APPLICATION NOTE

LIMITATIONS ON ULTIMATE VACUUM ACHIEVED IN A TURBOMOLECULAR PUMPED SYSTEM

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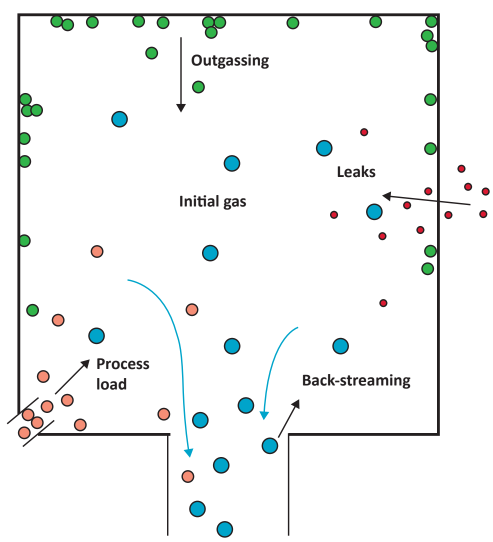
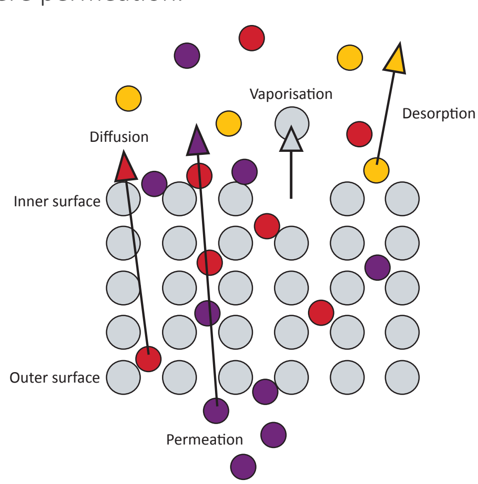
At high and ultra high vacuum the ultimate pressure achieved by a turbomolecular pumped system is limited by the conditions both at its inlet and exhaust. Here we describe why.

The process loads in a vacuum system can be summarised in the diagram below



In HV, UHV and XHV, the dominant gas load is from outgassing which is generally a summation of surface desorption, chamber wall bulk-diffusion and external atmosphere permeation.



In these vacuum ranges there is a corollary to a ‘process load’, for example in accelerators/colliders where surface ‘stimulated desorption’ from electron, photon and ion impacts can be a significant source of gas.

The total or ultimate pressure P_{tot} above a turbomolecular pump is:

1. $P_{tot} = \sum P_{Ti} + \sum P_{Qi}$

where P_{Ti} is the partial pressure of the ith gas; this is determined by the turbomolecular pumps backing line partial pressure (P_{Tbi}) via the Compression Ratio (C_{Ri}) of the turbomolecular pump for each of the ith gases.

2. $P_{Ti} = P_{Tbi}/C_{Ri}$

Outgassing (and other gas sources) in the chamber of the i^{th} gas provide an additional load P_{Qi}.

where Q_i is the gas load of the ith gas and S_i is the turbomolecular pump’s speed for the ith gas.

However there are complicating factors

P_{Qi} and P_{Ti} are functionally dependent since:

S_i and C_{Ri} are both dependent on inlet and backing pressure and flow

3. $S/S_o = 1 - K/K_{max}$

where S_o is the zero flow speed and Kmax is the ‘zero’ flow compression ratio. Hence ignoring outgassing and other gas loads, the expected ultimate pressure is

4. $P_{tot} = \sum P_{Ti} = \sum P_{Tbi}/C_{Ri}$

To illustrate this we will consider the following configuration:

An nXDS scroll pump, backing an nEXT85D turbomolecular pump, and operating at a pressure ~10^{-2} mbar with a measured partial pressure P_{Tbi} of H_2 to be ~10^{-5} mbar. The majority composition being water vapour, nitrogen and oxygen (here for simplicity we use an estimate of 10^{-2} mbar).

Although the partial pressure of H_2 in the backing line is significantly lower than that of water and permanent gases, if we consider the CR characteristics of a nEXT85D turbomolecular pump then the contribution to the total pressure P_{tot} can be seen to come mainly from H_2 as the turbomolecular pumps CR for H_2 is significantly lower than for N_2 etc. (> 10^{11}). Hence using equation 4 we can see that the contribution from H_2 is < 10^{-10} mbar.

A complication is that in UHV, especially after baking:

1. Water vapour can become a major load in the backing pump and ballast is needed to prevent condensation in the backing pump itself and the turbomolecular pump needs to be heated.
2. More significantly the H_2 partial pressure will rise in the backing line. This is because the gas load in the UHV chamber becomes dominated by H_2 including from bulk chamber wall permeation.

This can be compounded in oil-sealed pumps by H_2 being evolved from worked hydrocarbon stock oil and in dry pumps, having a generally reduced performance (especially in ultimate pressure achieved) for H_2.

As a result there can be an upwards drift in the ultimate UHV system pressure with time as the H_2 partial pressure builds up in the backing line.

An inert gas purge / ballast can be used to reduce the H_2 partial pressure in the backing line; the total backing pressure will rise but the pressure above the turbomolecular pump will fall.

It should also be noted that gauge and RGA sensitivity factors for H_2 can be significantly different to other gases resulting in significant errors if not corrected.

In summary a turbomolecular pumps ultimate pressure performance is effectively limited by outgassing, permeation, and process loads etc. but especially in UHV, by its compression ratio characteristics and the partial pressure of the constituent gases for which the turbomolecular pump has lowest compression ratios.

Appendix – ISO TMP standard

- 5302 Turbomolecular pumps- Measurement of performance characteristics

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