Cryogenics Safety Program

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UNIVERSITY OF NEW MEXICO
Department of Environmental Health and Safety

Casey Hall
Director

Zachary Peterson (Jul 5, 2023 09:26 MDT)

Zachary Peterson
Manager, Safety

Melissa Terry
Chemical Hygiene Officer

Viktor Gough (Jun 29, 2023 08:56 MDT)

Viktor Gough
Unit Administrator

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1	8/29/23	Changed title to Cryogenics Safety Program Added Definitions page Added an Introduction section Changed name of Section 1. Scope section to Scope & Applicability Changed name of Section 3. Hazard Data to Hazard Identification of Common Cryogenic Liquids + added more specific hazards and more detail Changed name of Section 4. General Safety Procedures to Hazard Control for Cryogenic Liquids + added more details on hazards Added a new Section 6. Transporting Cryogenic Liquids + guidance on this topic Refined language in Section 8. Information & Training Added more detail to Section 10.1 Spill Cleanup Procedures		M.Terry
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ACRONYMS & DEFINITIONS

EHS	Environmental Health and Safety
Asphyxiation hazard	The risk of death due to low oxygen concentration caused by the expansion of cryogenic gas and subsequent displacement of oxygen in a limited space
Cryogenic burn	Localized damage to skin and tissue due to contact with cryogenic liquids or materials
Cryogenic liquid	Any liquid with a boiling point below 93K (-180°C or -240°F) at 1 atmosphere of pressure. This includes but is not limited to liquid nitrogen, liquid helium, liquid oxygen and liquid argon
Cryogenic liquid cylinder	A pressurized double-walled vessel, evacuated between the walls that allows for the pressurized storage of cryogenic liquids for weeks or months. Either liquid cryogen or the gas phase may be extracted from a cryogenic liquid cylinder.
Dewar or cryogenic liquid dewar	A double-walled vessel, evacuated between the walls that provides thermal insulation to store liquid cryogens for days at a time. Dewars have loose fitting or vented caps to allow for escape of gas as the cryogenic liquid evaporates.
Dewar flask	A double-walled vacuum vessel with an open top. A loose-fitting foam lid may be provided to reduce evaporation rate.These flasks are intended for the open use of liquid cryogen and not for long-term storage.
Dry/vapor shipper	A double-walled vacuum vessel that contains an absorbent material capable of absorbing liquid cryogen and an internalspace for racks of samples that is capable of maintaining cryogenic temperatures of the samples during shipping, but which does not need to contain free liquid cryogen in order to keep samples cryogenically frozen. When properly used, dry/vapor shippers do not present a risk of cryogenic liquid spills.
Frostbite	Localized damage to skin and tissues due to exposure to freezing temperatures, often directly caused by a prolongedlack of blood flow to the area.
Oxygen deficiency hazard/ODH	A localized concentration of oxygen that is well below normal oxygen concentration in air. Any local oxygen concentration below 19.5% by volume is considered oxygen deficient.

Thermal stress	Stress that a material undergoes when it changes temperatures. As materials are heated and cooled, the contract and expand.

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1. INTRODUCTION

This program sets forth the safe handling, use and storage requirements for all persons who work with cryogens or operate cryogenic liquid handling systems at the University of New Mexico. This document is not a substitute for lab-specific and/or on-the-job training.

2. SCOPE AND APPLICABILITY

Cryogens and/or cryogenic liquids, for the purpose of this program, include the liquid phase of nitrogen, argon, helium, hydrogen and oxygen. Liquid nitrogen is the most frequently used cryogen at UNM.

This safety program applies to all occupational or research use of cryogens or cryogenic liquid handling systems at the University of New Mexico (UNM) campuses and properties by UNM employees, visitors, affiliates and contractors completing scopes of work for UNM.

3. RESPONSIBILITIES

3.1. Environmental Health and Safety

1) Preparing, reviewing and periodically revising this program
2) Monitoring compliance with this program
3) Providing general cryogenic liquid safety training
4) Consultation on safe usage of all highly toxic or highly hazardous gases
5) Investigating accidents

3.2. Deans, Directors, and Department Heads

1) Ensuring departmental compliance with all the procedures outlined in this program

3.3. Supervisors and PIs

1) Ensuring compliance with this program in their work area(s)
2) Developing Standard Operating Procedures (SOPs) that address the lab-specific safety measures to be implemented when using cryogenic liquids

3) Ensuring employees working around cryogenic liquids receive the appropriate training before handling and working with cryogenic liquids
4) Coordinating the provision of medical examinations, exposure monitoring and record keeping
5) Arranging for immediate emergency response, if necessary, for chemical spills, injuries and overexposures
6) Maintaining a Safety Data Sheet (SDS) for all cryogenic liquids used in the work area

3.4. Employees and Researchers

1) Knowing the provisions of the cryogenics safety program
2) Reporting accidents, possible exposures or unsafe conditions to their supervisor
3) Following proper safety protocols (lab-specific SOPs) when using cryogenic liquids
4) Utilizing engineering controls, administrative controls, and PPE

4. Hazard Identification for Common Cryogenic Liquids

4.1. Thermal (Low Temperature) Hazard

1) Contact can readily cause frostbite or cryogenic burns to eyes and skin
2) Release into the work area can damage equipment and property (e.g. frozen water pipes, damaged flooring, damaged electrical cables)

4.2. Pressurization and Venting

1) Cryogenic liquids confined and allowed to warm can generate very high pressures in excess of 10,000 psig.
2) The function of vent lines or pressure relief valves can be defeated by the formation of ice from condensed moisture.
3) If subjected to high heat, flash vaporization may occur, which can result in a rapid rise in pressure that can be described as a BLEVE (boiling liquid expanding vapor explosion).
4) Vents and pressure-relief devices must be vented to a safe location that can accommodate the presence of the specific cryogenic gases.

4.3. Oxygen Deficiency/Asphyxiation

1) Cryogenic liquids expand tremendously when changing from liquid to gas; the expansion ratios are as follows:
    a. LN2 is approximately 696 to 1
    b. LHe is approximately 757 to 1
    c. LAr is approximately 847 to 1
2) These ratios mean that any accidental release or overflow will quickly boil into gas and may create an asphyxiation hazard by displacing the oxygen concentration of the surrounding area.
3) Large-volume sources of cryogenic liquids stored and/or used in small laboratory spaces or in poorly ventilated areas increase the asphyxiation hazard. If oxygen levels could fall below 19.5% during routine operations, suitable control measures should be implemented (e.g. filling or storing dewars in a ventilated room, installing a permanent oxygen monitoring system or using smaller dewars).
4) An easy-to-use oxygen deficiency hazard (ODH) calculator developed by Lawrence Berkeley National Laboratory can be used to determine the need for an oxygen monitoring system in rooms where cryogenics are stored and/or used. The ODH calculator is included as Appendix A.

4.4. Oxygen Enrichment

1) Liquid nitrogen is cold enough to condense the surrounding air into a liquid form in which the oxygen concentration is approximately 50% (compared to 19.5% in ambient air); this “liquid air” will amplify any combustion and/or flammable hazards in the surrounding area.
2) Open dewars of liquid nitrogen can condense oxygen from the air into the liquid nitrogen, resulting in oxygen enrichment of the liquid with concentrations of oxygen as high as 80%.

4.5. Noise Hazard

1) Transfer or venting of cryogens can generate noise levels that may require hearing protection.
2) Sound levels in excess of 150 decibels have been recorded during routine tank filling.

5. HAZARD CONTROL FOR CRYOGENIC LIQUIDS

The hierarchy of controls methods are listed below in the order in which they should be implemented to reduce exposure to cryogenic materials. PPE is used as a last resort, in

an emergency, or as an extra layer of protection. PPE alone is not sufficient protection for employees working with cryogenic liquids.

5.1. Engineering Controls

In addition to the information below, lab-specific procedures (SOPs) must be followed.

1) Room Ventilation
    a. Cryogenic liquids must be stored in well-ventilated areas, such as a lab with an active fume hood or a room with a minimum of six air exchanges per hour.
    b. Containers should be stored away from air intakes, high traffic areas and floor drains.
2) Oxygen Sensors
    a. Oxygen concentration monitoring is required in small rooms or in rooms with poor ventilation to ensure that the oxygen concentration is maintained between 19.5% and 21%. Use the ODH calculator in Appendix A to determine if oxygen monitoring is required.
3) Pressure Relief Valves (PRVs)
    a. Containers/dewars must be equipped with a pressure relief valve which protects from over-pressurization.
    b. PRVs must be compatible with cryogenic temperatures and with the physical and chemical properties of the cryogen they are intended to vent.
    c. PRVs must not cease to function in extreme cold temperatures or be subject to failure from ice buildup.
    d. Not all cryogenic PRVs are suitable for all cryogenic gases; a PRV for liquid nitrogen may not function properly if used with liquid helium or liquid oxygen.
    e. Users must never attempt to replace or repair PRVs on cryogenic systems; contact the manufacturer of the system for repair or replacement.
4) Manual Shutoff Valves
    a. All cryogenic liquid systems which supply cryogenic liquid or vaporized gas from a cryogenic liquid source must be equipped with a manual shutoff valve that is accessible from the point of use.
        i. If the point of use is immediately near the main cylinder valve, then the main cylinder valve is considered to be a manual shutoff valve.

5.2. Administrative Controls

Administrative controls and SOPs should be in place to address all hazards in the lab. Common administrative controls for controlling the hazards of cryogenic liquids include:

1) Warning signs posted at entrance
2) Maximum quantity limits for room size
3) Written standard operating procedures (SOPs)
4) Mandatory training prior to working with cryogens
5) A 2-person rule/buddy system requirement
6) Limited access to cryogenic materials
7) Emergency response procedures in place

5.3. Personal Protective Equipment (PPE)

In addition to standard clothing required when working in a lab (long pants or equivalent and close-toed, non-perforated shoes), the following PPE is required when performing lab operations/tasks involving cryogenic liquids:

1) Safety glasses (if splash potential exists, use safety glasses + face shield instead)
2) Lab coat
3) Cryogen gloves
    a. Cryogen gloves should be made of non-porous material
    b. Should be loose-fitting and easy to remove
    c. Inspect before each use
    d. NOTE: Cryogen gloves are NOT meant to be submerged in a cryogenic liquid

6. SPECIAL HANDLING PROCEDURES:

1) Only work with cryogenic liquids in well-ventilated areas (such as a fume hood) to avoid localized oxygen depletion or buildup of flammable or toxic gas.

2) Wear cryogen gloves when dipping or inserting samples or equipment into cryogenic liquids.
3) When submerging a tool or sample into a cryogenic liquid, move slowly – the cryogen can boil violently and splash.
4) Cryogenic liquid cylinders and other containers (such as Dewar flasks) should be filled to no more than 80% of capacity to protect against thermal expansion.
5) Cryogenic liquid/dry ice baths should be open to the atmosphere to avoid pressure build up.
6) Keep dewar flasks loosely covered when not in use to prevent oxygen enrichment.
7) Keep liquid oxygen away from organic materials and ignition sources.
8) Cryotube thawing – when thawing cryotubes, place the cryotube in a heavy-walled container (e.g., a desiccator) or behind a safety shield to protect yourself in the event that the cryotube shatters.
9) Shield or wrap fiber tape around glass dewars to minimize flying glass and fragments should an explosion occur. Note: plastic mesh will not stop small glass fragments.
10) Immediately report defective or unsafe cryogenic equipment or systems to the PI or supervisor.

7. TRANSPORTING CRYOGENIC LIQUIDS

7.1. In Elevators

The transportation of cryogenic liquids in elevators poses a potential asphyxiation and fire/explosion hazard if people become trapped in an elevator with a container of cryogenic liquid.

1) Pressurized Cryogen Cylinders
    a. Passengers must not ride in an elevator with a pressurized cryogenic liquid cylinder under any circumstances; the elevator must be taken out of service and the pressurized cryogen cylinders sent to the appropriate floor in an unmanned elevator that is monitored by personnel at the elevator's entrance floor and exit floor.
    b. To take an elevator out of service:
        i. Post a clearly visible sign on the elevator doors, warning others not to enter the elevator while the cylinder is present
        ii. Post one person at the elevator door on the floor where the cylinder was placed in the elevator and post one person at the elevator door on the floor where the cylinder will be removed from the elevator; the intent is to not allow others to enter the elevator with the cylinder.

2) Low Pressure Cryogen Dewars

    a. It is always safer to *not ride* in an elevator with a cryogenic liquid dewar; use the instructions above to transport a low pressure dewar in an unmanned elevator.

    b. If it is not feasible to transport a low pressure dewar without riding in the elevator with it, a risk assessment should be performed to determine the oxygen deficiency hazard in the elevator in the event of a spill or in case a passenger is trapped in the elevator with the evaporating cryogen for a prolonged period. Call EHS at 505-277-2753 for assistance with a risk assessment.

7.2. In Vehicles

Although it is not illegal for UNM personnel to transport cryogenic materials in vehicles, EHS recommends that a viable alternative, such as a shipping service (e.g. FedEx or UPS), be utilized. If a viable alternative is not feasible, the general requirements for transporting cryogenic liquids are as follows:

1) Complete *Cryogenic Safety Training* on Learning Central
2) Use only double-walled, vacuum jacketed vessels with outer packaging that has sufficient cushioning and absorbent materials to protect the inner vessel from damage
3) Mark the outside of the packaging with the owner's contact information
4) Place the container upright in an open area such as the open bed of a truck
5) Secure the container against movement and tipping

8. STORAGE

Cryogenic liquid Dewars are to be stored in well-ventilated areas. Storage in unventilated closets, environmental rooms, and stairwells is prohibited.

1) Large Dewars must be tethered/anchored to a wall.
2) Store flammable cryogenic liquids and liquid oxygen away from combustible materials and sources of ignition.
3) Follow all storage guidance provided in the SDS for each cryogenic material.

9. EMPLOYEE INFORMATION AND TRAINING

Supervisors are responsible for ensuring that employees with potential exposure to cryogenic liquid are given the appropriate training before they begin working with or around cryogenic liquids. Appropriate training must include the following:

1) An online module entitled *Cryogenic Safety Training* is available through UNM Learning Central

Further lab-specific, on-the-job training must be done (e.g. reading SOPs and supervised handling of cryogenic liquids). Supervisors should conduct refresher training on the lab-specific SOPS on an annual basis.

10. Exposure Procedures (In Case of Emergency)

If skin or eye(s) comes in contact with a cryogenic liquid, rinse the area of skin under cool or warm water for fifteen minutes (do not use hot or cold water). DO NOT RUB OR MASSAGE AFFECTED AREAS— this can cause further tissue damage. Refer to the SDS for more specific instructions.

When medical attention is required, bring a copy of the SDS of the material to aid medical staff in proper diagnosis and treatment.

In cases of prolonged contact with cryogenic liquids, call 911 immediately. Prolonged contact will cause serious tissue damage, cryogenic burns and/or blood clots requiring more sophisticated medical treatment.

11. Spills

11.1. Spill Cleanup Procedures

1) In the event of a large spill (>1 gallon) of cryogenic liquid, the employee should restrict access to the spill area and dial 911.
2) A small spill or splash will rapidly evaporate into the atmosphere requiring no cleanup.
3) Report all spills to the lab supervisor and large spills UNM Environmental Health & Safety (EHS) at 505-277-2753.

11.2. Report Incident to Environmental Health & Safety (EHS)

As soon as it is safe to do so, report large spills to EHS at (505) 277-2753. If after regular business hours, call the EHS Duty Officer pager at (505) 951-0194 (enter your phone number and the Duty Officer will call you as soon as possible). Notify supervisor.

Be prepared to provide the following information:

1) Name and phone number of knowledgeable person who can be contacted
2) Name of chemical spilled, concentration and amount spilled (if known)

3) Number of injured, if any
4) Location of spill

12. REFERENCES

Stanford – General Use SOP for Cryogenic Liquids

University of Wisconsin – Cryogenic Liquids Policy

MIT – PSFC Cryogenic Liquids SOP

Airgas – Liquid Nitrogen SDS

Cryogenic Safety Program R1.1

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