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Safety Guidelines on **Cryogens and Compressed Gases**

National Institutes of Health • Office of Research Services (ORS) • Division of Safety (DS)

I. Introduction

A cryogen, or cryogenic liquid, is any liquid with a boiling point below 93K (-180°C or -240°F) at 1 atmosphere of pressure. The most common cryogens used in research laboratories are Liquid nitrogen (LN2), liquid helium (LHe), and occasionally liquid oxygen (LO2). Cryogenic liquids rapidly freeze human tissue, and they cause many common materials to crack or fracture under stress. All cryogenic liquids vaporize, generating large amounts of gases and may create an oxygen-deficient atmosphere. Toxicity is another hazard for cryogenic liquids like carbon monoxide, which can release large quantities of highly toxic carbon monoxide gas into the air. Cryogenic liquids with a boiling point below liquid oxygen can condense oxygen from the atmosphere. Violent reactions, e.g., rapid combustion or explosion, may occur if combustible materials encounter oxygen. Extreme care must be exercised when using liquid nitrogen as a cold trap coolant to avoid condensing liquid oxygen.

Compressed gases are defined as follows:

- A gas or mixture of gases enclosed in a container having an absolute pressure exceeding 40 psi at 70 deg. F (21.1 deg. C); or
- A gas or mixture of gases enclosed in a container having an absolute pressure exceeding 104 psi at 130 deg. F (54.4 deg. C) irrespective of the pressure at 70 deg. F (21.1 deg. C); or
- A liquid having a vapor pressure above 40 psi at 100 deg. F (37.8 deg. C) was estimated using the ASTM D-323-72 standard.

Compressed gas management is hazardous due to its unusual characteristics, such as pressure storage, flammability, and toxicity. Improper handling, storage, and use could lead to catastrophic events such as oxygen-depleted atmospheres, fires, or adverse health effects. A leaking compressed gas cylinder can penetrate through walls like a torpedo and cause structural damage, severe injury, and even death.

This document contains guidelines for proper storage, handling, use, and disposal of compressed gases and cryogens. This program has been established at the National Institutes of Health (NIH) to:

II. Purpose

- Guide management of compressed gases and cryogens in laboratory settings.
- Identify all hazards associated with compressed gases and cryogens.
- Guide monitoring (oxygen and other specialty gas monitoring) devices and management.

III. Scope

The policy of NIH is that special precautions are taken to ensure the safe use and storage of compressed gases and cryogens to minimize the risk of injury from falling cylinders and exposure to toxic chemicals. This policy applies to all NIH intramural research program personnel and contract staff supporting intramural research at NIH campuses in Maryland, Montana, and Arizona. Personnel at the NIEHS Research Triangle Park campus should refer to the policies established for their location. This policy does not supersede existing federal, state, or local applicable codes. Still, it is a supplement to clarify specific NIH requirements for the safe handling and storage of compressed gases and cryogens. Some hazardous materials may require additional precautions.

IV. Applicable Regulatory, Policy and Industry Standards

- Compressed Gases (General Requirements) are governed by OSHA 29 CFR 1910.101. There are additional requirements for specific compressed gases, such as acetylene, hydrogen, oxygen, and nitrous oxide under OSHA 29 CFR 1910.102. In addition, the US DOT Hazardous Materials Regulations (HMR) regulate the safe and secure transportation of hazardous materials in commerce (49 CFR 171-177).

- Occupational Safety and Health Administration (OSHA) Occupational Exposure to Hazardous Chemicals in Laboratories 29 CFR 1910.1450: contains requirements on laboratory use and scale for workers using hazardous chemicals in a laboratory setting.

- Occupational Safety and Health Administration (OSHA) Confined Space Standard 29 CFR 1910.146
  - "Hazardous atmosphere" means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of the ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness from one or more of the following causes:
    - (1) Flammable gas, vapor, or mist more than 10 percent of its lower flammable limit (LFL).
    - (2) Atmospheric oxygen concentration below 19.5 percent or above 23.5 percent.
  - Before an employee enters the space, the internal atmosphere shall be tested, with a calibrated direct-reading instrument, for oxygen content, flammable gases and vapors, and potential toxic air contaminants, in that order.

- Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard 29 CFR 1910.134:
  - "Oxygen deficient atmosphere" means an atmosphere with an oxygen content below 19.5% by volume.
  - All oxygen-deficient atmospheres shall be considered immediately dangerous to life and health (IDLH).

- **College of American Pathologists (CAP) Accreditation Program Requirements:
  - GEN.77550 Liquid Nitrogen and Dry Ice: Adequate policies, procedures, and practices are in place for liquid nitrogen and dry ice use.
  - GEN.84800 Environment Maintenance: There are oxygen sensors or sufficient airflow to prevent asphyxiation in areas where liquid nitrogen is used.

- National Institutes of Health Design Requirements Manual 13.10.7: Liquid Nitrogen (LN_2):
  - "Oxygen monitoring shall be provided in freezer rooms and other rooms where cryogenic fluids are supplied to warn of oxygen depletion…"

- NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals, 2015 Edition

- NFPA 55 Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks, 2015 Edition

- DOT 49 CFR 173 Hazardous Materials Transportation (https://www.fmcsa.dot.gov/regulations/hazardous-materials)

V. Responsibilities

Institute/Center (IC)

- Contact the Division of Safety (DS) to request a risk assessment for locations that use compressed gases and cryogenic liquids.
    - Notify the DS if significant changes in the volume of gas, work practices, or ventilation conditions occur in areas previously surveyed.
- As applicable, ensure proper oversight and maintenance of bulk storage tanks and delivery systems for compressed gases and cryogenic liquids.
- Ensure oxygen monitoring and any other required gas-specific monitoring devices are installed, maintained, and calibrated per the guidance in this protocol.
    - A service contract may be established with the manufacturer to meet these obligations.
    - The IC shall keep written or electronic records for all actions related to installation, calibration, maintenance, etc.
- Display all mandatory (Oxygen Monitoring Devices Signs)) signages (APPENDIX A) as applicable. Signage shall be displayed at easily viewable locations.
    - Conduct bulk tank inspections as detailed in Section VII "*Bulk Tank Inspection Schedule*". A service contract may be established with the manufacturer to meet these obligations.
    - The IC shall keep written or electronic records for all actions related to inspections, defects, maintenance, etc.

DS Industrial Hygiene and Campus Safety Branch (IHB)

- Develop guidelines and provide consultation on hazards associated with cryogens/ compressed gases and exposure control strategies.
- Develop criteria for the potential need for monitoring device(s) for oxygen deficient atmosphere or any chemical-specific monitoring requirements.
- Establish an inventory program for the locations and types of compressed gases/cryogens used in each location.
    - Conduct building surveys on a 3-year cycle to validate the inventory of oxygen monitoring devices and identify new locations where compressed gases or cryogenic liquids are used.
    - Provide guidance and oversight for DS technicians who provide program support in monitoring surveys.
- Perform risk assessments for locations to ensure proper storage, use, and management.
- Periodic review of the installed monitoring devices to ensure they are effective.
- Assist locations in preparation for accreditation inspections where compressed gas or cryogenic liquids storage and handling are part of the inspection.
- Provide support to NIH Office of Research Facilities (ORF) locations where oxygen-deficient or enriched areas may be present.
- Coordinate with NIH campus vendors to ensure the delivery locations are appropriate for the gas delivered.
- Provide consultation regarding the technical aspects of installation, maintenance, and calibration of monitoring devices.
- Annual review and update of this guideline.

Division of Safety (DS) Research Safety (RS) Personnel

- Provide consultation/guidance on hazards associated with cryogens/compressed gases and exposure control strategies.
- Assist in hazard recognition to determine the potential need for monitoring device(s), oxygen-deficient atmosphere, or chemical-specific monitoring requirements.
- Refer oxygen or other gas monitoring issues/inquiries to the DS Cryogen/Compressed gas Safety/Oxygen Monitoring Program Manager.

- Inspect laboratory locations that store/use compressed gases/cryogenic liquids to ensure implementation of regulatory guidelines and NIH policies.

VI. Ordering and Receiving

Before Ordering Compressed Gases and Cryogens:

- Review the Safety Data Sheet and other reference materials available to understand the physical and health hazards.
- Ensure that the planned storage/use locations have appropriate ventilation and meet other safety requirements to prevent injuries/exposures.
- Ensure compatible piping, regulator, etc., are available.
- If the gas is toxic, corrosive, flammable, etc., contact DS for a risk assessment.
- Train the laboratory staff on the hazards, pressure systems, regulators, etc.
- For the first time purchase compressed gases or cryogen, or store them in a new location, contact DS to perform a risk assessment of the area.

Before Receiving:

- Inspect all cylinders to ensure they are not damaged/dented and properly labeled. The color of the cylinder is not a reliable method for identifying the gas. Different suppliers may use different colors for cylinders of the same gas.
- Look for visible signs of leaks. Odor, visible fumes, or hissing sound can be signs of a leak.
- Make sure the hydrostatic pressure test stamped on the cylinder is within the required time (usually five years).
- Do not accept cylinders that are rusted, unlabeled, mislabeled, or damaged. They must be returned to the vendor right away.
- Once accepted, mark the cylinder as “Full” with the date received on it.
- All compressed gases received must be fabricated and labeled according to the specifications of the Department of Transportation (DOT) and the Occupational Safety and Health Agency (OSHA) regulations.

VII. General Guidelines for Managing Compressed Gases and Cryogens

A. Managing Cryogens

- Always store and use cryogens in well-ventilated areas. Only use manufacturer-rated containers that are specifically designed to hold cryogenic liquids. These containers should be insulated and impact-resistant, have handles (or secondary trays), and have a loose-fitting lid. Cryogen containers should have a relief valve to release pressure when the cryogen boils and releases gas over time. A damp cloth should be used to remove any ice or frost buildup on a pressure relief valve. When performing this task, appropriate PPE must be worn. Do not chip away ice that has built up on the pressure relief valve or piping. Do not plug, cap, seal, or remove any relief or venting device on cryogenic liquid storage containers.
- Never store cryogens in cold rooms.
- When using cryogen, wear appropriate personal protective equipment (PPE), such as safety goggles, cryogloves, and safety shoes, with proper lab attire. In addition to the PPE listed above, a face shield is required when dispensing cryogenic liquids into an open container. Never leave the area unattended during the manual filling of cryogenic liquid in dewars.

- Containers of cryogens must be transported, stored, and used at an upright position and firmly secured to prevent falling. Avoid excessive movement of the containers of cryogens, as this may cause pressure buildup and explosion. For details Refer to the fact sheet at https://ors.od.nih.gov/sr/dohs/Documents/cryogen-fact-sheet.pdf

B. Managing Compressed Gases

- All cylinders must be marked with a label or a tag specifying their contents.
- Safety Data Sheets (SDS) must be obtained and maintained for all compressed gases. SDSs can be obtained online or from the vendor.
- Only trained employees wearing appropriate PPE are allowed to handle compressed gas cylinders. Required PPE depends on the type of gas you are handling. Consult with DS for guidance. Compressed gas cylinders must be transported, stored, and used at an upright position and firmly secured to prevent falling.
- Never use a leaking, corroded, or damaged gas cylinder. Contact the supplier for immediate return.
- Never transfer gases from one vessel to another except for cryogenic liquids.
- Never use a gas cylinder without a regulator that is specifically designed for the gas inside the cylinder.
- Do not have full and empty cylinders connected to the same manifold or stored together.
- Keep the cylinder cap on when the cylinder is not in use (empty or full). A container that has held compressed gas is empty when the pressure in the container approaches atmospheric 40 CFR 261.7 (b)(2) .
- Do not purposely vent a cylinder.

C. General Storage Guidelines for Compressed Gases and Cryogens

- All compressed gases and cryogens including inert gases can displace oxygen to produce a localized oxygen-deficient atmosphere, therefore should not be stored/used in enclosed or confined spaces without proper ventilation.
- Signage should be posted near cryogenic storage freezers, compressed gas storage areas, and cryogenic liquid dispensing stations to remind users of appropriate PPE and safe work practices. Refer to APPENDIX A to select appropriate signage.
- Gas cylinders must always be secured in racks, holders, or clamping devices. Since gas cylinders come in different sizes, it is important to ensure the mounting brackets are placed at an appropriate height to safely secure the cylinder. Measure 2/3 up the straight side (distance below cylinder shoulder) of the cylinders to mark the height on the mounting wall for the mounting bracket. Fasten cylinders individually or up to a maximum of two cylinders of the same size within one chain/strap in a well-ventilated area.
- Cylinders secured near benchtops should be bolted at the benchtop or placed in a cylinder holder that is bolted to the floor.
- Close valves, and release pressure on the regulators when cylinders are not used.
- Minimize the number of gas cylinders present in the laboratory.
- Avoid storing cylinders near elevators, gangways, exits, or egress routes.
- Never store cylinders at extreme temperatures or near combustible materials. Keep heat sources, sparks, flames, and electrical circuits away from gas cylinders.
- Never store empty and full cylinders together and return cylinders without use for more than a year.
- Cylinders “not in use” shall not be stored in a laboratory unit. If necessary, one reserve cylinder may be maintained next to the cylinder that is in use. A cylinder shall be “in use” if it follows the following.
    - Connected through a regulator to deliver gas to a lab operation.
    - Connected to a manifold used to deliver gas to a lab operation.
    - A single cylinder is secured alongside the cylinder described above as the reserve.

D. Labeling and Signage

- Empty cylinders must be marked EMPTY and never stored along with full cylinders.
- Rooms or cabinets containing compressed gases must be conspicuously labeled COMPRESSED GAS.
- Areas of flammable and toxic gases must be posted with the hazard class, and emergency contact information (see signs E and F on page 16).
- Refer to APPENDIX A for details on required signage**.**

E. Storage and Handling of Specialty Gases

1. Facility Requirements

A continuously mechanically ventilated hood or other continuously mechanically ventilated enclosure is required for the storage and use of lecture bottles (typically 12-18 inches long and 1-3 inches in diameter) of the following types of gases:

- Gases that have health hazard ratings of 3 or 4.
- Gases that have a health hazard rating of 2 without physiological warning properties.
- Pyrophoric gases.

At a minimum, a continuously mechanically ventilated gas cabinet is required for the above gases in cylinders that exceed a lecture bottle size.

2. Maximum Internal Cylinder Volume per laboratory

Maximum allowed usage and storage of compressed gases are set for laboratory work areas by Fire Codes, and standards such as NFPA 45 and 55.

Class	Labs less than 500sq.ft	Labs greater than 500sq.ft
Liquefied flammable gas	1.2 sft^3	0.0018 ft^3 per sq.ft of lab space
Flammable gas	6.0 sft^3	0.012 ft^3 per sq.ft of lab space
Oxidizing gas	6.0 sft^3	0.012 ft^3 per sq.ft of lab space
Toxic gas	0.3 sft^3	0.0006 ft^3 per sq.ft of lab space
Corrosive gas	0.3 sft^3	0.0006 ft^3 per sq. ft of lab space

A maximum of 25 lecture bottles of all gases combined is specified for any laboratory area.

3. Flammable Gases

Follow the below guidelines while working with flammable gases. Acetylene, hydrogen, methane, etc. are some examples of flammables.

- PI must develop SOPs when using flammable gases in their research areas. These SOPs shall include emergency response and training for all involved employees. Only trained employees wearing appropriate PPE are allowed to work with Flammable gases.
- Flammable gases must be stored in well-ventilated areas away from flammable liquids, combustible materials, oxidizers, open flames, sparks, and other sources of heat or ignition. 20 feet or a noncombustible barrier having a fire rating of at least 1⁄2 hour is the minimum separation requirement for oxidizer gases.
- All piping and equipment associated with flammable gas systems must be grounded and bonded.
- Use spark-proof tools when working with, or on, a flammable gas cylinder or system.
- Post a warning sign (APPENDIX A) on access doors to areas where flammable gases are stored and used.

- Manifold systems must be designed and constructed by trained personnel. Consultation with the gas supplier and DS before installing manifolds is required.

4. Oxidizer Gases

Oxidizers are gases that can support and accelerate the combustion of other materials in the presence of an ignition source and fuel. Examples include oxygen and nitrous oxide.

Follow the below guidelines to work safely with oxidizer gases:

- Oxidizer gases shall be stored separately from flammable or combustible materials. 20 feet or a noncombustible barrier at least 5 feet high having a fire rating of at least 1⁄2 hour is the minimum separation requirement.
- Do not use oil or other hydrocarbon products to clean equipment containing oxidizer gases.
    - Gauges and regulators for oxygen use should be labeled with a warning statement - "Oxygen - Use No Oil."

5. Highly Toxic Gases

Toxic gases have a health hazard (HH) rating of 3 or 4, as defined by NFPA 704. Toxic effects of a substance can be either acute or chronic. Examples include arsine, phosphine, hydrogen sulfide, phosgene, and nitrous oxide.

DS must be notified before obtaining HH3 and HH4 gases (regardless of quantity). DS program manager can be notified at 301-496-3353.

Guidelines for working with toxic gases.

The PI is responsible for developing SOPs in consultation with DS. They are also responsible for training the employees on the use and management of toxic gases. These SOPs shall include emergency response and training for all involved employees. Only trained employees are allowed to work with highly toxic gases.

- Store all toxic gases with a health hazard rating of 3 or 4 in continuously, mechanically ventilated gas cabinets, or other exhausted enclosures. Exhausts must be vented directly to the outside. Lecture bottles of toxic gases must be kept in fume hoods. Container Storage Areas must be posted with the hazard signs (APPENDIX A)
- Work with toxic gases must be performed only under a certified fume hood connected to emergency power.
- Appropriate PPE must be always used while working with toxic gases. Consult with DS to identify appropriate PPE.
- A gas detection system with visible and audible alarms to detect the presence of leaks, etc. must be installed for all toxic gases with hazard rating 3 or 4 (in compliance with NFPA 55 Guidelines). Signage for monitoring systems must be posted outside the door (APPENDIX A). Contact DS to identify appropriate gas detection and monitoring systems.
- Emergency power must be provided to the gas cabinet exhaust, system shut-offs, monitoring, alarms, and associated components.
- Follow the manufacturer's guidelines for servicing and maintaining the gas detection and alarm system.
- All work involving toxic gases must be performed inside a certified chemical fume hood. The fume hood must be connected to emergency power.
- As per CGA 3.6.1, personnel handling and using poison gases should have immediate access to use gas masks or self-contained breathing apparatus approved by U. S. Bureau of Mines for the

service desired. Such equipment should be kept close by but kept out of the area of work to avoid contamination.

6. Corrosive Gases

Examples of corrosive gases include hydrogen bromide, hydrogen chloride, and ammonia. Cylinders of corrosive or unstable gases should be returned to the vendor when the maximum retention period expiration date has been reached. In the absence of this date, a 36-month interval should be used. In the case of hydrogen chloride and Hydrogen fluoride, the cylinder should be returned to the vendor after 2 years.

Special precautions for the use of corrosive gases:

- It is the responsibility of the PI to develop SOPs in consultation with DS and train the employees on the use and management of corrosive gases. These SOPs shall include emergency response, PPE, and training for all involved employees. Only trained employees are allowed to work with corrosive gases.
- Work only under a certified fume hood and always use the required PPE.
- An emergency shower and eyewash must be installed within 50 feet of where corrosive gases are used and the path to the fixture must not be hindered by obstructions.
- Post warning signs (Appendix A) on the door to alert everyone about the hazards.

7. Lecture bottles

Lecture bottles, just like regular cylinders, contain pressurized gases that pose hazards with the chemical composition of the gases, stored energy of compression, and the possibility of release. Lecture bottles present a potential hazard even for inert gases. All work with lecture bottles must follow the guidelines specified for cylinders of regular sizes. A maximum of 25 lecture bottles of all gases combined is specified for any laboratory area.

F. Transportation

When cylinders and tanks are being moved from a storage area into the laboratory or from one lab to another:

- Transport using a suitable hand truck specifically designed to transport gas cylinders with a chain and belt to secure the cylinder. Use hand trucks even for short distances.
- Never move without the cylinder cap in place and the cylinder is chained or otherwise secured to the cart.
- Do not lift cylinders by the cap.
- Avoid dragging or sliding cylinders.
- Once the cylinder reaches its destination, it must be secured to a wall, or other firm support.
- Use freight elevators to transport cylinders. When moving cylinders in an elevator, place the cylinder chained securely to the cart in the middle of the elevator with the cart handgrip. Do not use a passenger elevator to transport gas cylinders or cryogen tanks. It is a confined space that would be impossible to escape from if there were an accidental release of gases.

G. Oxygen Monitoring and other Monitoring Devices

Compressed gases and cryogens are simple asphyxiants, meaning they displace oxygen from the air when present in high concentrations. Displacing oxygen creates the potential for an oxygen-deficient atmosphere or hazardous atmosphere. OSHA specifies a hazardous atmosphere may include one where the oxygen concentration is below 19.5% or above 23.5%. In situations where oxygen levels exceed 23.5%, oxygen enrichment and other flammability hazards may be present. Areas where compressed gases and cryogens are handled may require oxygen monitoring. Using toxic gases might require additional chemical-specific

monitoring. Contact the Division of Safety (DS) Oxygen Monitoring Program Manager for concerns related to hazardous atmosphere.

Bulk Tank Inspection Schedule

Item	Inspection Interval
Valves and fittings for leaks and other malfunctions	Annually
Indicating gauges for malfunction	Annually
Relief valves and rupture discs to verify proper settings	2 years
Foundation anchors	5 years

VIII. Compressed Gas / Cryogen Related Emergencies

Reference: Safety Checks for Vacuum Insulated Cryogenic Tanks, British Compressed Gas Association (2014).
Emergency Response

All leaking gas cylinders are an emergency. Leaks, which occur away from the cylinder in gas lines, tubing, or apparatus: can generally be stopped by closing the main cylinder valve.

1. Compressed Gas Leak-Flammable, Toxic or Corrosive
   If there is a leak of a flammable, toxic, or corrosive gas outside of a ventilated enclosure that will contain the gas or a large spill or rupture of a cryogenic container, immediately activate the building fire alarm system and evacuate the building. Call the Fire Department Immediately.
   - Bethesda: call the NIH Fire Department at 301-496-2372 (301-496-9911 from a cell phone).
   - All other locations: call 911.

   • Evacuate the laboratory but have someone remain nearby at a safe distance to prevent the entry of others until an emergency response arrives.
   • Cold burns should be immediately flushed with tepid water or placed in a lukewarm water bath. Do not rub the skin to try to warm it.
   • Seek immediate medical attention – call 911 or report to your local OMS, depending on severity. When safe to do so, notify the supervisor and OMS (if the initial call was to 911)

2. Compressed Gas Leak – Inert gas
If closing the cylinder valve cannot stop the leak and it is an inert gas (e.g., nitrogen, argon, etc.), clear the affected area.
• Call the fire department for Bethesda Campus or 911 for satellite locations.
• Restrict access to the area.
• Contact your supplier and return all problem cylinders.

3. Oxygen Monitor Alarm Troubleshoot
   • Evacuate the lab.
   • Remain nearby to prevent others from entering.
   • Call the NIH Fire Department
     - 301-496-2372 (301-496-9911 with a cell phone) or 911 for off-campus sites
     - If levels stay above 18.5%, alarm will turn off. If oxygen levels are deemed safe by the fire department, first responders can manually turn the alarm off at or below 18.5%.
   • If the sensor is bad or the monitor has a maintenance issue:
     - Call your third-party vendor to address ASAP.
   • If you believe it is a false alarm:
     - DS can review procedures/change settings/modify work processes.
     - DS contact: (301) 451-5993.

4. Emergency Plan
   If your area is using compressed gas/cryogen, plans should be developed to address both minor and major leaks before using the gas. This plan should consider the nature of the gases being handled, which are their chemical and physical properties.
   At a minimum, the plan should specify the following:
   - Alarm System (if needed) & Evacuation Procedure.
   - Response Personnel.
   - Emergency Equipment.
   - Containment or disposal methods.

   Before use, consult DS for additional safety procedures and recommended methods for responding to leaks and emergencies. Emergency plans for toxic and flammable gases must have approval from DS.

IX. Training

Individuals using compressed gases and cryogens must be trained by the PI/Supervisor on safe use of compressed gases and pressurized systems. SOPs and SDS must be part of the training. Primary responsibility for specific operations training is with the employee's supervisor. DS may be consulted as necessary.

X. Disposal

Close the valve and place the safety cap and contact the vendor for returns.

XI. References

Standard Gas Cylinder Chart (for reference)

1. Compressed Gas Association: (http://cganet.com)
   CGA P-1, *2000. Safe Handling of Compressed Gases in Containers*
2. NFPA 45 *Standard on Fire Protection for Laboratories Using Chemicals*, 2015 Edition
3. NFPA 55 *Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks*, 2015 Edition
4. OSHA 29 CFR 1910.101 *Compressed Gases – General Requirements* (http://www.osha.gov)
5. DOT 49 CFR 173 *Hazardous Materials Transportation* (http://hazmat.dot.gov/)

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https://commons.lbl.gov/display/rpm2/Cryogenic+Liquid+Hazards+and+Controls (8 Dec 2023)

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NIH ORF Occupational Health & Safety Manual, Section 3-3 – Confined Space. https://orf.od.nih.gov/TechnicalResources/Documents/DRM/DRM1.503262020.pdf (8 Dec 2023)

Occupational Safety & Health Administration (OSHA). Permit Required Confined Spaces – 1910.146. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.146 (8 Dec 2023)

Occupational Safety & Health Administration (OSHA). Respiratory Protection Standard – 1910.134. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134 (8 Dec 2023)

Occupational Safety and Health Administration (OSHA) Occupational Exposure to Hazardous Chemicals in Laboratories 1910-1450. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1450. (8 Dec 2023)

APPENDIX A **Signage**

Instruction:

Additional signage is recommended in areas where compressed gases and cryogenic liquids are stored in publicly accessible locations, where cryogenic liquids are dispensed, and to increase awareness of safe handling and storage practices.

Sign A issues a caution about potential cold hazards in areas where cryogenic liquids are stored in public areas (e.g. hallways, freight elevator lobbies). Sign A should be posted near cryogenic liquid vessels in a position that allows for clear visibility to passersby. Sign A has a fillable component to insert at least two local emergency contacts (e.g. lab manager and PI).

Sign B provides information on appropriate Personal Protective Equipment (PPE) when handling cryogenic liquids (e.g. dispensing cryogenic liquids, storing or removing samples from cryo storage tanks). Sign C should be posted near cryogenic liquid vessels in a position that allows for clear visibility to users.

Sign C provides instruction on the safe handling and storage of compressed gases. Sign B should be posted near compressed gas storage areas in a position that allows for clear visibility to occupants.

Sign D provides information on safe dispensing of cryogenic liquids (e.g. filling liquid nitrogen dewars). Sign D should be posted at cryogenic liquid dispensing sites in a position that allows for clear visibility to users.

Sign E is the signage for the areas storing and using toxic gases. Additional signage for chemical-specific monitoring may be required for certain gases.

Sign F is the recommended signage for areas with flammable gases.

Sign G instructs room occupants to evacuate immediately if the alarm sounds. Sign G shall be posted as close as possible to each oxygen monitoring device in a position that allows clear visibility to the room occupants.

Sign H prevents additional personnel from entering a room with an alarm sounding and shall be posted on or adjacent to the outside of each entry door to a room with an oxygen monitoring device at approximately eye level. Sign H has a fillable component to insert at least two local emergency contacts (e.g. lab manager and PI).

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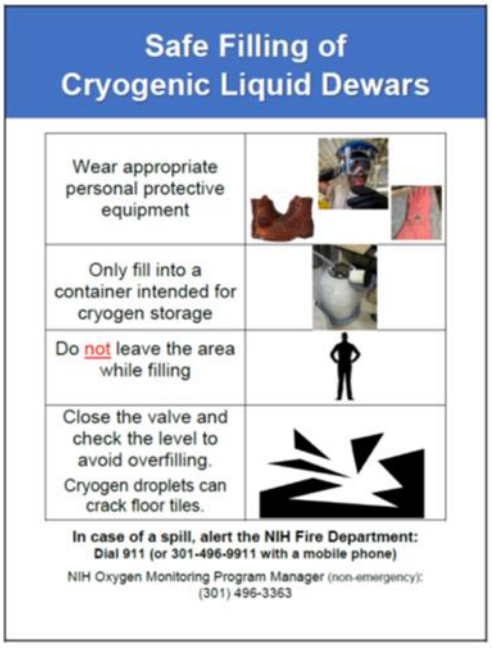
Sign A

Sign B

Sign C

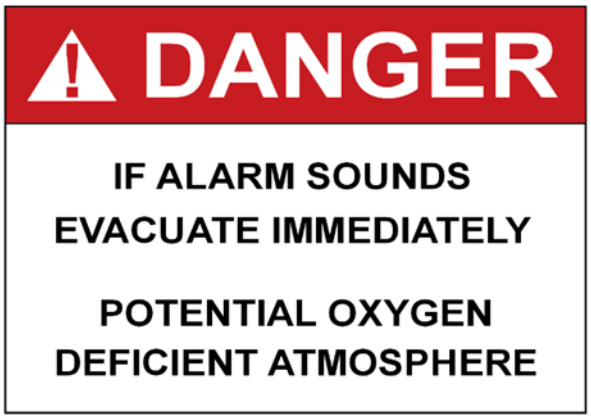
Sign D



Sign E

Sign F

Sign G



Sign H