OSEH Occupational Safety & Environmental Health	**OCCUPATIONAL SAFETY AND ENVIRONMENTAL HEALTH GUIDELINE**	
Subject: Cryogenic Liquid Use (Research)		
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SUMMARY:

Cryogenic liquids have boiling points below -130º F (- 90 º C) and are used in research to provide extremely low temperatures for frozen storage and experimentation. Common cryogenic liquids of concern include nitrogen, helium, hydrogen, argon, methane, and carbon

monoxide. Several hazards are associated with their use that must be properly controlled to avoid any contact with components or liquid, or exposure to its gases. This document describes administrative controls necessary to protect personnel from contact or exposure during handling of cryogenic liquids.

SCOPE: This Guideline applies to all U-M personnel that use cryogenic liquids.

REFERENCE DOCUMENTS:

CGA P-12-2009, *Safe Handling of Cryogenic Liquids*

MIOSHA Part 75 Flammable & Combustible Liquids
http://www.michigan.gov/documents/CIS_WSH_part75_35492_7.pdf

NFPA 45, *Fire Protection for Laboratories Using Chemicals*

NFPA 55, *Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks*

Air Products *Safetygrams*

OSEH Personal Protective Equipment Guideline

DEFINITIONS:

Chemical Hygiene Plan (CHP) - a written policy developed and implemented by lab management which sets forth procedures, equipment, personal protective equipment, and work practices that protect employees from the health hazards associated with the use of hazardous chemicals. In essence, it is a lab safety manual.

Cryogenic Liquid (Cryogen) – a liquid with a boiling point below -130 ^{o}F.

Cryogenic Liquid Cylinder – an insulated, vacuum-jacketed, pressure vessel equipped with safety relief valves and rupture disks to protect against excessive pressure build-up.

Dewar – open-mouthed, unpressurized, vacuum-jacketed vessels used to hold cryogenic liquids (usually helium, argon, nitrogen, or oxygen).

Safety Data Sheet (SDS) - informational tool developed by chemical manufacturers detailing safety and health aspects for a hazardous chemical. SDS can be obtained from chemical suppliers, internet sites, and should be available to those working with the material.

Personal Protective Equipment (PPE) - items worn by lab personnel to guard against hazards in the environment, primarily by creating a barrier between the hazard and the user. Examples include: safety glasses, goggles, face shields, respirators, gloves, hard hats, safety-toed shoes, and hearing protection.

Standard Operating Procedure (SOP) - a concise, written, document that provides safety instructions specific to experimental materials and methods.

RESPONSIBILITY: Everyone working at the University of Michigan has the right to expect a safe and healthy work environment. They also have a responsibility to help assure a safe and healthy environment for themselves and others. These responsibilities are detailed in the University of Michigan Academic Laboratory and Research Safety Policy, issued jointly by the Department of Occupational Safety & Environmental Health (OSEH) and the Office of Research Ethics & Compliance (UMOR). Please click on the Policy link to view role specific responsibilities including but not limited to the following categories:

- All faculty, staff, other employees and students
- Graduate Student Research Assistants/Trainees
- Post-Doctoral Trainee/Fellow
- Laboratory Director (Faculty/Lab Manager/Supervisor
- Department Chair
- Facility Managers/Department Managers/Key Administrators/Chief Department Administrators
- Unit (School/College/Department) Safety Coordinators

Additional responsibilities specific to the implementation of this guideline follow.

Laboratory Director

Implement and document appropriate safety policies and procedures in accordance with the U-M Chemical Hygiene Plan.

Ensure that adequate facilities, ventilation, and equipment are provided for the safe use of cryogens.

Ensure employees are instructed on and follow proper procedures and utilize protective equipment provided during their work as detailed in written SOPs.

Review chemical hazard information detailed on MSDS before beginning work with cryogens.

PROCEDURES:

Types of Cryogenic Liquids

Each cryogenic liquid has its own specific properties, but most can be placed into one of three groups:

Inert Gases: Inert gases in general are chemically non-reactive. They do not burn or support combustion. Examples of this group are nitrogen, helium, neon, argon, and krypton.

Flammable Gases: Some cryogenic gases produce a gas that can burn in air. The most common examples are hydrogen, methane, and liquefied natural gas.

Oxygen: Many materials considered as non-combustible can burn in the presence of liquid oxygen. Organic materials can react explosively with liquid oxygen. The hazards and handling precautions of liquid oxygen must therefore be considered from other cryogenic liquids.

Applications

Cryogenic Liquids have many applications including freezing and storing biological specimens, experimental applications, and superconducting electromagnets for particle acceleration.

Potential Hazards

The primary hazards associated with cryogenic liquids are: frostbite/cryogenic burns/hypothermia, asphyxiation, fire/explosion, sudden release of pressure, and structural embrittlement.

Frostbite/Cryogenic Burns: Cryogenic liquids and their associated cold vapors and gases can produce effects on the skin similar to a thermal burn. Brief exposures that would not affect skin on the face or hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite. Unprotected skin can stick to metal that is cooled by cryogenic liquids. The skin can then tear when pulled away.

***Asphyxiation*:** Cryogenic liquids have large liquid-to-gas expansion ratios and in confined or poorly ventilated areas the expanding gases will displace oxygen, presenting an asphyxiation hazard to personnel working in the area.

***Fire/Explosion*:** Oxygen has a higher boiling point (-183°C) than cryogenic liquids such as nitrogen (-195°C), hydrogen (-252.7), and helium (-269°C).

As a result of this disparity, oxygen can be inadvertently condensed out of the atmosphere during the use of these lower-boiling cryogenic liquids, resulting in the creation of highly hazardous oxygen enriched atmosphere that can greatly increase the risk of fire or explosion. Additionally, if a cryogenic liquid is subjected to a large amount of heat input, a flash vaporization can occur, resulting in a boiling liquid expanding vapor explosion (BLEVE). Liquid oxygen condensation in vacuum traps or from ice plug formation or lack of functioning vent valves in storage dewars can also pose a serious explosion hazard.

***Sudden Release of Pressure*:** Sealed containers or closed off piping systems that contain cryogenic liquids can rupture when the cryogenic liquids are allowed to warm to room temperature. The rupture results as the warming cryogenic liquids change to the gas state and expand, producing enormous pressure within the container or piping system.

***Structural Embrittlement*:** Materials that are normally structurally sound, such as carbon steel, zinc, plastic, and rubber, can become brittle and fail due to thermal stress fracturing when subjected to cryogenic temperatures.

Injury

Personnel should be aware of the hazards associated with handling and usage of cryogens. If a lab worker is injured, the person should seek immediate medical attention (Occupational Health Services or University Hospital Emergency Department). Their supervisor must complete a Work Connections Injury or Illness Report.

Personal Protective Equipment (PPE)

The extreme cold and unique properties of cryogenic liquids make strict observance of the use of proper personal protective equipment (PPE) an absolute necessity. Failure to use proper PPE while working with cryogens will result in severe injury or death.

***Eye/Face Protection*:** Safety Glasses and a face shield must be worn while dispensing cryogenic liquids. Never wear contact lenses while working with cryogenic liquids.

***Hand Protection*:** Hands must be protected with *cryogenic* gloves that fit loose enough to be quickly removed in case the liquid becomes entrapped close to the skin.

***Lab Coats/Aprons*:** A lab coat that can be easily removed must be worn over a long sleeve shirt and long pants without cuffs. The use of an apron made of non-woven material, such as leather, is also strongly recommended as a secondary form of protection when working with any more than just a few milliliters of cryogenic liquid. Short sleeved shirts and shorts offer no protection and must not be worn.

***Foot Protection*:** Closed toed leather or safety shoes that are impervious to liquid spills must be worn. Sandals or sneakers/gym shoes offer no protection and must not be worn.

Engineering Controls

Cryogenic liquids must only be used in well-ventilated areas. Large laboratory spaces, designed to have 6-12 air changes per hour, are generally acceptable. Users of cryogenic liquids must always consider the size of the room, amount of cryogenic liquid they are using, and be mindful of the ability cryogens have to create an oxygen-deficient atmosphere. In some circumstances, an oxygen monitor may be needed as an additional engineering control.

Routine Tasks and Maintenance Procedures

A. Use of Cryogenic Liquids

Cryogenic liquids have properties that make them more dangerous to use than other liquids: extremely cold temperatures, high liquid-to-vapor expansion ratios, and flammability for certain liquids.

Contact with cryogenic liquids, cryogenic equipment, or splashing liquid can cause severe tissue damage. Burns, frostbite, tearing of the flesh, and eye damage are all possible injuries. Vapors from boiling liquids can also cause eye damage, frostbite to the skin, and oxygen deficient environments.

To minimize exposure during use implement the following procedures:

- Perform a Personal Protective Equipment (PPE) assessment in accordance with the OSEH Personal Protective Equipment Guideline to determine the level of protection needed for the task.
- Where appropriate PPE as discussed in PPE section
- Do not wear jewelry or other materials that could trap liquid to the

skin if spilled.

- Stay out of the vapor pathway.
- Ventilate area in case of a spill or leak.
- Use fume hoods when working with cryogens if possible.
- Always use tongs when handling objects in liquid.
- 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.
- Periodically inspect equipment and remove ice and frost blockages from openings to prevent over pressurization.

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

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

B. Dispensing and Transport of Cryogenic liquids

Special precautions must be taken to prevent a spill while dispensing or 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 exposure:

- Always wear proper PPE when dispensing or transferring cryogenic liquids.
- When obtaining liquid from a large dispensing dewar or cryogenic liquid cylinder, cool the secondary container by adding a little cryogenic liquid first. Then:
  - Dispense slowly to mitigate thermal stress
  - Stay in constant attendance of the filling operation
  - Do not overfill
  - Do not allow the cryogenic liquid to fall through a distance to reach the receiving vessel
- When manually pouring liquid into a smaller dewar, ensure:
  - Secondary container is secured
  - Pour slowly to prevent excess splashing
  - Do not overfill
  - Use a phase separator, if available, to control the vapor path while pouring

- Use no fewer than two personnel to transport cryogenic liquids and use handcarts equipped with brakes for large dewars and cryogenic liquid cylinders.
- Never transport cryogenic liquids on an elevator with live passengers. When transporting cryogenic liquids via elevator the sender should remain outside the elevator, push the button for the desired floor and let the doors close. Another person should be ready on the receiving floor to take the container off the elevator. All elevator doors from the starting floor to the floor of final destination should be manned to prevent entry by anyone between floors.
- Always use care when handling equipment. Damage to dewars could result in the loss of vacuum in the jacket and increased evaporation.
- When carrying a dewar, wear PPE and hold it as far away from the face as possible. Containers that cannot be easily and safely carried should be placed on a stable wheeled base designed for the dewar.

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:

- 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.
- Store dewars in well-ventilated rooms with a minimum of six air changes per hour. If the ventilation rate is unknown, contact OSEH to evaluate the storage area.
- OSEH may recommend the installation of oxygen detection systems and alarms for cryogenic liquid storage areas depending on location, ventilation, and quantity of material stored.
- Bulk cryogenic liquid dispensing areas within buildings must also be well ventilated. OSEH recommends continuous oxygen monitoring equipment in these areas.
- Dewars and cryogenic liquid cylinders should be placed so that vents and openings are oriented away from personnel and lab equipment.
- Do not store cryogenic liquids with corrosive or flammable chemicals.

- Storage of cryogenic liquid cylinders or dewars in hallways, unventilated closets, environmental rooms, and stairwells is prohibited.
- No more than one backup dewar or cryogenic liquid cylinder is allowed per piece of equipment. Additional dewars or cryogenic liquid cylinders must be stored in areas designed for such storage. Contact OSEH at 763-6973 to evaluate potential storage locations.

D. Special Precautions for Flammable Liquids and Oxygen

Flammable cryogenic liquids like methane, hydrogen, and liquefied natural gas introduce an additional hazard. Oxygen does not burn, but accelerates and supports combustion. High concentration oxygen atmospheres substantially increase combustion rates of other materials and may form explosive mixtures with other combustibles.

It is important to implement the following procedures when using flammable cryogenics and oxygen.

- Contact OSEH at 763-6973 to assess engineering and work practice controls if you plan to work with these materials.
- There are several industry guidelines that refer to flammable liquids that should be considered in addition to these recommendations (see Related Documents).
- All combustible materials should be kept away from flammable liquids and oxygen. There should be "No Smoking" signs posted, and no sources of ignition should be present in this area.
- Oxygen dewars and equipment should be kept very clean and dry. Surface contamination could become ignited if oxygen leaks from the dewar and provides a local oxygen enriched area.
- Stationary equipment should be properly grounded and mobile equipment should be properly bonded when dispensing (See Related Documents for more detailed standards for electrical requirements).
- Valve operation should occur very slowly to prevent ignition of contaminants in the system.
- Hydrogen venting should be independent from other ventilation systems and may require a nitrogen purge capability.

E. Special Precautions for the Use of Cold Traps

Cold traps are used when using instrumentation, a building vacuum piab system, water aspirator, or a vacuum pump. Cold traps prevent the introduction of liquids and vapors into and out of the system by providing a low temperature surface for molecules to condense. When using liquid nitrogen (LN2) in cold traps, the following procedures must be implemented to prevent over pressurization and explosion:

- Do not open the system to the atmosphere until the trap is removed.
- In the event that the system is opened with the trap still in place, there is a possibility that oxygen will condense out of the air and combine with the organic material inside the trap.
  There are two possible scenarios that could result: it could immediately create an explosive mixture and explode, or the oxygen could stay condensed in the liquid. DO NOT RECLOSE THE SYSTEM. The condensed oxygen will vaporize after the trap is removed or the bath has evaporated resulting in an over pressurization and possible explosion.

F. Special Precautions for the Use of Cooling Baths

Cooling baths are used to maintain low temperatures, typically between 13 °C and −196 °C. These low temperatures are used to collect liquids after distillation, to remove solvents using a rotary evaporator, to perform a chemical reaction below room temperature, or to freeze cells. Cooling baths use ice, dry ice, or liquid nitrogen (LN2) mixed with a solvent to achieve the low temperatures.

- PPE for working with LN2 cooling baths should include safety glasses, face shield, insulated heavy gloves, a buttoned lab coat, closed toe shoes, pants with no cuffs, and a long sleeve shirt.
- Cool Dewar to mitigate stress.
- Add a small amount of liquid nitrogen to Dewar, then add remaining LN2, lastly add solvent to LN2.
- Liquid nitrogen can create an asphyxiation hazard by displacing oxygen from the room. Work only in a well-ventilated area.
- Always use tongs when handling objects in cooling bath.

G. Special Precautions for the Use of Cryotubes

- Cryotubes containing samples stored under liquid nitrogen may explode without warning. Tube explosions are caused by liquid nitrogen entering the tube through minute cracks and then expanding rapidly as the tube thaws.
- Cryogenic storage vials are designed for vapor phase storage in the extremely cold nitrogen gas that sits just above the reservoir of liquid nitrogen in the bottom of the freezer or dewar. If the

freezer/dewar is overfilled with liquid nitrogen and the vials are immersed, leakage of liquid nitrogen into the vial occurs. To avoid this problem do not overfill the freezer/dewar with liquid nitrogen and visually check each cryotube prior to filling to ensure there are no defects around the rim.

- Cryotubes should never be re-used.
- As a precaution, slowly remove vials from the dewar, holding the vial in the neck of the dewar for a moment before bringing them into room atmosphere. A tube that is going to explode will usually do so early in the warm-up process.
- PPE for thawing cryotubes should include safety glasses, face shield, insulated heavy gloves, a buttoned lab coat, closed toe shoes and pants.
- Cryotubes should be kept in a heavy, walled container or behind a safety shield while warming.

H. Emergency Procedures

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 cryogenic liquid cylinder could spill 180 L of LN2 - in gas form this 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:

- Periodic equipment inspections, removal of ice blockages, and replacement of damaged or old storage units will reduce the probability of the catastrophic failure of a storage unit. Ice blockages that prevent the container from venting properly can cause an explosion hazard. Contact OSEH immediately at 763-4568 if ice blockages are observed.
- 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 OSEH immediately to monitor oxygen levels in the area and determine when it is safe to re-enter.
- If experiencing symptoms such as lightheadedness, dizziness, or confusion, immediately seek fresh air and receive medical attention.

- 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). DPS should be immediately notified at 9-1-1 (if calling from a cell phone must notify dispatch that you are calling from U of M campus) to coordinate emergency rescue services. Over fifty percent of deaths associated with asphyxiation in confined spaces occur to would-be rescuers.
- Once personnel have been removed to fresh air, provide rescue breathing or CPR until paramedics arrive.

In the event of contact with cryogenic gases or liquid:

- 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.*
- Flush or soak the area with warm water (no greater than 105^{o}F).
- Do not apply dry heat or rub damaged flesh or eyes.
- Employees should notify their supervisor of injuries and report to Occupational Health Services or University Hospital Emergency Department for medical evaluation and follow-up. The supervisor must complete the Work Connections Injury and Illness form to report the incident.

TECHNICAL SUPPORT: OSEH (763-6973) will provide technical support for the proper use and storage of cryogenic liquids.