Technical Note

Applicable Models	CryoCore	CryoAdvance 50 CryoAdvance 100	s50 s100 s200
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Purpose

This document is intended to explain the cryopumping dynamics, how it can affect the performance of cryostats, and how users can optimize the operation of their Montana Instruments equipment.

Background

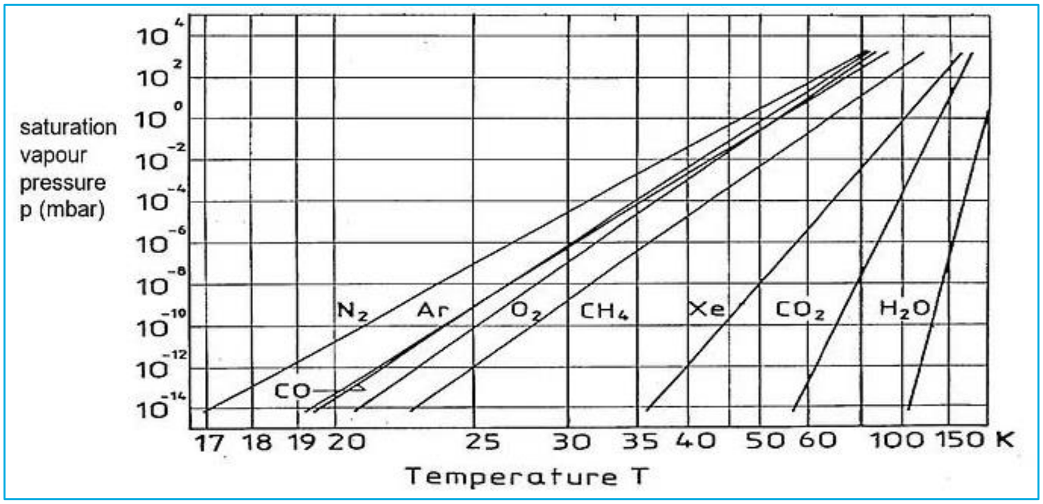
Certain customer use cases can encounter unexpected results simply due to low temperature phenomena. We will describe an example use case to help illustrate this:

- A user desires to study a sample's material attributes at various temperatures between the base and 300 K.
- The sample temperature is varied by setting the platform target temperature in the cryostat control software.
- The amount of time spent at each temperature set-point varies from a few minutes to several hours—the temperature set-points are arbitrary.

This or similar use-cases may result in reduced performance in one or more aspects of a cryostat as detailed below.

Applicable Theory

The chart below shows the well-established relationship between an environment's achievable vacuum pressure and the temperature required. At a given temperature, the pressure contributed by select molecular compounds will vary. For example, the desire to maintain a 10^{-8} vacuum level would require a temperature below ~23 K to prevent any nitrogen, oxygen, carbon dioxide (most common) condensate from vaporizing and decreasing the system's ability to maintain that vacuum level. However, if 10^{-2} is an acceptable vacuum level then the temperature requirement rises to ~35 K.



Cryostats rely on cryopumping to maintain a strong vacuum which, in turn, is critical in maintaining performance for cooling power, temperature stability, and environmental hold time. For the cryopump to be most effective the platform temperature, and therefore the sample chamber environment, must be <25 K. Once the environment exceeds 25 K the cryopumping effect begins to weaken, condensates turn to vapor, and the risk to vacuum level (increasing pressure) begins to rise. As more molecules unfreeze and reenter a gaseous state, they enable greater convective heat transfer between warm and cold surfaces. Thus, rising pressure allows higher heat loads into the cryostat and sample chamber.

As temperature and pressure of the platform rise, so does the risk that performance to the key specifications mentioned above will begin to degrade; the extent of that degradation depends on the specific configuration of the cryostat and may include undesirable outcomes, such as:

- Condensation and/or frozen water vapor on the exterior of the system or sample chamber
- Reduced available cooling power
- Degraded temperature stability
- Warmer base temperatures
- Compromised ability to hold a given temperature setpoint

Summary

This does not mean that the system will fail to function at temperatures above 25 K, but users should be aware that the ability of any cryostat to maintain the best possible stability is compromised to some degree. Most customers find that they can maintain effective and acceptable working conditions inside the sample chamber for extended hold times up to ~100 K.

To fully eliminate the risk to performance described in this document, Montana Instruments recommends our customers consider a customized variable-temperature solution, or the Agile Temperature Sample Mount (ATSM) module – this product localizes temperature changes to the sample, can rapidly vary the temperature from base to 350 K, and will maintain excellent temperature stability across that temperature range.

References

- **https://www.vacuumscienceworld.com/blog/cryopumps**
- **https://mmrc.caltech.edu/Stark/manuals/Intro%20to%20Cryogenics.pdf**
- **http://research.physics.illinois.edu/bezryadin/links/practical%20Cryogenics.pdf**