Experimental studies on cryogenic thermal storage in superconducting cable terminations to protect against unexpected heat loads

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Background and Objectives

- Cryogenic gaseous helium (GHe) is more advantageous over liquid nitrogen (LN2) for cooling some specific high temperature superconducting (HTS) power applications.
  - Can reach lower temperatures than LN2.
  - GHe-cooled HTS systems are much lighter than LN2 counterparts.
  - Preferred by the US Navy for HTS devices on future all-electric ships.
- One major drawback of GHe-cooled HTS power devices is low heat capacity.
  - Particularly vulnerable to unexpected heat loads.
  - Fault currents and vacuum breaches could shut down system operation.
- Cryogenic thermal storage using solid nitrogen (SN2) is being studied as a solution to improve system resiliency.
  - This strategy takes advantage of the latent heat of nitrogen's phase changes to maintain operational temperatures while taking on heat.
  - Used in conjunction with gas adsorption onto activated carbon can help keep system temperature as low as possible during a contingency.

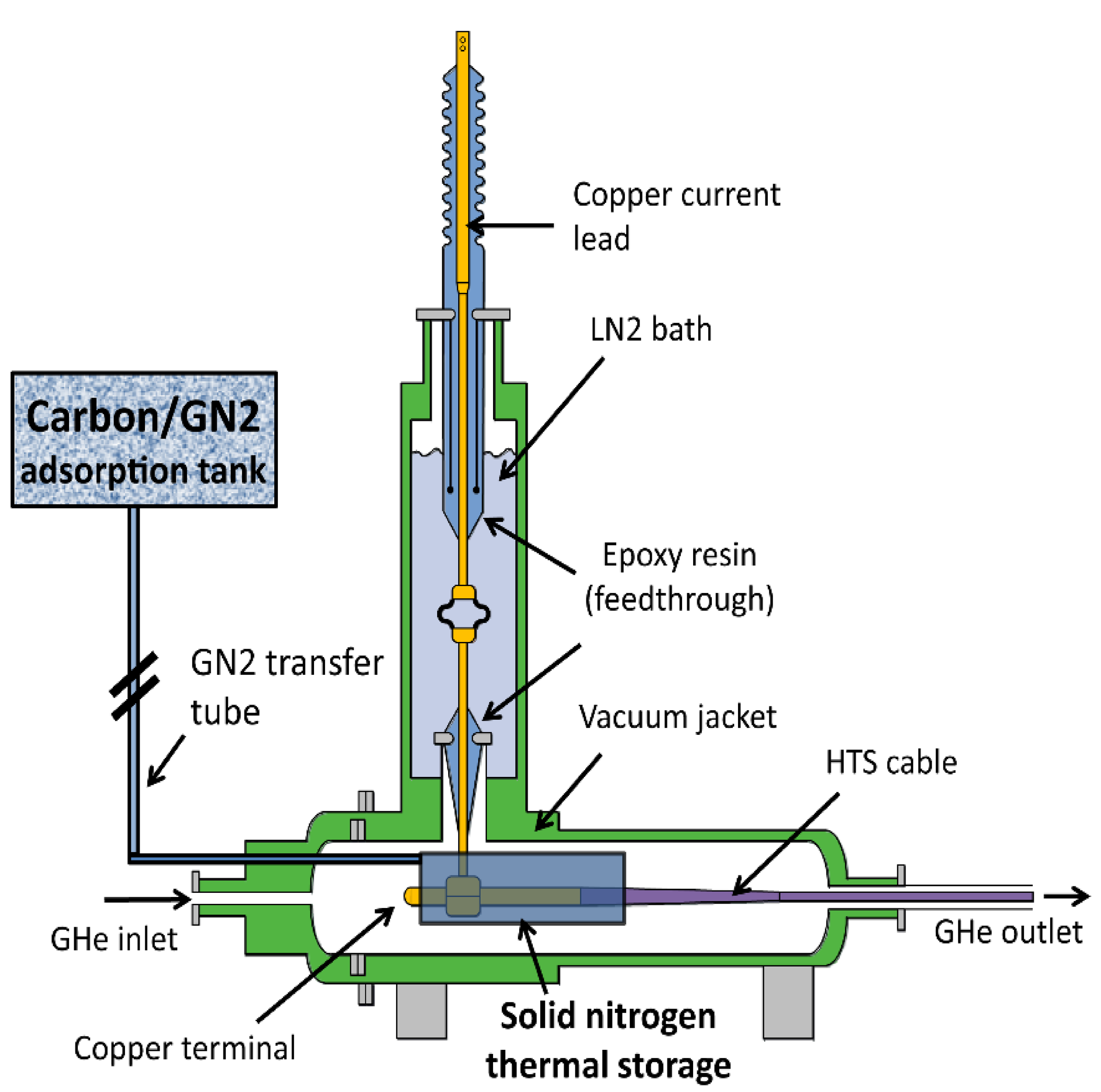

Figure 1. Schematic of HTS termination incorporating a solid nitrogen thermal storage and an external activated carbon tank to adsorb GN2.

Conclusion

- A fault current is simulated to calculate amount of SN2 needed to maintain operation of HTS cable.
- Calculations show that 237 g of solid nitrogen is required to absorb 200 W of heat for 5 minutes.
- Using activated carbon to adsorb nitrogen gas created by a heat surge can save 80% of the gas volume.
- Future experimental tests will be compared to calculations to determine accuracy and feasibility.

The process of adsorption

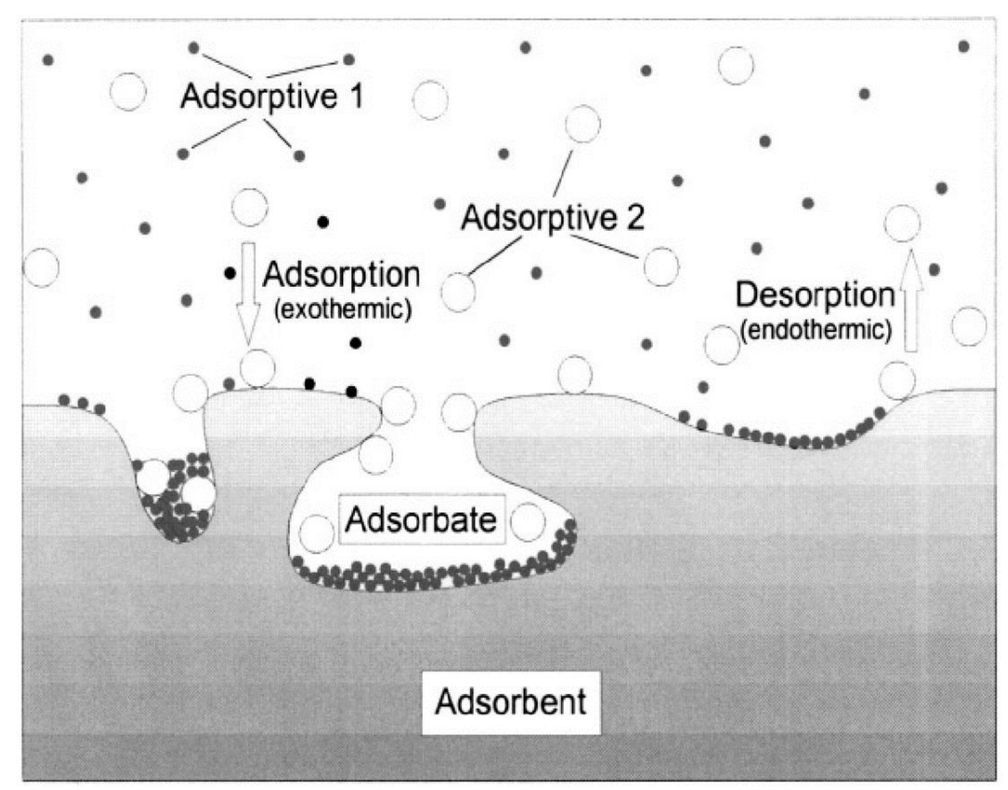

Figure 2. Example adsorption system.

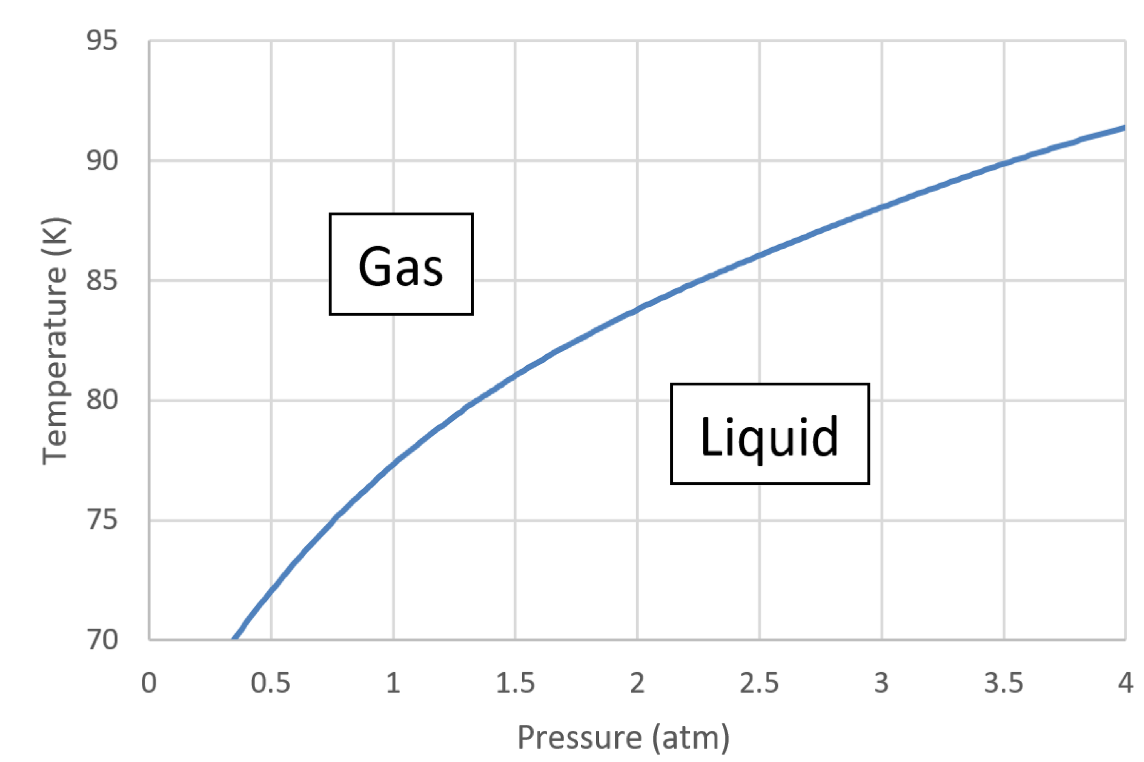

Figure 3. Nitrogen phase diagram.

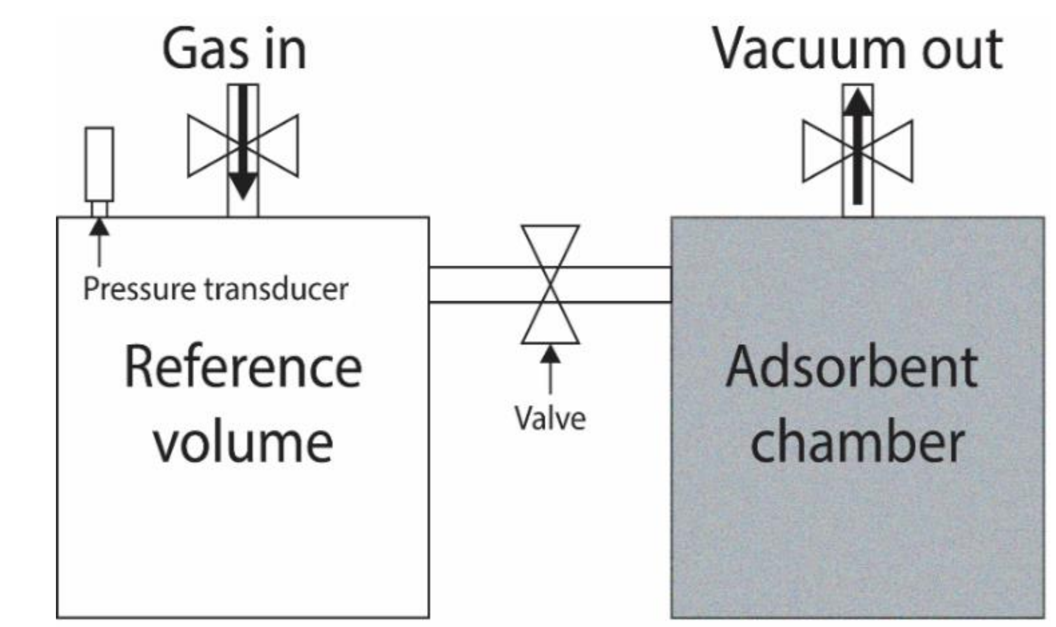

Figure 4. Pycnometer test used to measure carbon density.

Preliminary results

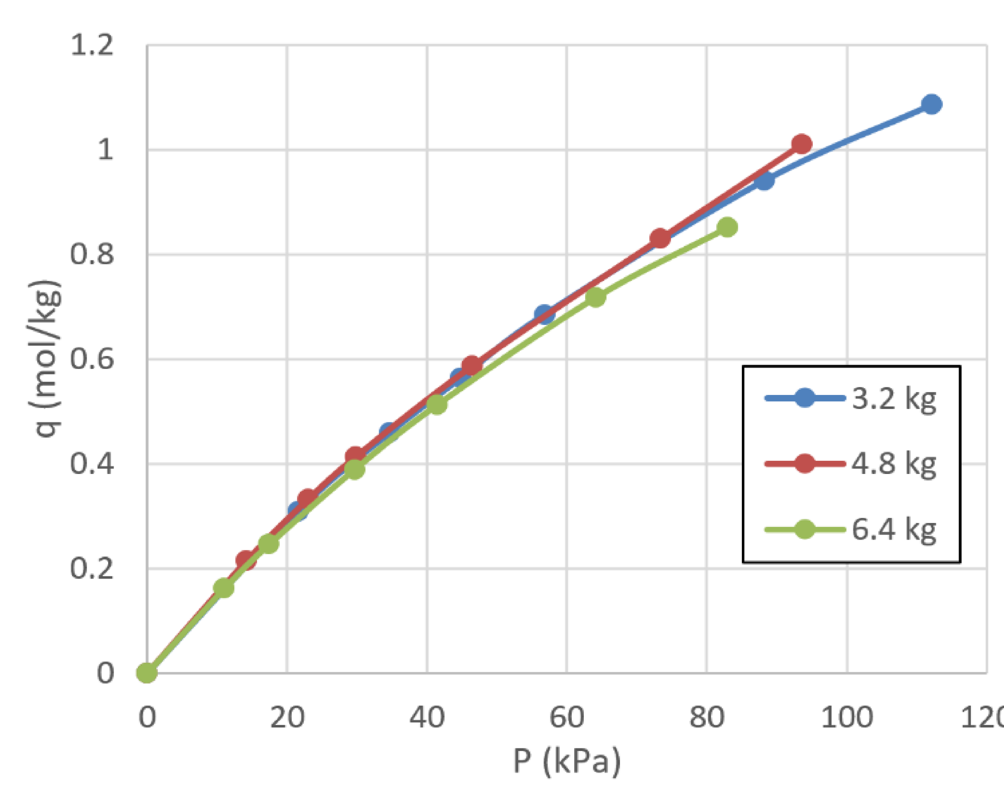

Figure 5. nitrogen adsorption isotherm obtained from pycnometer test.

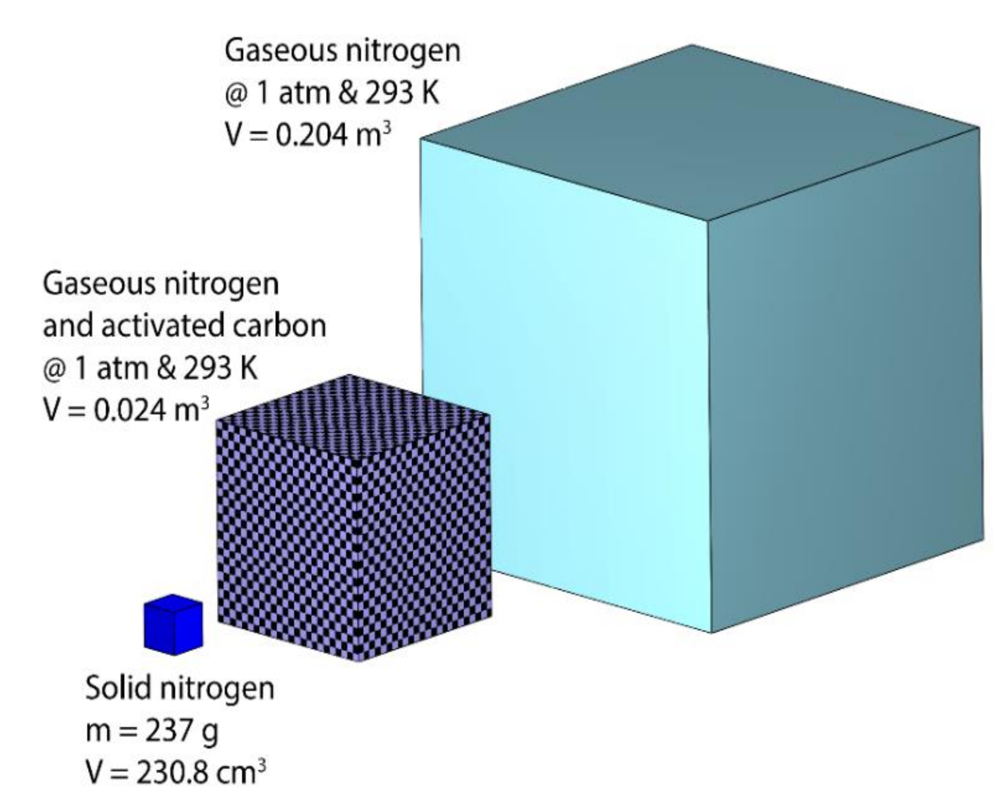

Figure 6. Volume comparison of different nitrogen substances.

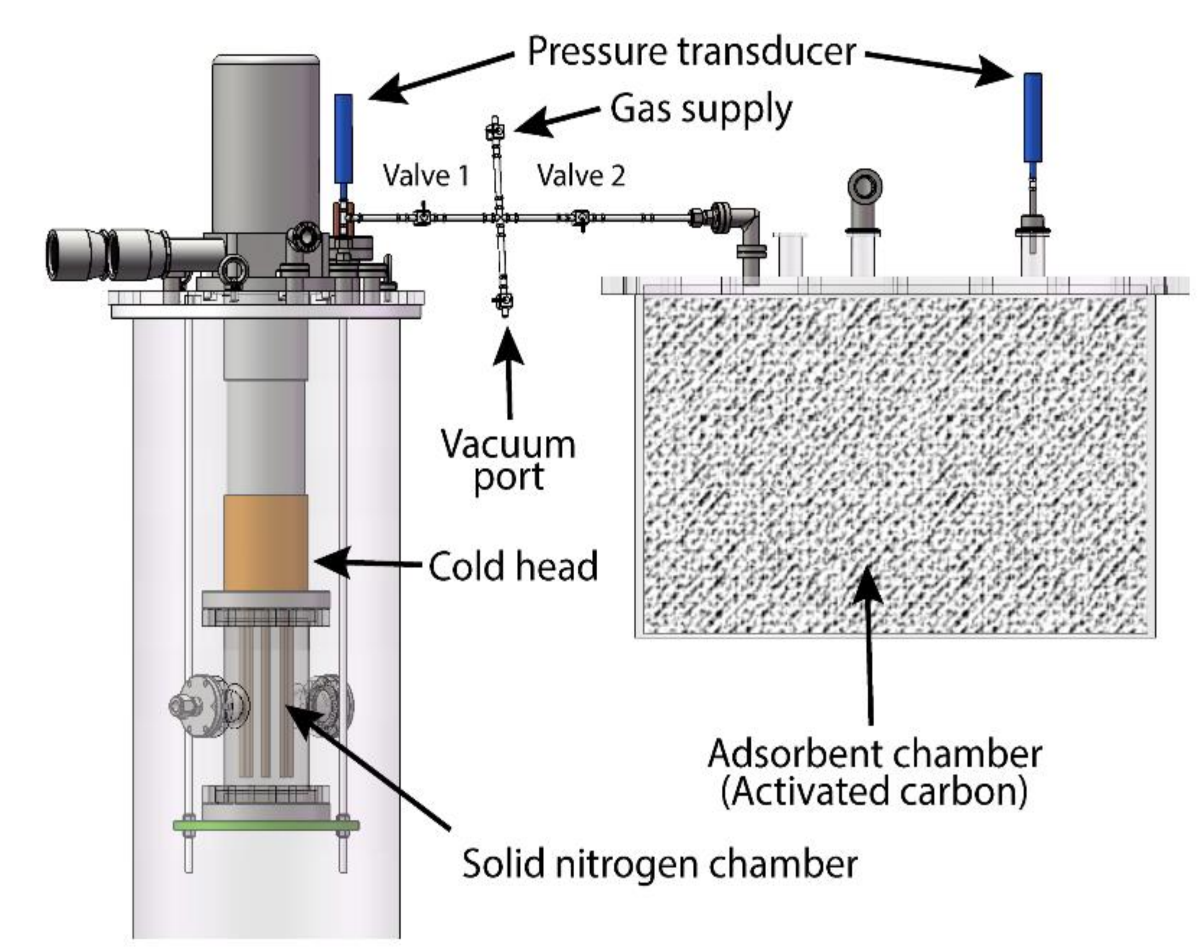

Figure 7. Cryogenic experimental setup.

References:
1. Cryogenic thermal modeling and experimental validation of a novel heat sink for helium gas cooled superconducting devices. D. Shah et al.
2. Transient cryogenic thermal modeling of HTS cable systems cooled with gaseous helium. N. Suttell et al.

Financial support provided by: