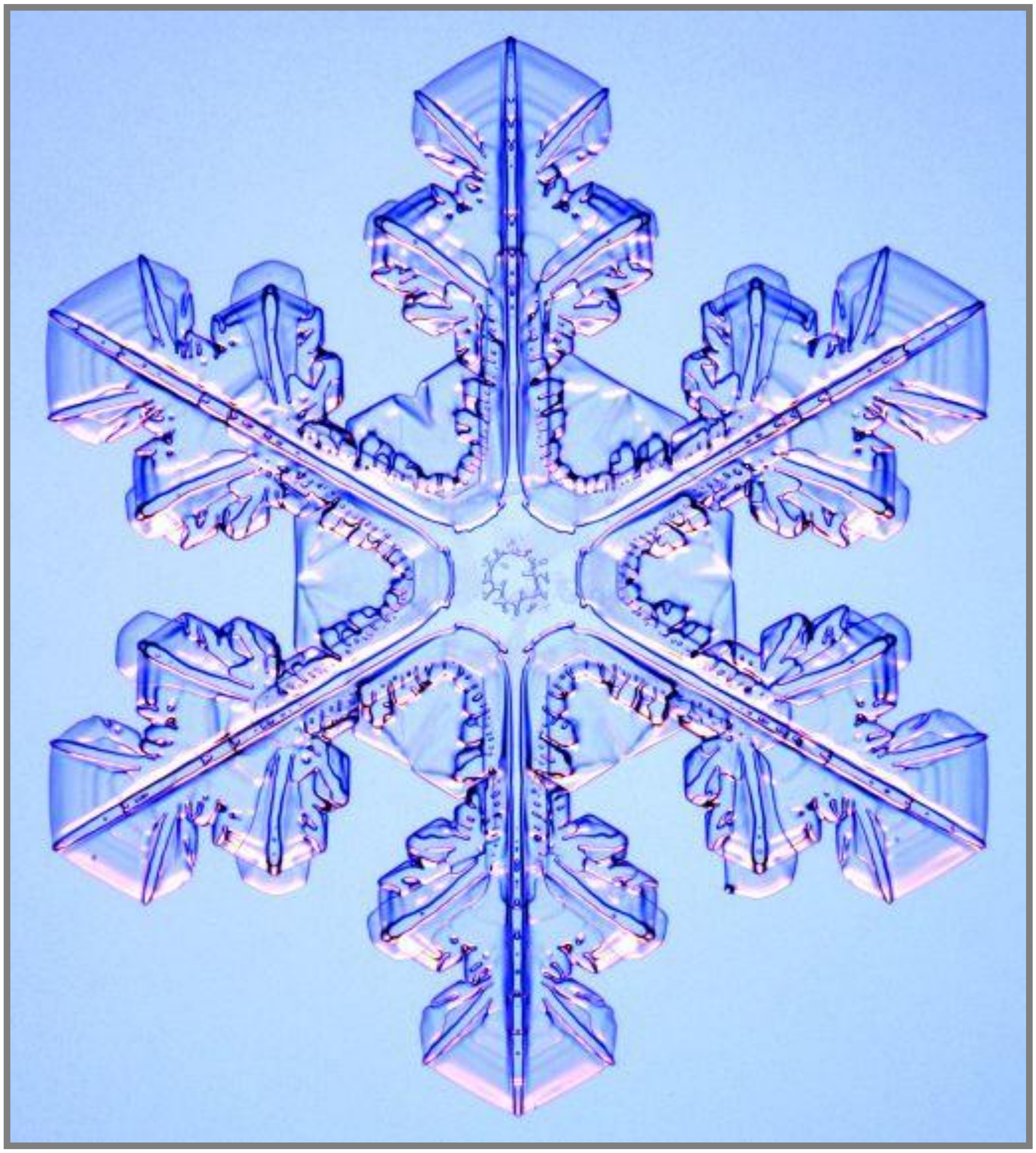
Fulton School of Engineering

Safety Handling Procedures for Cryogenic Materials



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I. Introduction

Cryogenic materials are very cold substances (gases, solids and liquids at or below -100° F) that are used in a wide variety of processes. By definition, cryogenic liquids have boiling points below minus 130° F (minus 90° C). Common cryogenic liquids of concern include nitrogen (N), helium (He), argon (Ar), hydrogen (H), methane and carbon dioxide (CO_2).

Hazards associated with cryogenic fluids include personnel exposure (cold burns, frostbite), material and construction compatibility, high pressure gases, explosions, implosions, toxicity, and asphyxiation.

II. Scope

This document provides guidelines for the safe use of cryogenic fluids. It applies to all Fulton School personnel engaged in the transport, storage, or use of such fluids.

III. Responsibilities

A. Department Chiars and Responsible Parties are responsible for ensuring that FSE Safety Office guidance is implemented. Dissemination of this information to the relevant persons including faculty, staff and students, and ensuring that suitable training, maintenance and inspection procedures are set up and documented will help ensure safety in handling cryogenic materials.

B. Personnel who are responsible for any cryogenic equipment must conduct a safety review prior to the commencement of operation of the equipment. Supplementary safety reviews must follow any system modification to ensure that no potentially hazardous condition is overlooked or created and that updated operational and safety procedures remain adequate.

Key elements of ensuring safety are:

- Risk assessment of each storage and dispensing area.
- Risk assessments of activities involving cryogenic materials.
- Training users and keeping records of this training.
- Providing the necessary equipment and personal protective equipment (PPE).
- Written procedures and emergency procedures for the use and handling of cryogenic materials.
- Consulting with EH&S when significant changes are being considered.
- Carrying out periodic inspections to confirm that procedures are being followed.
- Ensuring that there is adequate security to prevent unauthorized access.

C. Personnel working with cryogenic fluids must follow the guidelines for use, handling, transportation and storage listed in this document.

VI. Hazards Associated with Cryogenic Materials

Cryogenic liquids are liquids that exist between -66°C and -266°C. The most common cryogens used in the laboratory are liquid nitrogen, liquid helium, and solid carbon dioxide (dry ice), although there are others including liquid oxygen, liquid hydrogen and liquid argon. Table 1 lists the physical properties of common cryogens.

	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
R-12 Refrigerant	243.4	294	4.35	385	40.6	1487

Table 1. Physical Properties of Common Cryogens

Cryogens Can Present One or More of the Following Hazards

A. ***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.

B. ***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.

C. ***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 itself a flammable gas, can combine with combustible materials and cause spontaneous combustion. Oxygen clings to clothing and cloth items and presents an acute fire hazard for approximately one-half hour after exposure.

D. ***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.

V. RISK ASSESSMENT

An initial risk assessment must be performed in which the potential depletion in oxygen concentration from the largest foreseeable spillage must be calculated for all facilities where cryogenic materials are stored or handled. The calculation is shown in Section V.A below. Where this could result in an oxygen concentration below 18%, corrective actions must be implemented to mitigate the potential. Possible actions include limiting the maximum quantity of cryogenic fluid handled so that oxygen depletion cannot arise, moving the operation to a larger room, providing mechanical ventilation with indicators that it is operating and installing oxygen alarms. Where the risk assessment shows that mechanical ventilation and oxygen alarms are needed, Facilities Management and EH&S must be consulted before any action is taken.

Risk assessments, written operating procedures and training are needed to cover the full range of hazards associated with storage and use of cryogenic materials. The PI is responsible for the development of workplace specific safety information related to the use and storage of cryogenic liquids.

A. Oxygen Deficiency and Asphyxiation

The **most significant risk** of cryogenic liquids is death by asphyxiation where a spill or leakage depletes the atmospheric oxygen. If the oxygen concentration falls below 18% adverse effects will occur resulting in loss of mental alertness and performance combined with distortion of judgment. In atmospheres containing less than 10% oxygen death by asphyxiation is rapid: just two breaths of oxygen-free air kills. For example, oxygen depletion resulting from a spill of 50 liters of liquid nitrogen in a room 10m x 8m x 3m is calculated below can be determined using the equation

$$\frac{100 \times V_O}{V_R}$$

$\mathbf{V_O = 0.209\ (V_R - V_G)}$ *for cryogens other than oxygen*
$\mathbf{V_R}$ *is the volume of the room*
$\mathbf{V_G}$ *is the maximum gas release upon the expansion of the cryogenic liquid*

$\mathbf{V_R}$ = 10 x 8 x 3 = $\mathbf{240\ m^3}$
$\mathbf{V_G}$ = 710 x 0.05 m^3 = $\mathbf{35.5\ m^3}$ *(1 m^3 = 1000 liters)*
$\mathbf{V_O = 0.209\ (V_R - V_G)}$ = 0.209 (240 – 35.5) = $\mathbf{42.7\ m^3}$
Oxygen Content = (100 x 42.7)/240 = **17.8%**

To calculate the oxygen concentration when oxygen is the spilled cryogenic liquid, then $\mathbf{V_O = 0.209\ (V_R - V_G) + V_G}$.

If someone is seen unconscious in a cryogenic handling or storage area it is likely that they are already dead and there is a serious risk to rescuers of being asphyxiated unless they are wearing self contained or air line supplied breathing apparatus and are trained in entry procedures for confined spaces. In such circumstances the first actions should be to raise the alarm, evacuate the immediate area opening doors and windows if safe to do so on the way out.

B. Cold burns, Frostbite and Hypothermia

1. Contact of the skin with cryogenic liquids (or even cold gas) can cause severe cryogenic burns; the tissue damage that results is similar to that caused by frost bite or thermal burns. While the cold itself can reduce the feeling of pain, the subsequent thawing of tissue can cause intense pain.

2. Contact with non-insulated parts or equipment or vessels containing cryogenic liquids can produce similar damage. Unprotected parts of the skin may stick to low-temperature surfaces and flesh may be torn upon removal.

3. Inhalation of cold vapor can cause damage to the lungs and may trigger an asthma attack in susceptible individuals.

4. Hypothermia is a risk due to the low temperatures arising from the proximity of cryogenic liquids. Risk is dependent upon the length of exposure, the atmospheric temperature and the individual; those exposed for prolonged periods should be warmly clothed.

C. Oxygen Enrichment

Although not flammable, oxygen when present in higher concentrations can significantly increase the chance of fire or an explosion. The boiling point of oxygen is above those of nitrogen and helium. In closed systems (such as cold traps cooled with liquid nitrogen) these liquids can cause oxygen to condense on their surface (resulting in a bluish liquid on the surface). This can lead to the ignition of normally non-combustible materials and the flammability limits of flammable gases and vapors are widened. Oil and grease may spontaneously ignite and as such should not be use where oxygen enrichment may occur.

D. Pressurization and Explosion

Cryogenic liquids vaporize with a volume change ratio of 700-900 can cause violent changes in pressure, particularly if this occurs in a confined space. This in turn can result in an explosion. Vent systems must be in place to allow gas to escape from confined spaces. Pressurization can occur due to the following:

1. Ice forming on the venting tube, plugging it and preventing gas release.
2. Damaged equipment resulting in cryogenic fluids leaking into small areas, upon vaporization the cryogenic liquid vaporizes and causes pressure build up.
3. Loss of vacuum inside a cryostat or Dewar.
4. If a liquid helium-cooled superconducting magnet "quenches" (changes spontaneously from a superconducting state to a normal state).
5. Liquid nitrogen having permeated through sealed cryotubes containing samples which then return to room temperature.
6. Direct contact of the cryogenic liquid with water in a tube results in rapid vaporization of the cryogenic liquid and can cause the tube to explode.

E. Damage to Equipment

The very cold temperatures of cryogenic liquids can damage equipment and materials, which can result in danger. Examples of damage include the following:

1. Spilled liquid nitrogen can crack tiles and damage flooring such as vinyl.
2. Rubber tubing may become brittle and crack during use.
3. Condensation of water around electrical cables may result in an electrical shock hazard.

F. Flammable gas - Hydrogen

Hydrogen is extremely flammable and should be treated with extreme caution. Areas of use should be restricted, clearly marked and well ventilated. No naked flames, electrical ignition sources, sources of static electricity, or potentially combustible materials should be allowed within the restricted area as any of these could result in an explosion if gas has escaped.

Liquid hydrogen can condense and solidify air resulting in an explosion hazard. For this reason closed hydrogen systems should be used to prevent backflow of air.

VI. GENERAL SAFETY PRACTICES

A. Personnel Safety

1. Face shields and goggles shall be worn during the transfer and normal handling of cryogenic fluids.
2. Loose fitting, heavy leather, or other insulating protective gloves shall be worn at all times when handling cryogenic fluids. Shirt sleeves will be rolled down and buttoned over glove cuffs, or an equivalent protection such as a lab coat will be worn in order to prevent liquid from spraying or spilling inside gloves. Pants without cuffs will be worn.

B. Safety Practices

1. Cryogenic fluids must be handled and stored only in containers and systems specifically designed for these products and in accordance with applicable standards, procedures, or proven safe practices.
2. Transfer operations involving open cryogenic containers, such as dewars, must be conducted slowly to minimize boiling and splashing of the cryogenic fluid. Transfer of cryogenic fluids from open containers must occur below chest level of the person pouring liquid.
3. Such operations shall be conducted only in well ventilated areas to prevent the possible gas or vapor accumulation, which may produce an oxygen-deficient atmosphere and lead to asphyxiation. The volumetric expansion ratio between liquid and atmospheric nitrogen is approximately 700 to 1.
4. Equipment and systems designed for the storage, transfer, and dispensing of cryogenic fluids shall be constructed of materials compatible with the products being handled and the temperatures encountered. There is no single source of information that will provide exact specifications and standards for cryogenic equipment. ASME Codes B31.1 through B31.7 apply, ASME Code B31.3 contains the majority of the relevant information. The American Society of Testing Materials (ASTM) handbook provides information concerning tensile strength of metals at various temperatures and other relevant information. The Code of Federal Regulations, 49 CFR, provides some useful guidelines, although it only references cryogenic vessels used in rail transportation. In each case, the design specifications are left to the discretion of the designing engineer.
5. All cryogenic systems, including piping, must be equipped with pressure-relief devices to prevent excessive pressure build-up. Pressure-reliefs must be directed to a safe location. It should be noted that two closed valves in a line

form a closed system. The vacuum insulation jacket should also be protected by an over-pressure device if the service is below 77° Kelvin. In the event a pressure-relief device fails, do not attempt to remove the blockage; instead call EH&S immediately.

6. If liquid nitrogen or helium traps are used to remove condensable gas impurities from a vacuum system that may be closed off by valves, the condensed gases will be released when the trap warms up. Adequate means for relieving the resultant build-up of pressure must be provided.

VII. SPECIFIC PROCEDURES

A. REFILLING DEWARS IN LABORATORIES

1. Never refill Dewars or transfer cryogenic liquids alone!

2. Make sure that there is good ventilation. Open a door if you are in a small room.

3. Remove watches, rings and other metal jewelry on hands and wrists

4. Wear required Personal Protective Equipment identified in the PPE hazard assessment (29 CFR 1910.133). In general the following PPE is the minimum acceptable:

   a. Cryogenic gloves.

   b. Lab coat with sleeves pulled over cuffs of cryogenic gloves.

   c. Full length cuffless pants that extend over shoes tops.

   d. Closed-toed shoes that are impervious to liquids, such as leather, or covered with liquid proof shoe covers/spats.

   e. Safety Glasses or Chemical Splash Goggles and a Full Face Shield.

5. Use Dewars rated for the cryogen being transferred.

   a. Never use a Dewar that does not have a pressure relief valve or pressure venting lid/stopper.

   b. Use pressure venting lids/stoppers supplied by the Dewar manufacturer.

   c. Never use Dewars with makeshift or homemade lids/stoppers.

d. Glass Dewars must be taped solidly around the outside. The plastic mesh which comes with some small thermos bottles primarily provides some protection for the Dewar, but does not necessarily protect against glass shards resulting from implosion.

6. Dewars larger than 20 Liters will be lifted and poured by two people.

7. Never use a funnel as during overfill cryogenic liquid may be propelled upward.

8. Ensure the receiving vessel is dry.

9. The receiving vessel must be raised so the delivery tube is immediately above the mouth of the vessel (i.e., the cryogenic liquid should never be allowed to fall through air to reach the receiving vessel). Use a table, cart or other mechanical means to position the vessel in the proper location. Never hold the vessel with unprotected hands while filling.

10. To reduce thermal shock, first cool the receiving vessel by dispensing a small amount of cryogenic fluid then continue the dispensing process. Delivery should be conducted slowly to minimize splashing, spilling and thermal shock to the receiving vessel.

11. Do not move or bend the fill tube during filling.

12. Stay out of the vapor pathway during dispensing.

13. Do not leave a filling operation unattended.

14. Only use approved materials with cryogens. Unapproved materials (such as plastic, rubber, wrought iron, hollow tubes, and carbon steel) will become brittle and shatter, or in the case of hollow tubes become over pressurized.

15. Periodically inspect equipment and remove ice and frost blockages from openings to prevent over pressurization.

16. Do not tamper with pressure relief valves. Report any leaks or improperly set relief valves to the manufacturer.

17. Equipment should be kept clean without the use of corrosive cleaning materials that could damage the metal jacket.

18. When manually pouring liquid into a smaller Dewar, assure that the secondary container is secured, pour slowly to prevent excess splashing, do not overfill, and use a phase separator, if available, to control the vapor path while pouring.

B. TRANSPORT OF CRYOGENIC LIQUIDS

Special precautions must be taken to prevent a spill while transporting cryogens in addition to minimizing exposures from liquids and vapors. The high liquid to vapor expansion ratio could rapidly displace all oxygen in a room and result in asphyxiation. Implement the following procedures to minimize exposures:

1. Transport within the laboratory or lab building

a. Wear all required PPE (see VII.A.4).

b. Use no fewer than two personnel to transport cryogenic liquids and use handcarts equipped with brakes for large Dewars and cylinders.

c. Never transport an open container of cryogenic liquid, no matter how small.

d. Plan the route of transport. The **BEST PRACTICE IS TO AVOID USING AN ELEVATOR.** In event of an elevator failure or spill, the space may quickly undergo oxygen displacement. If this is not avoidable, send your buddy to the receiving floor. Then load the Dewar. Remain on the sending floor while you send the Dewar to the receiving floor unmanned. After your buddy unloads the Dewar, join him/her for the rest of the transport. If the transport by elevator takes place over multiple floors, clearly label the Dewar with a warning to anyone who may want to use the elevator between the sending and receiving floors to wait until the transport process is complete.

e. Always use care when handling equipment. Damage to Dewars could result in the loss of vacuum and increased evaporation. Transport of helium Dewars requires extra care because they are fragile.

f. When at all possible, do not hand-carry cryogenic liquids. For larger Dewars use a stable wheeled base designed for the Dewar transport. Check to ensure stability before commencing transport.

g. When carrying a Dewar, make sure it is the only item you are carrying. Hold the Dewar as far away from the face as possible. Be on the lookout for other people who may run into you or bump you.

h. Large mobile Dewars used for transport should be equipped with a braking mechanism. Do not use feet to brake. Steel toed boots are recommended.

i. Take care to avoid crushing hands or fingers between the vessel or cart and walls or door frames.

j. If there is any risk of tipping, a cart should be used. Wheeled trolleys may not be used if the vessel must pass over elevator thresholds or other slots/crevasses wider than 25% of the wheel width.

2. Transport between buildings

a. Follow the guidelines in VII.B.1 above.

b. In addition, avoid grates, large cracks in sidewalks/pavements, or other hazards that could cause tripping.

c. For transport of large nitrogen Dewars outside -- over pavement, sidewalks, wheelchair curb-cuts a 4-wheel tipcart should be used. The casters welded to the tank, and/or the casters on the trollies in common use, are not meant for transport over pavement and concrete.

d. While in route exercise great care stay completely clear of sewer grates, large cracks, and/or uneven portions of the pavement, and any other hazards which could catch a cart wheel and cause tipping.

3. Vehicular transport (see note at end of this section)

a. NEVER take liquid nitrogen or other cryogenic fluids in a car or a van where the driver's compartment is not segregated and sealed from the load. The load compartment of the van must be ventilated. Where a specimen needs to be transported frozen, consider whether dry ice would be suitable since it reduces the risks.

b. Before transporting cryogens, ensure that the following have been addressed:

- A risk assessment has been conducted.
- The container of the cryogenic material is labeled with the IUPAC name of its contents and a danger hazard warning sign.
- The driver has been fully informed as to what is being carried and its associated hazards.
- The appropriate Personal Protective Equipment has been provided.
- An information sheet is carried within the vehicle to provide emergency response services with specific data about the material in the event of an accident.
- The quantity to be transported is consistent with DOT regulations.

NOTE: Transportation of cryogenic substances is covered by the US Department of Transportation (DOT), 49 CFR 173. These regulations cover specific volumes/mass of dangerous goods that may be transported, duties of responsibility, correct packaging and labeling of goods, vehicle usage and driver training. Exceptions for cryogenic liquids can be found in 49 CFR 173.320 as follows:

(a) *Atmospheric gases and helium, cryogenic liquids, in Dewar flasks, insulated cylinders, insulated portable tanks, insulated cargo tanks, and insulated tank cars, designed and constructed so that the pressure in such packagings will not exceed 25.3 psig under ambient temperature conditions during transportation are not subject to the requirements of this subchapter when transported by motor vehicle or railcar except as specified in paragraphs (a)(1), (a)(2), and (a)(3) of this section.*

(1) Sections 171.15 and 171.16 of this subchapter pertaining to the reporting of incidents, not including a release that is the result of venting through a pressure control valve, or the neck of the Dewar flask.

(2) Subparts A, B, C, and D of part 172, (Secs. 174.24 for rail and 177.817 for highway) and in addition, part 172 in its entirety for oxygen.

(3) Subparts A and B of part 173, and Secs. 174.1 and 177.800, 177.804, and 177.823 of this subchapter.

C. STORAGE OF CRYOGENIC LIQUIDS

A cryogenic liquid storage unit left open to the atmosphere, or catastrophic failure of a storage unit, could create an oxygen deficient atmosphere. Follow these procedures to reduce the likelihood of this occurrence:

1. Glass Dewars must have an exterior coating/cover to minimize projectiles in the event of an explosion. Newer Dewars may have a plastic mesh over the exterior for this purpose. Older Dewars must be thoroughly taped or replaced.

2. Only store Dewars in well-ventilated rooms with a minimum of six air changes per hour.

3. If the ventilation rate is unknown, contact EH&S and Facilities Management (FACMAN) to evaluate the storage area.

4. EH&S and/or FACMAN may recommend the installation of oxygen detection systems and alarms for cryogenic liquid storage areas depending on location, ventilation, and quantity of material stored.

5. Do not store cryogenic liquids with corrosive or flammable chemicals.

6. Storage units should be placed so that vents and openings are oriented away from personnel and lab equipment.

7. Bulk cryogenic liquid dispensing areas within buildings must be well ventilated. EH&S recommends continuous oxygen monitoring equipment in all these areas. All new installations should be designed with oxygen monitoring system and alarm.

8. Storage of cryogenic liquid Dewars in hallways, unventilated closets, environmental rooms, and stairwells is prohibited.

9. No more than one backup Dewar is allowed per piece of equipment using cryogenic liquids in research labs. Additional Dewars must be stored in areas designed for such storage. Contact EH&S to evaluate potential storage locations.

D. EMERGENCY PROCEDURES AND FIRST AID

Liquid Nitrogen (LN2) is the most commonly used cryogenic liquid. Oxygen depletion resulting from nitrogen gas may occur rapidly with no warning properties. A person entering an oxygen deficient environment may become disoriented and unable to respond properly. Nitrogen gas is odorless, colorless, tasteless, and inert. The failure of a large Dewar could spill 180 L of LN2 which in gas form will completely displace all oxygen in a 21x21x10 ft room. A much smaller spill in the same room could still create a safety hazard.

Simply reducing the oxygen content in a room below 19.5 % is considered an oxygen deficient environment. Implement the following procedures to minimize the risk of asphyxiation:

1. If ventilation in the room is less than six air changes per hour, contact EH&S for advice about installing oxygen level detection alarm.

2. If a spill occurs, immediately exit the area. With adequate ventilation, it may be appropriate to return to the area after thirty minutes. For large spills, contact EH&S immediately as the area may need to be monitored for oxygen levels area and determine when it is safe to re-enter.

3. If experiencing symptoms such as lightheadedness, dizziness, or confusion, immediately seek fresh air and receive medical attention.

4. If an employee becomes unconscious in a cryogenic liquid storage area they should only be retrieved by personnel using proper PPE (such as a Self Contained Breathing Apparatus). ASU does not have the proper equipment to mount an extraction in a confined or oxygen deficient space; therefore the fire department should be immediately notified (911). Over fifty percent of deaths associated with asphyxiation in confined spaces occur to would-be rescuers.

5. Once personnel have been removed to fresh air, provide rescue breathing or CPR until paramedics arrive. In the event that skin or the eyes come into contact with cryogenic gases or liquid, follow first aid procedures, then immediately seek medical attention.

6. Immediately remove any clothing that has been contaminated. In the event of clothing contamination with oxygen, hydrogen, or carbon monoxide, it is important to remove clothing, evacuate personnel from the facility, and keep away from ignition sources.

7. Flush or soak the area with warm water (no greater than 105 ^{o}F).

8. Do not apply dry heat or rub damaged flesh or eyes.

9. Employees should notify their supervisor of injuries and complete the ASU EH&S Accident/Near Miss/Quality Improvement Report located at the following web address: http://www.asu.edu/uagc/EHS/incident_employee.htm. If medical evaluation and follow up is required, employees should report to: Tempe St. Luke's Hospital, 1500 South Mill Avenue, Tempe, Arizona, (480) 968-9411.

E. SPILLS AND DISPOSAL

1. MINOR SPILL ($\leq$ 1 liter)

a. Allow liquid to evaporate, ensuring adequate ventilation.

b. Following return to room temperature, inspect area where spillage has occurred.

c. If there is any damage to the floors, benches or walls, report it to Facilities Management.

d. If any equipment has been damaged following the spillage, inform your Supervisor and the Fulton School Health & Safety Office, (480) 965-8498.

2. MAJOR RELEASE ($>$ 1 liter)

a. Shut off all sources of ignition.

b. Evacuate area of all personnel.

c. Inform EH&S and supervisor.

d. **DO NOT** return to the area until it has been declared safe by EH&S.

3. DISPOSAL

Care needs to be taken when disposing of cryogenic liquids.

DO NOT	pour cryogenic liquids down the sink - they will crack waste pipes causing potentially dangerous leaks
DO NOT	store cryogenic substances or allow them to vaporize in enclosed areas, including: fridges, cold rooms, sealed rooms and basements
DO	ensure that the area in which the cryogenic liquid is left to vaporize is well ventilated

F. TRAINING

Training should be given in all aspects of the use and handling of cryogenic materials. A combination of on the job skills, instructions and information covering the following areas provides a minimum standard to which all users must be trained:

1. Understanding of the Material Safety Data Sheet (MSDS), the risks involved and where to obtain information.
2. Understanding the risks and effects of oxygen depleted atmospheres.
3. Conducting a risk assessment.
4. Use of Personal Protective Equipment (PPE).
5. Handling cryogenic materials.
6. Moving containers of cryogenic materials (> 1 liter).
7. Emergency procedures.
8. Spillage procedures.

And if necessary

9. Manual handling of larger storage vessels
10. Dispensing bulk quantities (> 1 liter)
11. Vehicular transportation and delivery of cryogenic materials

Much of the training will be carried out as on the job training and should be done by a competent person within the lab group. Individual training records shall be kept for each person handling cryogenic substances by the PI who shall maintain this information within the posted Laboratory Training Records, as required by ASU CHP.

VIII. REFERENCES

- CGA P-12-1993, Safe Handling of Cryogenic Liquids
- CGA S-1.1, Pressure Relief Device Standards- Part 1-Cylinders for Compressed Gases [6]
- CGA S-1.2, Pressure Relief Device Standards- Part 2-Cargo and Portable Tanks for Compressed Gases [7]
- CGA S-1.3, Pressure Relief Device Standards- Part 3-Compressed Gas Storage Containers [8]
- CGA V-1, American National, Canadian, and Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet
- ASME Boiler and Pressure Vessels Code Section VIII, Division 1
- NFPA 45, Fire Protection for Laboratories Using Chemicals
- ACS Handbook of Chemical Health and Safety, Robert J. Alaimo, ed. Oxford University Press, 2001
- CRC Handbook of Laboratory Safety, 2nd edition, Norman V. Steer, ed., CRC Press, 1985.
- Numerous college and university EH&S web sites, including, but not limited to Cornell, U Del, Purdue, U MI, UNR, Princeton and U Dundee.