National Institutes of Health

Protocol for Use and Maintenance of Oxygen Monitoring Devices

2021

Authored by the Division of Occupational Health and Safety (DOHS) Oxygen Monitoring Program Manager.

CONTENTS

ACRONYMS

BAS	Building Automation System
DOHS	Division of Occupational Health and Safety
DRM	Design Requirements Manual
IC	Institute/Center
MRI	Magnetic Resonance Imaging
NMR	Nuclear Magnetic Resonance
OSHA	Occupational Safety and Health Administration
PI	Principal Investigator
TEM	Transmission Electron Microscope
TAB	Technical Assistance Branch

INTRODUCTION

Compressed gases and cryogenic liquids (e.g. nitrogen, helium, carbon dioxide, oxygen and argon) may be used in laboratories and other locations for various applications and work procedures. Cryogenic liquids are gases that are kept in their liquid state through application of temperature and pressure. Their freezing properties are advantageous when storing laboratory samples and/or components, or to maintain extremely low temperatures and preserve superconductivity in magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) machines.

When cryogenic liquids are dispensed, they release vapors and gases with various properties. Nitrogen and helium gases, for example, are inert, colorless, odorless, noncorrosive and nontoxic. They are also simple asphyxiants, meaning they displace oxygen from air when present in high concentrations. Displacing oxygen creates the potential for an oxygen deficient or hazardous atmosphere, which is an occupational hazard. The Occupational Safety and Health Administration (OSHA) specifies that 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. Per the Lawrence Berkeley National Laboratory, cryogenic liquids may condense the surrounding air into a liquid form, which increase the oxygen concentration. This "liquid air" can be composed of up to 50% oxygen and will amplify any combustion/flammable hazards in the surrounding areas. Loose-fitting covers on storage dewars that allow for the gradual boil-off of gas and vacuum-jacketed/insulated transport lines will reduce this hazard. Compressed oxygen gas, liquid oxygen and liquid hydrogen also present additional combustion and flammability hazards.

Contact the Division of Occupational Health and Safety (DOHS) Oxygen Monitoring Program Manager for any concerns relating to hazardous atmosphere.

I. PURPOSE

This protocol has been established at the National Institutes of Health (NIH) to:

1) Provide guidance on the installation, maintenance, and calibration of oxygen monitoring devices in animal and laboratory areas in all NIH owned and leased buildings; and
2) Identify and list all device locations.

II. SCOPE

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. The following are common locations where compressed gases and/or cryogenic liquids are found, potentially creating a hazardous atmosphere:

- Magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) rooms;
- Cryogenic/Transmission Electron Microscope (TEM) rooms;
- Freezer and tank farms;
- Bulk storage tanks, particularly if kept indoors or outdoors below ground level; and
- Compressed gas manifold rooms or other compressed gas bulk storage.

Oxygen monitoring devices are recommended to be installed in these common locations, which could reside in animal, laboratory, and/or clinical areas. This recommendation is to meet general safety and health considerations and requirements in the NIH Design Requirements Manual (DRM) for Biomedical Laboratories and Animal Research Facilities as well as laboratories subject to College of American Pathologists requirements. Oxygen monitoring is often necessary for safe work within permit-required confined spaces. The permit-required confined spaces regulation may have some applicability and should be reviewed in conjunction with this protocol and the NIH Permit-Required Confined Spaces program.

III. APPLICABLE REGULATORY, POLICY, AND INDUSTRY STANDARDS

- **Occupational Safety and Health Administration (OSHA) Confined Space Standard 29 CFR 1920.146:**
    - "Hazardous atmosphere" means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of 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 in excess of 10 percent of its lower flammable limit (LFL)
        - (3) 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, for flammable gases and vapors, and for potential toxic air contaminants, in that order.
- **Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard 29 CFR 1920.134:**
    - "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 the use of liquid nitrogen and dry ice.

GEN.84800 Environment Maintenance

There are oxygen sensors or sufficient airflow to prevent asphyxiation in areas where liquid nitrogen is used.

**CAP Program Requirements apply to CAP-accredited programs only. Please contact the DOHS Oxygen Monitoring Program Manager at 301-496-3353 or OxygenMonitoring@nih.gov for more information.

- **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…"

IV. RESPONSIBILITIES

Institute/Center (IC):

- Contact the Division of Occupational Health and Safety (DOHS) to request a risk assessment for locations that use compressed gases and/or cryogenic liquids.
    - Notify the DOHS if significant changes in the volume of gas, work practices, and/or ventilation conditions occur in areas that have previously been surveyed.
- As applicable, ensure proper oversight and maintenance of bulk storage tanks and delivery systems for compressed gases and/or cryogenic liquids.
- Ensure oxygen monitoring devices are installed, maintained, and calibrated as per guidance in this protocol.
    - A service contract may be established with the manufacturer to meet these obligations.
    - The IC shall keep written and/or electronic records for all actions related to: installation, calibration, maintenance, etc.
- Display mandatory (see Appendix A) and recommended (see Appendix B) signage as applicable. Signage shall be displayed in easily viewable locations.
- Conduct bulk tank inspections as detailed in the Section V "*Bulk Tank Inspection Schedule*" below.
    - A service contract may be established with the manufacturer to meet these obligations.
    - The IC shall keep written and/or electronic records for all actions related to: inspections, defects, maintenance, etc.

Division of Occupational Health and Safety (DOHS) Safety Operations and Support Branch (SOSB) Safety Personnel:

- Assist in hazard recognition to determine the potential need for oxygen monitoring device(s).
- Refer oxygen monitoring issues and inquires to the DOHS Oxygen Monitoring Program Manager.

  NOTE: The SOSB Safety Specialist and the IC should review related health and safety considerations not specific to this protocol, such as the safe handling and storage of compressed gases and/or cryogenic liquids. For example, compressed gases should be stored upright and secured. As a result of the significant freezing hazards related to the handling of liquid nitrogen and helium, proper personal protection equipment (PPE)—such as, loose-fitting insulated gloves and goggles/face shields—must be worn when handling and dispensing these cryogenic liquids. Also, containers used to transport liquid nitrogen, such as dewars, should be used in a safe and appropriate manner.

DOHS Technical Assistance Branch (TAB) Oxygen Monitoring Program Manager:

- Conduct building surveys on a 3-year cycle to validate inventory of oxygen monitoring devices and identify new locations where compressed gases and/or cryogenic liquids are in use.
    - Provide guidance and oversight for DOHS technicians who provide program support in oxygen monitoring surveys.
- Perform risk assessments for locations where installation of a fixed oxygen monitoring device may be recommended.
- Assist locations in preparation for accreditation inspections where compressed gas and/or cryogenic liquids storage and handling are a component of inspection (i.e. College of American Pathologist accreditation).
- Provide support to NIH Office of Research Facilities (ORF) locations where oxygen deficient and/or enriched areas may be present.
- Coordinate with NIH campus vendors to maintain awareness of potential safety issues relating to storage and handling of compressed gases and/or cryogenic liquids.
- Provide support regarding the technical aspects of installation, maintenance, and calibration.
    - If the manufacturer is not retained to calibrate the units, the Oxygen Monitoring Program Manager will review accepted vendors to calibrate the units.
- Annually review and update this protocol.

V. TECHNICAL INFORMATION

Installation:

An oxygen monitoring device shall be installed in any indoor location where compressed gases and/or cryogenic liquids are stored and/or dispensed in manner that could create the potential for the displacement of oxygen. The NIH DRM notes that both "*carbon dioxide manifold rooms… [and] nitrogen holding rooms shall include oxygen level monitoring alarms*". At a minimum, the following factors should be used in determining if a device should be installed: manufacturer (e.g., magnet) guidance, volume of gas used, work practices, location of gas, and ventilation estimates in the room/area. Additionally, compressed gases or cryogenic liquids shall not be located or dispensed in any indoor location that does not have adequate ventilation.

The IC should contact their DOHS Safety Specialist and perform an assessment of the activities and area with respect for the need of an oxygen monitoring device. Compressed gases used for instrument calibration, for example, may not require the installation of an oxygen monitoring device.
The installation of the oxygen monitoring device will rely on the manufacturer's specific requirements and recommendations. Some of these requirements may include, but not be limited to:

1) Installing the device sensor(s) close to an area where a gas release would most likely occur;
2) Placing the device sensor(s) at the proper height depending on the density of the gas and the simulation of an individual's breathing zone;
3) Ensuring the device's display is accessible; and
4) Performing a leak test of the oxygen monitoring device's sample lines, system components and fittings.

<u>Alarm Notification</u>:

As per the manufacture's recommendation, a low oxygen alarm shall be installed along with the monitoring device to alert persons in the surrounding area of a hazardous condition. If possible, the monitoring device should also be interlocked with the building automation system (BAS). Where applicable, the device shall also be interlocked with an emergency exhaust fan or ventilation system that is located at the monitored location. An alarm will trigger emergency ventilation of the space. Alarms installed during new construction, or building alteration, should include both visual and audible warnings to notify occupants. If BAS interlocking is not possible, the alarm will alert local occupants but will not notify any emergency response systems.

<u>Alarm Setpoints</u>

OSHA specifies that a hazardous atmosphere may include one where the oxygen concentration is below 19.5% or above 23.5%. The device alarm and warning levels should be set according to these oxygen concentration levels.

If both oxygen enrichment and oxygen deficiency are a concern, the alarm setpoints should be set to reflect these levels. For oxygen monitors where multiple setpoints are possible, such as "Caution," "Warning," and "Alarm," setpoints can be programmed according to the hazards present in the environment. If oxygen levels reach the "Alarm" setpoint, the alarm in some oxygen monitors may "latch," and will not stop alarming unless physically reset. The "latch" setting is a safety feature that requires a physical check of the space to determine that it has been cleared of occupants in an emergency and that no one has been overcome by a hazardous atmosphere.

Maintenance and Use:

General maintenance/troubleshooting:

Any maintenance or repair on the monitoring device should only be performed by the manufacturer or manufacturer's representative using manufacturer specific replacement parts. Most oxygen monitoring devices require minimal periodic maintenance. The device itself can be periodically cleaned with a clean, dry cloth.

Sensor replacement:

Oxygen sensors are the main monitoring components of these devices. Sensor replacement is dictated by the manufacturer of the oxygen monitoring device. The scheduled replacement requirements should be noted by the IC during installation. For example, oxygen sensors on the MSA Toxgard® II Monitor typically last a maximum of two years. Some devices may also give a display reading when the sensor needs to be replaced. The IC shall have a program in place to track and ensure the proper maintenance of each monitor.

Calibration:

Calibrations are performed to verify the accuracy of the oxygen sensor, which is the main component of an oxygen monitoring device. There are generally two different types of calibrations: *initial* and *12-month interval*. *Initial* and *12-month interval* calibrations should be performed by the manufacturer or manufacturer's representative. Records shall be kept of all calibrations, preferably in a designated notebook located near the alarm (readily available to a spot check inspection).

Initial Calibration:

An initial calibration must be performed by the manufacturer or manufacturer's representative when an oxygen monitoring device and/or new oxygen sensor is installed.

12-Month Interval Calibrations:

These calibrations should be performed by the manufacturer or manufacturer's representative either every 12 months or per the recommendation of the manufacturer, whichever is more frequent. A more frequent calibration schedule may be necessary if readings are out of range.

The building automation system connection (BAS) and emergency exhaust fan, where applicable, should also be verified as operational during the 12-month interval calibration. Additionally, a leak check of the sample lines, system components and fittings should also be performed at the interval calibration.

If the manufacturer is not retained to calibrate the units, a third-party vendor must be retained to calibrate the units.

The IC shall keep written and/or electronic records for all actions related to: installation, calibration, maintenance, etc. Additional calibration stickers placed on/near the oxygen monitor are encouraged as a clear visual indicator of when the unit is due for calibration.

Daily Observation Checks:

The display/readout on the device should be visually checked daily to ensure that the device is functioning, and oxygen levels are within normal parameters.

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

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

Space intentionally left blank

VI. REFERENCES

College of American Pathologists (CAP). GEN.77550: Liquid Nitrogen and Dry Ice. https://www.cap.org/laboratory-improvement/accreditation/accreditation-checklists. (29 September 2020)

College of American Pathologists (CAP). GEN.84800: Environment Maintenance https://www.cap.org/laboratory-improvement/accreditation/accreditation-checklists. (29 September 2020)

Compressed Gas Association (CGA) P-12-2017 Safe Handling of Cryogenic Liquids. https://portal.cganet.com/Publication/Details.aspx?id=P-12 (29 September 2020)

British Compressed Gas Association (BCGA). The Safe Use of Liquid Nitrogen Dewars – Code of Practice 30. www.bcga.co.uk (29 September 2020)

Lawrence Berkeley National Lab Safety Manual. Chapter 29 Safe Handling of Cryogenic Liquids – Safety Manual.
https://commons.lbl.gov/display/rpm2/Cryogenic+Liquid+Hazards+and+Controls (29 September 2020)

Mine Safety Appliance Company (MSA). Monitoring for Oxygen Deficiency: MRI Units – Data Sheet. (March 2016)
http://s7d9.scene7.com/is/content/minesafetyappliances/Toxgard%20II%20MRI%20bulletin%20-%20EN (29 September 2020)

Mine Safety Appliance Company (MSA). Toxgard® II Monitor – Instruction Manual, Rev. 9.
http://s7d9.scene7.com/is/content/minesafetyappliances/Toxgard%20II%20Instruction%20Manual%20-%20EN (29 September 2020)

National Fire Protection Association (NFPA). Standard 45-2019. Standard on Fire Protection for Laboratories Using Chemicals.
https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=45 (29 September 2020)

National Fire Protection Association (NFPA). Standard 55-2020. Compressed Gases and Cryogenic Fluids Code. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=55 (29 September 2020)

NIH Design Requirements Manual (DRM). Section 13.10.7 Liquid Nitrogen (2016)
https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx (29 September 2020)

NIH ORF Occupational Health & Safety Manual, Section 3-3 – Confined Space. https://www.orf.od.nih.gov/TechnicalResources/Pages/DesignRequirementsManual2016.aspx (29 September 2020)

Occupational Safety & Health Administration (OSHA). Permit Required Confined-Spaces – 1910.146. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.146 (29 September 2020)

Occupational Safety & Health Administration (OSHA). Respiratory Protection Standard – 1910.134. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134 (29 September 2020)

Space intentionally left blank

APPENDIX A – MANDATORY SIGNAGE

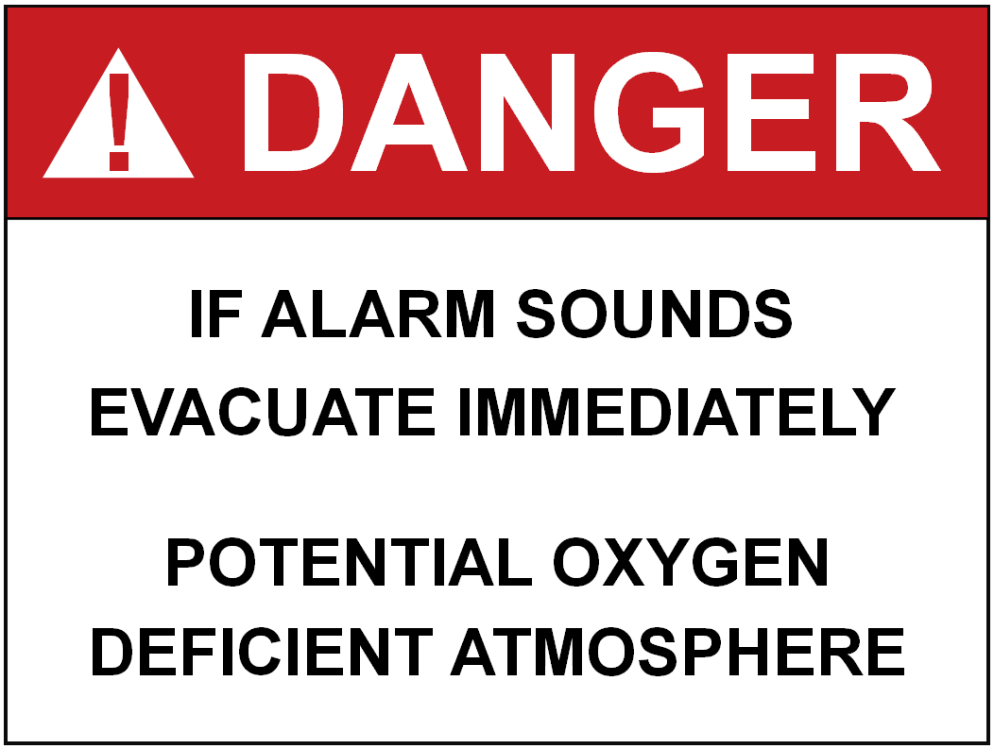
Instruction:

A minimum of two signs is required with every oxygen monitoring device installation:

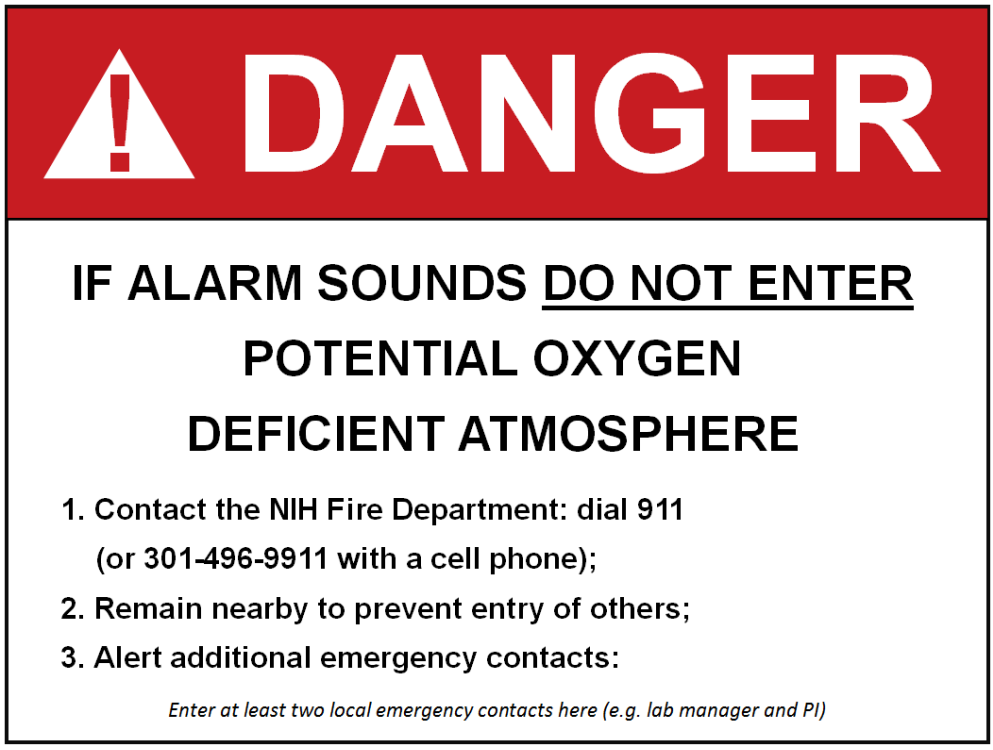
- Sign A instructs room occupants to evacuate immediately if the alarm sounds.
    - Sign A shall be posted as close as possible to each oxygen monitoring device in a position that allows for clear visibility to the room occupants.
- Sign B prevents additional personnel from entering a room with an alarm 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 B has a fillable component to insert at least two local emergency contacts (e.g. lab manager and PI).

Space intentionally left blank

Sign A:


DANGER
IF ALARM SOUNDS
EVACUATE IMMEDIATELY
POTENTIAL OXYGEN
DEFICIENT ATMOSPHERE

Sign B:


DANGER
IF ALARM SOUNDS DO NOT ENTER
POTENTIAL OXYGEN
DEFICIENT ATMOSPHERE
1. Contact the NIH Fire Department: dial 911
(or 301-496-9911 with a cell phone);
2. Remain nearby to prevent entry of others;
3. Alert additional emergency contacts:
Enter at least two local emergency contacts here (e.g. lab manager and PI)

APPENDIX B – RECOMMENDED SIGNAGE

Instruction:

Additional signage is recommended in areas where compressed gases and/or cryogenic liquids are stored in publicly accessible locations, where cryogenic liquids are dispensed, and/or to increase general 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 instruction on 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 C provides information on appropriate Personal Protective Equipment (PPE) when handling cryogenic liquids (e.g. dispensing cryogenic liquids, storing or removing samples from cryostorage tanks). Sign C should be posted near cryogenic liquid vessels in a position that allows for clear visibility to users.

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

Space intentionally left blank

Sign A:

CAUTION

COLD
HAZARD

CRYOGENIC LIQUIDS
STORED IN THIS AREA

Emergency Contact(s):

Enter at least two local emergency contacts here (e.g. lab manager and PI)

NIH Oxygen Monitoring Program Manager: (301) 496-3353

Sign B:

Compressed Gas Safety

Store-Separate-Secure-Inspect-Close

1. **Store** cylinders in cool, well-ventilated, fire-resistant areas in compliance with local, state and federal regulations.
2. **Separate** flammable gases from oxygen.
3. **Secure** cylinders vertically with restraints. Do not roll or drop cylinders.
4. **Inspect** cylinders for leaks and check support restraints regularly.
5. **Close** valves and tighten caps when not in use.

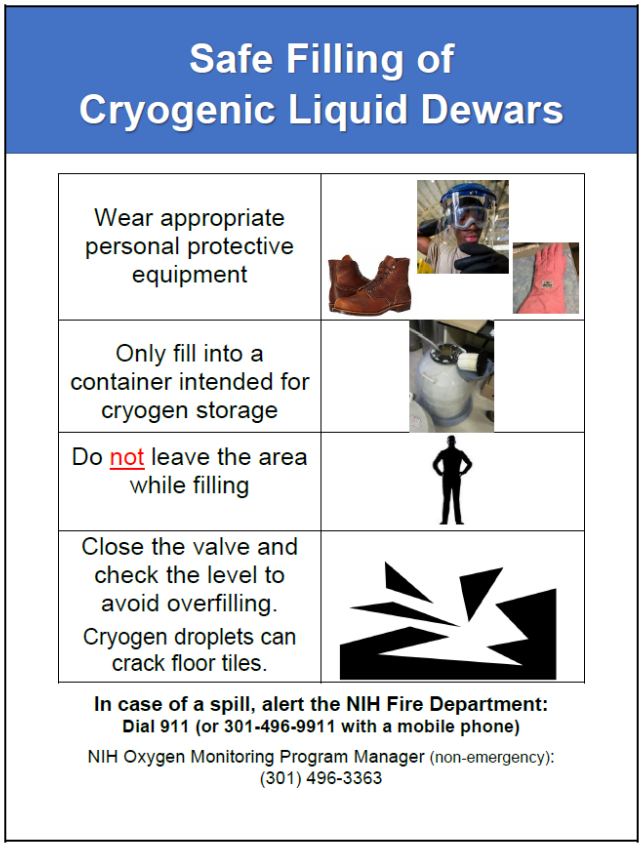
For questions or concerns, contact the
Division of Occupational Health and Safety's
Oxygen Monitoring Program Manager at (301) 496-3353

In case of a leak, alert the NIH Fire Department:
Dial 911 (or 301-496-9911 with a mobile phone)

Sign C:


CAUTION
COLD
HAZARD
APPROPRIATE PPE
REQUIRED WHEN USING
CRYOGENS
NIH Oxygen Monitoring Program Manager: (301) 496-3353

Sign D:


Safe Filling of
Cryogenic Liquid Dewars
Wear appropriate personal protective equipment
Only fill into a container intended for cryogen storage
Do not leave the area while filling
Close the valve and check the level to avoid overfilling.
Cryogen droplets can crack floor tiles.
In case of a spill, alert the NIH Fire Department:
Dial 911 (or 301-496-9911 with a mobile phone)
NIH Oxygen Monitoring Program Manager (non-emergency):
(301) 496-3363