group includes diffusion, molecular drag, turbomolecular, and turbo/drag pumps. In all these cases, they require a support pump to reduce the inlet pressure to a low enough level to allow the high vacuum pump to work. At this point, the support pump changes its role to maintaining a low enough pressure at the high vacuum pump’s exhaust to allow efficient compression.

When the pressure is being reduced from atmospheric to the specified inlet pressure, the support pump's role in called "roughing," and when it is maintaining a low exhaust pressure its role is "backing."

The degree of compression that a pump can produce depends upon a ratio between the inlet and exhaust and the molecular weight of the gases being pumped. The line connecting the exhaust port and the inlet of the backing pump is called the foreline. The limiting foreline pressure is then called the foreline tolerance, and this limit will vary greatly between pump type and individual design so no firm overall specification is possible.

During this pumping process, a number of potential contamination scenarios can occur, and each needs to be considered separately.

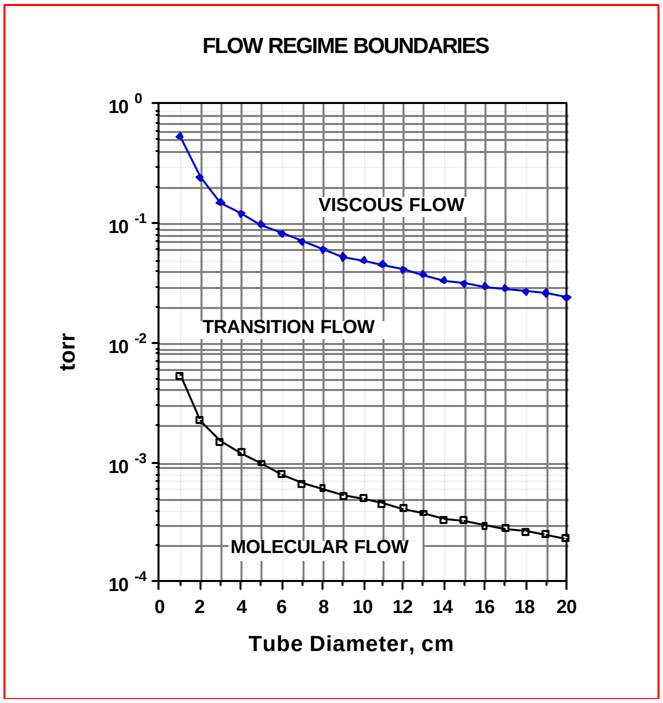
Water Vapor

Water vapor is a major problem for most vacuum processes in that it desorbs slowly from the internal surfaces of all vacuum chambers. It becomes the major residual gas as the chamber is pumped to pressures below 10^{-3} torr, and this transition is aptly termed as entering the drydown zone. In the drydown zone, the momentum transfer pump is required to either pump away the desorbing water completely or maintain a fairly low partial pressure by continuous removal by pumping.

This means that the entire pumping line from inlet to the backing pump's exhaust is exposed continuously to water vapor. If, as often the case, the chamber is rough pumped through the high vacuum pump, all of the water vapor contained within the chamber's air as humidity is moved through the entire pumping line. Consider that a liter of air at room temperature and 50% relative humidity contains roughly 20 torr liters of water vapor.

The internal surfaces of a member of the turbo family can be rather large, and these surfaces will adsorb water vapor as it passes through the pump. In addition, compression of the wet air in the roughing/backing pump will cause condensation, and some of that condensed vapor will re-enter the foreline as the pump reaches lower pressures and higher temperatures. At this stage, the pumping system will have difficulty pumping more water vapor from the chamber since compression will become less efficient due to more water vapor collecting in the foreline. At this point, we can stop fighting the gas laws and turn them to our advantage.

Oil-sealed mechanical pumps and scroll pumps will tend to have ultimate pressures that reach into the molecular flow regime. By definition, molecular flow occurs when the mean free path or the distance between molecule-to-molecule collisions is longer than the diameter of the chamber or pumping line. Since no other molecule is then impacting the water molecules they are free to move back into the momentum transfer pump and water back-emanating from the backing pump will not be pumped away.



The flow regime is a function of both diameter and pressure. In an existing system, you can read off the boundary by tracing the diameter to the boundary line. For designing a new system, you can read off the required diameter by tracing from the required pressure.

This condition can be overcome easily by introducing a continuous flow of dry gas into the foreline at a flow rate high enough to raise the pressure above the molecular flow limit. Under these conditions, the number of molecule-to-molecule collisions increase and some or all of the water vapor is swept into and through the backing pump. Any dry gas can be used, and nitrogen, argon, and air are commonly used.

Ideally, the pressure should be raised into the viscous flow regime, but this isn't always possible. The foreline tolerance of the turbo, molecular drag, or turbo/drag pump might not be high enough to allow viscous flow pressures, but raising the pressure above the molecular flow threshold will help a great deal.

Oil Vapor

Any time an oil-sealed mechanical pump is used for roughing/backing, the presence of oil vapor that's backstreaming from the pump is likely. As the pump's oil gets hot due to mechanical agitation, the oil's vapor pressure rises sufficient to cause it to enter the foreline. If, as is usually the case, during extended operation, the inlet pressure is in the molecular flow regime, there won't be pumped molecule-to-oil molecule collisions to stop the oil vapor from entering the momentum transfer pump where it can traverse the pump and enter the process chamber. Various oil vapor backstreaming traps are available that help solve this problem, but they require very careful operation and maintenance.

The same gas flow solution that's already been described for water vapor contamination will solve this problem as well. If the foreline is operated at viscous flow levels, the molecules of the flow gas will increase the collision rate and stop the backstreaming.

This technique is also very useful when backstreaming traps are being regenerated. Oil molecules that are trapped either on cold surfaces or within the pores of molecular sieve will escape during regeneration; either during warmup of cryogenic traps or bakeout of molecular sieve traps. If the trap and foreline are flushed with dry gas at viscous flow pressures, the oil vapor is prevented from spreading upstream from the trap.

Light Gases

All momentum transfer pumps have a low compression ratio for helium (He) and hydrogen (H_2), and this results in the light gases that are compressed into the foreline being able to flow back through the pump or slow the pumping speed. All this can result in a relatively high partial pressure of the light gas in the chamber. A flow of heavier dry gas into the foreline will then sweep the lighter gas into the backing pump.

The Diameter Trick

In cases where the foreline tolerance pressure isn't high enough to allow the foreline pressure to extend into the viscous flow regime, you can work around the problem by changing the diameter of the foreline. Remember that the flow regime is a function of both pressure and diameter, so it's possible to increase the foreline diameter to a point where viscous flow conditions can be met without raising the foreline pressure above the foreline tolerance level of the momentum transfer pump.

Conclusions

The disadvantages of contamination problems resulting from the operation of common vacuum systems can often be overcome by carefully applied gas flow into the foreline of momentum transfer-pumped systems. Pressure regulation can be either manual or with the help of gas flow controllers. If thermal conductivity gauges such as thermocouple or Pirani gauges are used in the foreline, you need to be sure that you're applying the sensitivity correction for the gas that's being introduced, and this is especially true with argon.