Everything You Always Wanted to Know about Continuous Flow Cryostats ... but Were Afraid (or too busy) to Ask

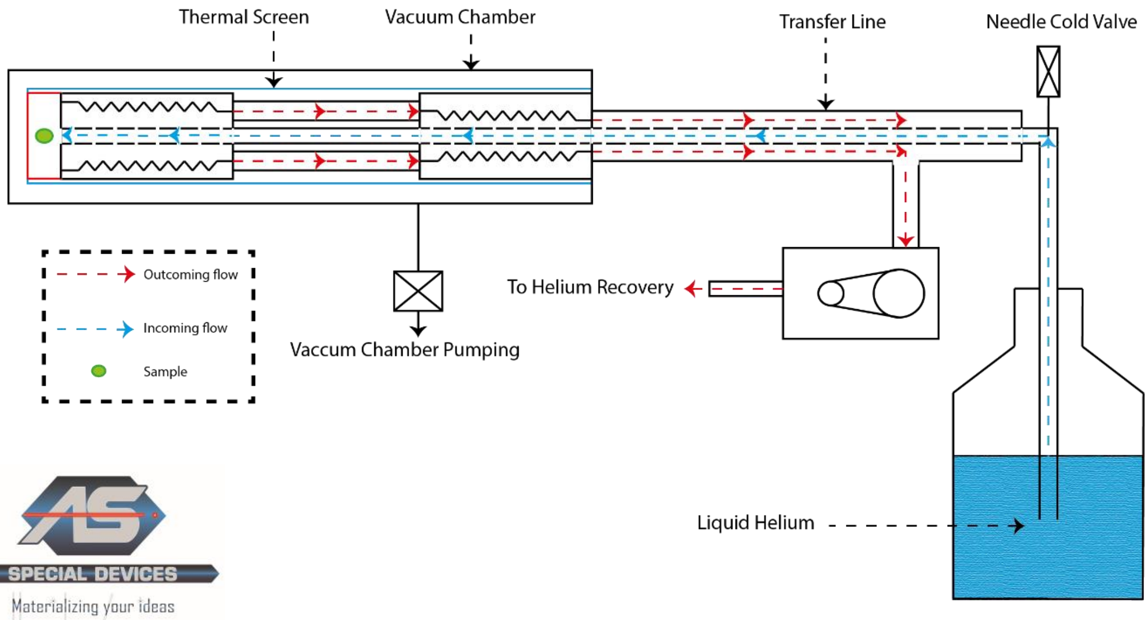
After the suggestion made by Nicol & Bohm (1959) to pump only a small volume of liquid Helium and the legendary article of Delong, Symco & Wheatly (1971) describing the famous 1K pot, techniques to reach temperatures below 4K have significantly progressed. From the bath cryostat to the pulse tube refrigerator we can find a well-adapted device to measure a specific sample.

Of course, we seek for the most performant, versatile, reliable and less expensive cryogenic tool. How to choose it? A famous physicist working on the string theory, after learned calculations, came to the conclusion that the best way to win a horse race is to have a spherical horse of negligible mass. Our case is not very different: we want a cryostat that cools down instantaneously, with a negligible thermal mass, a low Helium consumption, vibration free, working in any position, weighting a few grams, reliable and (why not?) plug and play.

In this note we intend to present the "spherical horse of negligible mass" or, at least, something approaching it. It's known as Continuous Flow Cryostat (CFC - nothing to do with Chlorofluorocarbons!).

Let me give you a succinct description about how the CFC works:

- To run the cryostat, we need a Dewar with liquid helium, a coaxial transfer tube (type LLT from Oxford instruments) and a Helium vacuum pump (like Sogevac from Leybold or Hena from Pfeiffer).
- The liquid Helium in the Dewar is drawn through a transfer tube and injected into the cryostat continuously.
- The flow of liquid Helium is transformed into gas at very low temperature (< 4K) and injected into a heat exchanger (the main exchanger) to cool the sample.
- After flowing through the main exchanger, the Helium gas enters the secondary exchanger, where a part of the remaining gas enthalpy is used to cool the thermal screen and create an environment of low radiation heat.
- Following the secondary exchanger, the Helium exits the cryostat through the transfer tube, flowing around the incoming Helium gas, thereby helping to protect the incoming Helium from any radiation from the environment. The outgoing Helium flows through the vacuum pump and enters into the Helium recovery installation.

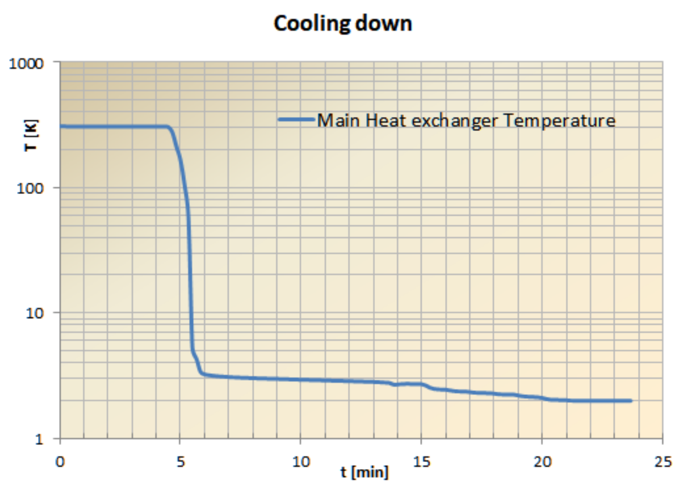


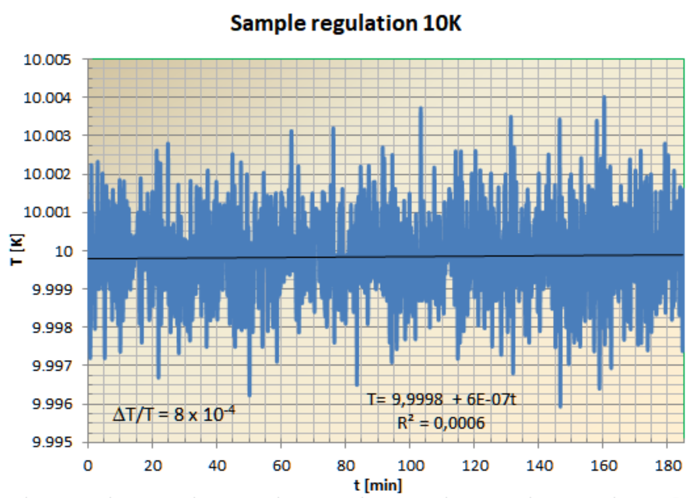
The cooling power of the cryostat is a function of the Helium flow rate and the capacity of the exchangers to transfer heat (efficiency). This power is determined by two factors: firstly by the cold valve on the transfer tube, which limits the Helium flow rate, and secondly by the pumping speed of the Helium vacuum pump.

Tweaking the transfer tube cold valve allows reaching different temperature ranges. Of course, a temperature controller is essential for the regulation and stabilization at a given temperature.

Have we found our spherical horse of negligible mass? Let me show you some measured values of a basic CFC and compare it with our “desired specifications”. We want a cryostat that:

- **Cools down instantaneously** -> cool down from room temperature to 4K in less than 7 min.
- **negligible thermal mass** -> a 5K step (from 5K to 10K) in 93 seconds with $\Delta T/T \sim 10^{-3}$
- **vibration free** -> (average displacement measured by interferometer He-Ne + Bragg cell) < 11nm
- **Low Helium Consumption** -> 2.5l/day at 100K , 7.1l/day at 10K, 12.8l/day at 2.5K,.
- **working in any position** -> 6 freedom degrees (in which 2 angular tilt of “only” 180°)
- **weighting a few grams** -> weight (without vacuum valve) ~670g
- **reliable** -> no moving parts at low temperature, no valve, no maintenance need
- **Plug and Play** -> plug the transfer line, start the pump, set the pumping pressure and play.





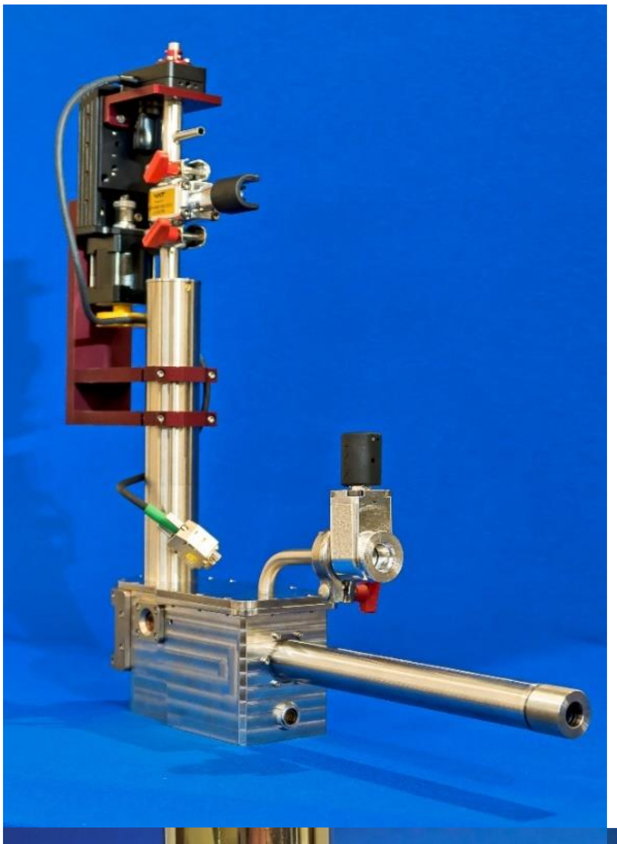
You may find this tale too pretty to be true. In fact, you are not far off the mark because not all CFC are comparable and work as well as described here up. That’s because the heart of this instrument is the heat exchangers, its calculation and design is the crucial point to obtain the best performances. You can find in the market several companies offering CFC, some of them propose CFC with only one heat exchanger, others name the exchangers after a science fiction movie, specifications are partial or lacking, and so on.

The unique way to know if this kind of instrument corresponds to your needs is to contact somebody who already has one and works with it regularly. We can provide you several references, just ask!

One last thing, and maybe one of the most important, the continuous flow technology allows doing almost any (Helium or Nitrogen) cryostat: top loading, sample in vacuum, sample in vapor, sample in cryogen stream and the new hybrid cryostat. Obviously, CFC works with both X-ray and neutron beam.

For instance, see below a new type of CFC tailored for one of our customers:

Top Loading Hybrid Cryostat :



This instrument allows a quick sample change, we are talking minutes, and an accurate sample positioning. The sample chamber works with a Helium gas flow assuring a good thermalization and a precise temperature measurement of the sample. Particularly useful for low thermal conductivity samples, its sample holder can accommodate 4 pellets of 5mm diameter.

- *Temperature range: ~2K to 250K (depending of windows material and size).*
- *Temperature stability: ΔT/T < 10^{-3} in the full range of temperature.*
- *Cooling down: from room temperature to 4K in 7 minutes.*
- *Can work in static vacuum (internal sorption pump)*
- *Angular positioning 0.02°*
- *Axial resolution 0.5µm.*
- *Air-lock chamber*.

We are looking forward to answering any of your questions and, of course, to make your own spherical horse!

Alexis STEINMANN

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