Appendix 11: Cryogenic Materials*

A. Physical Properties of Cryogenic Materials

	Boiling Point (K)	Liquid to Gas Expansion Ratio	Gas Specific Density	Critical Temp (K)	Critical Pressure (atm)	Liquid Density (g/L)
Air	---	---	1.00	---	---	---
Argon	87.3	860	1.39	150.9	48.3	1402
Carbon Dioxide	194.7	790	1.70	304.2	72.8	1560
Helium	4.2	780	0.14	5.2	2.2	125
Hydrogen	20.3	865	0.07	33.0	12.8	71
Nitrogen	77.3	710	0.97	126.3	33.5	808
Oxygen	90.2	875	1.11	154.8	50.1	1410

B. Cryogen Hazards

i. *Physiological Hazards* - Severe cold "burns" or frostbite may be inflicted if the human body comes in contact with cryogenic fluids, boiled-off vapor, or surfaces cooled by cryogenic fluids. The evolution of large volumes of gases associated with evaporation of cryogenic liquid spills can result in asphyxiation. For instance, nitrogen expands approximately 700 times in volume, going from liquid to gas at ambient temperature. Asphyxiation and chemical toxicity are hazards encountered when entering a cryogenic vessel that has been used to store cryogenic liquids if proper ventilation/purging techniques are not employed.

ii. *Material and Construction Hazards* - The selection of materials calls for consideration of the effects of low temperatures on the properties of those materials. Some materials become brittle at low temperatures. Brittle fracture can occur very rapidly resulting in almost instantaneous failure. Low temperature equipment can also fail due to thermal stresses caused by differential thermal contraction of the materials. Over pressurization of cryogenic equipment can occur due to the phase change from liquid to gas if not vented properly. All cryogenic fluids produce large volumes of gas when they vaporize.

iii. *Flammability and Explosion Hazards* - Fire or explosion may result from the escaping of flammable gases such as hydrogen, carbon monoxide, or methane. Escaping liquid oxygen, while not a flammable gas itself, can combine with combustible materials and cause spontaneous combustion. Oxygen can cling to clothing and cloth items and presents an acute fire hazard for approximately one-half hour after exposure.

iv. *High Pressure Gas Hazards* - Potential hazards exist in highly compressed gases because of the stored energy. In cryogenic systems high pressures are obtained by gas compression during refrigeration, by pumping of liquids to high pressures followed by rapid evaporation, and by confinement of cryogenic fluids with subsequent evaporation. If this confined fluid is suddenly released through a rupture or break in a line, a significant thrust may be experienced.

*Adapted from: J.W. Crozier, *Safety Handling Procedures for Cryogenic Materials*, Fulton School of Engineering, Arizona State University, 2008