INDIANA UNIVERSITY

OFFICE OF THE EXECUTIVE VICE PRESIDENT
FOR UNIVERSITY ACADEMIC AFFAIRS

Public Safety and Institutional Assurance
University Environmental Health and Safety

Compressed Gas Safety Program

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1. INTRODUCTION

Compressed gas is a generic term used for describing compressed gases, liquefied compressed gases, refrigerated liquefied gases (cryogenic gases), and dissolved gases. Compressed gases may also be referred to as gas cylinders.

1.1. Purpose

Indiana University Environmental Health and Safety (IUEHS) has developed this program to cover general procedures for the safe handling and storage of all compressed gases and provide recommended safe practices for the handling, storage, and transport of cylinders.

1.2. Scope

This program applies to all Indiana University (IU) faculty and staff that use, handle, store, or transport compressed gases.

2. AUTHORITY AND RESPONSIBILITY

2.1. University Environmental Health and Safety is responsible for:

- Developing the written Compressed Gas Safety Program and revising the program as necessary
- Developing a training program on the safe handling, use, storage, and transport of compressed gases
- Conducting routine inspections to ensure proper storage and usage
- Providing specific hazard control protocols, which include proper personal protective equipment (PPE), administrative controls, and engineering controls for the use and storage of toxic, reactive, corrosive, and other specialty gases as needed

2.2. Departments shall be responsible for:

- Understanding and complying with the requirements of this program
- Ensuring the proper handling, use, storage, and transport of compressed gases according to this program
- Developing emergency response procedures and training for specific gases, if required
- Training personnel on the safe use, handling, storage, and transport of compressed gases

- Contacting IUEHS if assistance is needed
- Informing IUEHS of any acquisition of toxic, reactive, corrosive, or other specialty gases and consulting with IUEHS regarding specific hazard protocols to be implemented for use and storage
- Maintaining an inventory of compressed gas cylinders, including their locations and volumes
- Developing protocols, in consultation with IUEHS and/or industry experts, for response to damaged, leaking, or otherwise malfunctioning cylinders, training personnel on these protocols, and ensuring that the protocols are posted or readily available to IU personnel or other responders
- Conducting regular evaluations of compressed gas inventories, and promptly returning or disposing materials that exhibit visible deterioration of either the cylinder or the manufacturer's markings or labels

2.3. Employees shall be responsible for:

- Completing online and building/laboratory specific training
- Complying with the procedures outlined in this program and any specific protocols developed for the gas being used
- Informing their supervisor of any problems, defective equipment, or lack of proper storage space for compressed gases used by them
- Inspecting cylinders before each use, and informing their supervisor of any visible signs of deterioration of the cylinders or their manufacturer's markings or labels

3. PROGRAM ELEMENTS

3.1. Inspection

When a gas cylinder is received, it shall be inspected by the user for the following:

- A stamped hydrostatic test date within the last five years
- A stenciled or labeled identification of its contents
- Expiration or shipped date
- Presence of a valve protection cap
- Signs of damage or leakage

If the test date, identification, markings, or cap is not in order, if the cap is rusted or inoperable, if the cylinder is damaged, or if the gas is expired, it shall be rejected or returned by the user. If an expiration or shipped date is not present, the user/purchaser shall record the received date.

Cylinders containing corrosive chemicals shall be periodically checked to ensure that the valve has not corroded.

3.2. Labeling

All compressed gases received, used, or stored must be labeled according to the United States Department of Transportation (DOT) and the Occupational Safety and Health Agency (OSHA) Hazard Communication regulations.

Each cylinder must be marked by label or tag with the name of its contents, either stenciled or stamped on the cylinder or printed on a label. The primary identifier of cylinder contents is the manufacturer's printed label. Do not accept cylinders without the appropriate labels. Never rely on the color of the cylinder for identification. Cylinder colors may vary depending on the supplier. Labels on caps have little value because caps are interchangeable.

All gas lines leading from a compressed gas supply shall be clearly labeled to identify the gas, with a label every 20 feet. If the gas line extends outside of the room the supply is located in, there shall be another label outside of the room.

When a cylinder becomes empty, it must be marked EMPTY.

Storage areas shall be prominently posted with the hazard class or the name(s) of the gas(es) stored.

3.3. General Precautions

There are two types of hazards associated with the use, storage, and handling of compressed gas cylinders: the chemical hazard associated with the cylinder contents (corrosive, toxic, flammable, etc.) and the physical hazard represented by the presence of a high-pressure vessel.

Compressed gas cylinders shall only be handled by those familiar with the hazards and who understand how to safely handle, transport, and store compressed gas cylinders. Safety Data Sheets (SDS) must be obtained and maintained for all compressed gases. Before using any compressed gas, be familiar with the SDS for the gas being used.

When using compressed gas cylinders, the following precautions shall be followed at all times:

- Only properly trained personnel shall handle and/or use compressed gas cylinders.
- Cylinders shall not be used as rollers, supports, or for any purpose other than to contain and use the contents as received.
- Employees and other personnel shall keep all open flames and oxidizing, flammable, and ignitable sources away from medical oxygen tanks, oxygen machines or concentrators, and oxygen tubing.
- Repair or alteration of compressed gas cylinders is prohibited.
- Cylinders shall not be placed where they might become part of an electrical circuit. When compressed gas cylinders are used in conjunction with electric welding, they shall not be grounded or used for grounding.
- Compressed gas cylinders shall not be exposed to temperature extremes.
- If compressed gas cylinders have been exposed to fire, contact the supplier immediately.
- All tubing shall be periodically checked for integrity. If tubing is damaged, cracked, or missing, it shall be removed from service until properly repaired or replaced.
- When a cylinder or valve is noticeably corroded, dented, cut, damaged, or involved in an accident, notify the supplier.
- Gases are not to be transferred from one vessel to another (except dry ice and cryogenic materials for research purposes and with IUEHS approval). Do not try to refill a compressed gas cylinder.
- Disposable gas cylinders, including lecture bottles, shall not be refilled.

3.4. Safe Handling of Cylinders

When handling and transporting compressed gas cylinders, the following shall be observed at all times:

- Move cylinders using a suitable hand truck or cart.

- Transport, store, and use cylinders upright (with the valve up). An upright position includes conditions where the cylinder may be reclined up to 45° from vertical.
- Securely fasten cylinders to prevent them from falling or being knocked over. Suitable racks, straps, chains, or stands are required to support cylinders.
- Never drop, bang, or strike cylinders against each other or other objects.
- Remove regulators and secure valve protection caps before moving cylinders.
- Do not lift or move the cylinder by the cap.
- Do not subject cylinders to rough handling or abuse.
- Handle only one cylinder at a time unless a two-cylinder cart is used and each cylinder is restrained by its own chain/strap.
- Transport cylinders only in freight/cargo elevators if they are available. Passenger elevators shall only be used when freight/cargo elevators are not present in the building.

3.5. Valve Protection Caps and Regulators

In order to preserve the integrity of compressed gas cylinders, the following shall be observed at all times:

- Valve protection caps for a cylinder shall always be in place and hand tight except when cylinders are secured, in use, or connected for use.
- Never force a cap. Only tighten a valve protection or cylinder cap by hand.
- Cylinder valves are to be protected with the standard cap when not in use (empty or full). Regulators are to be protected with covers where there is a likelihood of damage.
- Never use a cylinder without a regulator.
- Regulators are gas-specific and are generally not interchangeable. Make sure that the regulator and valve fittings are compatible.
- After attaching the regulator and before the cylinder valve is opened, check the adjusting screw of the regulator to see that it is released. Never permit the gas to enter the regulator suddenly.
- Never try to stop a leak between a cylinder and regulator by tightening the union nut unless the valve has been closed first.
- Never use adapters to fit valves to cylinders or regulators to valves.
- Disconnect cylinders if there is no planned use within the near future or semester.

3.6. Storage

Because of the high internal pressure in compressed gas cylinders, they can become projectiles if stored in a manner that could damage the valve. Leaking cylinders can also cause an atmospheric hazard or create an oxygen deficient atmosphere. Due to the hazards associated with compressed gas cylinders, the following rules for storing compressed gas cylinders shall be observed at all times:

3.6.1. General Storage Requirements

- All cylinder storage areas must be prominently marked with the hazard class or the name of the gases to be stored, e.g. Flammable Gas Storage Area signs posted where necessary. (HALS sign is sufficient)
- Always secure gas cylinders upright (with valve end up) to a wall, cylinder hand truck, cylinder rack or post, or a laboratory bench unless the cylinder is specifically designed to be stored otherwise. Both empty and full cylinders need to be secured. An upright position shall include conditions where the cylinder is inclined as much as 45° from the vertical. If being

secured to a laboratory bench, cylinder bench clamps can only be attached to a bench that is adequate to support the weight of the cylinder.

- Cylinders with a water volume less than 1.3 gallons (5 L) are allowed to be stored in a horizontal position.
- A chain, bracket, or other restraining device shall be used at all times to prevent cylinders from falling. The number of cylinders should not exceed restraint capacity. Restraints must be fastened on the upper half of the cylinder – above the center of gravity.
- Where gases of different types are stored at the same location, cylinders (empty or full) shall be grouped by the type of gas, e.g., flammable, oxidizer, or corrosive. Inert gases can be stored with any other type of gas.
- Full cylinders shall be stored separately from empty cylinders. Cylinders shall be used by the "first in, first out" guideline.
- Cylinders shall be stored in a well-ventilated area away from sparks, flames, or any source of heat or ignition.
- Cylinders containing flammable gases such as hydrogen or acetylene must not be stored in close proximity to open flames, areas where electrical sparks are generated, or where other sources of ignition might be present.
- Oxygen cylinders, full or empty, shall never be stored in the same vicinity as flammable gases or materials. The proper storage of oxygen cylinders requires a minimum of 20 feet between flammable gas and oxygen cylinders or the areas need to be separated, at a minimum, by a firewall five feet high with a fire rating of at least ½ hour.
- Greasy and oily materials must never be stored around oxygen cylinders and fittings must never be greased or oiled.
- Storage areas should be dry, well drained, ventilated, and fire-resistant.
- Cylinders may be stored outside on a slab, however, where extreme temperatures prevail, cylinders shall be stored so that they are protected from the direct rays of the sun. Do not expose cylinders to temperatures above 125° F. Cylinders shall not be exposed to continuous dampness or stored near salt or other corrosive chemicals or fumes. Corrosion may damage cylinders and cause their valve protection caps to stick.
- Never store cylinders, regardless of empty or full, in elevator lobbies, corridors, stairways, paths of egress, or any other location that could obstruct the safe exit pathway of the building occupants. Cylinders shall not be stored in front of fresh air intakes.

3.6.2. Oxygen-Fuel Welding Gas Storage

Oxygen behaves differently than other compressed gases. Typically, air contains about 21% oxygen, but even a small increase in the amount of oxygen in the air will result in increased flammability, even for materials that are not usually flammable. A fire burning in an oxygen-rich environment may also be extremely difficult to quench. The following rules for work with compressed oxygen-fuel should be observed at all times:

- Cylinders shall be kept away from radiators and other sources of heat.
- Inside of buildings, cylinders shall be stored in a well-protected, well-ventilated, dry location at least 20 feet from highly combustible materials such as oil or excelsior.
- Cylinders shall be stored in definitively assigned places away from elevators, stairs, or gangways.

- Assigned storage spaces shall be located where cylinders will not be knocked over or damaged by passing or falling objects or subject to tampering by unauthorized persons.
- Cylinders shall not be kept in unventilated enclosures such as lockers and cupboards.
- Empty cylinders shall have their valves closed.
- Valve protection caps, where cylinder is designed to accept a cap, shall always be in place and hand-tight, except when cylinders are in use or connected for use.
- Fuel-gas cylinder storage inside a building, except those in actual use or attached ready for use, shall be limited to a total gas capacity of 2,000 cubic feet or 300 pounds of liquefied petroleum gas.
- For storage in excess of 2,000 cubic feet total gas capacity of cylinders or 300 pounds of liquefied petroleum gas, a separate room or compartment shall be provided, or cylinders shall be kept outside or in a special building.
- Acetylene cylinders shall be stored valve end up. They contain acetone, which can discharge instead of or along with acetylene. Do not use an acetylene cylinder that has been stored or handled in a non-upright position until it has remained in an upright position for at least 30 minutes.
- The outlet line of an acetylene cylinder must be protected by a flame arrestor.
- Compatible tubing must be used to transport gaseous acetylene. Some tubing, such as copper, forms explosive acetylides.
- Oxygen cylinders shall not be stored near: reserve stocks of carbide and acetylene or other fuel-gas cylinders, an acetylene generator compartment, highly combustible material like oil and grease, or any other substance likely to cause or accelerate fire.
- Oxygen cylinders in storage shall be separated from fuel-gas cylinders or combustible materials (especially oil or grease), by a minimum distance of 20 feet or by a noncombustible barrier at least five feet high having a fire-resistance rating of at least ½ hour.
- Oxygen and acetylene may be stored together if it is reasonably anticipated that the gas will be used in the next 24 hours.

3.7. Compressed Gas Emergency Procedures

In the event of a leaking compressed gas cylinder, close the valve and call IUEHS. If the gas is flammable, corrosive, or acutely toxic, call 911/IUPD Dispatch and evacuate.

3.8. Disposal of Cylinders

Refer to your campus Waste Management Guide for information regarding disposal of compressed gases and pressurized liquids. Prior to vendor disposal or transfer to IUEHS, valves shall be closed and tightened, valve caps shall be replaced, and cylinders shall be marked as empty if empty. In addition, observe the following:

- Cylinders with hydrogen fluoride, hydrogen bromide, or liquid hydrogen cyanide shall be returned to the vendor within two years of the shipping date.
- Cylinders of corrosive or unstable gases shall be returned to the vendor when the expiration date or the maximum recommended retention period has been reached. If no maximum recommended retention time is provided by the vendor, a 36-month (three year) time limit, from shipping or received date, shall be used unless otherwise approved by IUEHS.
- All cylinders must be used or disposed of within 10 years, from shipping or received date, unless otherwise approved by IUEHS.

3.9. Specific Gases Handling Procedures

Many gases fall into multiple hazard classes. Please ensure that guidelines and recommendations are followed for each hazard class to which a compressed gas cylinder belongs.

3.9.1. Flammable Gases

The following information applies to the use and handling of flammable gases. Some common examples of flammable gases include acetylene, hydrogen, methane, propane, and isobutane.

- Flammable gases must be stored in well-ventilated areas away from flammable liquids, combustible materials, oxidizers, open flames, sparks, or other sources of heat or ignition.
- No more than two cylinders can be manifolded together, however, several instruments or outlets are permitted for a single cylinder.
- A portable fire extinguisher (carbon dioxide or dry chemical powder type) must be available for fire emergencies where flammable gas is stored. Contact IU's Office of Insurance, Loss Control & Claims for guidance on the type, quantity, and distance of fire extinguisher.
- "Flow" experiments with flammable gases are not to be left unattended. An explosimeter or combustible gas alarm may be required.
- Spark-proof tools shall be used when working with flammable gas cylinders.
- In the event of an emergency involving a flammable gas, such as a gas leak, fire, or explosion, personnel must immediately evacuate the area. Do not attempt to extinguish burning gas if the flow of product cannot be shut off immediately without risk.
- Flames involving a highly flammable gas must not be extinguished until the source of the gas has been safely shut off as the gas can reignite and cause an explosion.
- All lines and equipment associated with flammable gas systems must be grounded and bonded. Do not ground to an electrical outlet.
- Acetylene shall not be utilized in lines or hoses at a pressure exceeding 15 psi.

3.9.2. Oxidizing Gases

The following information applies to the use and handling of oxidizing gases. Some commonly used oxidizing gases include oxygen, chlorine, nitrous oxide, and compressed air.

- All equipment used for oxidizing gases must be cleaned with oxygen compatible materials free from oils, greases, and other contaminants (hydrocarbons and neoprene are not oxygen-compatible; PTFE Teflon is compatible). The equipment must state that it is oxygen compatible. Do not handle the cylinder with oily hands or gloves.
- Oxidizers shall be stored separately from flammable gas cylinders or combustible materials. A distance of 20 feet or a noncombustible barrier at least five feet high and having a fire rating of at least ½ hour is the minimum separation requirement.
- Oxygen and acetylene may be stored together if it is reasonably anticipated that the gas will be used in the next 24 hours.

3.9.3. Corrosive Gases

The following information is provided for corrosive gases. Examples include chlorine, hydrogen chloride, fluorine, hydrogen fluoride, hydrogen sulfide, carbon monoxide, and carbon dioxide.

- Keep exposure to gas as low as possible. Use in a fume hood or other vented enclosure when possible. Avoid contact with skin and eyes.
- Wear safety goggles when handling compressed gas cylinders that contain corrosives. Safety glasses equipped with side shields are not sufficient protection from corrosive gases.
- An emergency shower and eyewash must be installed within 10 seconds of areas where corrosive materials, including corrosive gases, are used. Safety showers and eyewashes must be free of obstructions at all times.
- An emergency response procedure must be in place and everyone working in the area must be trained on the procedure.

3.9.4. Toxic and Highly Toxic Gases

The following information applies to the use and handling of toxic gases. Examples include chlorine, fluorine, phosgene, and nitrogen dioxide.

- Toxic and highly toxic gases shall not be stored or used outside of laboratories.
- Large cylinders of toxic and highly toxic gases may be required to be stored in gas cabinets, exhausted enclosures, or gas rooms.
- Keep exposure to toxic and highly toxic gases as low as possible. Use in a fume hood or other vented enclosure when possible. Avoid contact with skin and eyes.
- A gas detection system with visible and audible alarms to detect the presence of leaks may need to be installed for toxic and highly toxic gases that exceeds the maximum allowable quantities.
- Contact IUEHS if assistance is needed or for specifics on gas monitoring system requirements and maximum allowable quantity limits.
- An emergency response procedure must be in place and everyone working in the area must be trained on the procedure.

3.9.5. Cryogenic Liquids and Asphyxiant Gases

Due to their large expansion rate, cryogenic liquids have the potential to create an oxygen deficient atmosphere when released if not properly managed and controlled. Normally air is comprised of nitrogen (78%), oxygen (21%), and argon (0.9%), with the remainder being a mixture of gases. An oxygen deficient atmosphere is “an atmosphere containing less than 19.5% oxygen by volume.” An oxygen deficient atmosphere can cause asphyxia in two ways: sudden or gradual. Humans vary considerably in their reaction to oxygen deficient atmospheres and it is not possible to predict exactly how they will react. However, a general indication of what may happen is listed below:

i. Sudden and acute asphyxia would occur from the inhalation of little to no oxygen. At levels below 16%, impaired perception and judgement, fatigue, and poor muscular coordination would impede self-rescue due to being wholly unaware that anything is wrong. Unconsciousness without warning would be immediate upon one breath of oxygen concentrations at levels below 10%. Due to impairment, a person exposed to this environment could not evacuate or use an air-line respirator or self-contained breathing apparatus (SCBA). Sudden asphyxia may occur with a large release of an asphyxiant gas such as LN_2.

ii. Gradual asphyxia can occur at any level below 20.9%. Symptoms of hypoxia (i.e. reduced oxygen to tissue), such as accelerated breathing and heart rate, are more severe at levels closer to 17% although these symptoms may vary with individuals. A feeling of euphoria can set in during hypoxia, making the victim unaware of the danger and need to self-rescue. Gradual asphyxia may occur during an increased use of gaseous or liquid nitrogen, as cylinders normally relieve pressure, or if valves or fittings freeze and stick open.

Cryogenic liquids and their boil-off vapors rapidly freeze human tissue and cause embrittlement of many common materials that may crack or fracture under stress. All cryogenic liquids produce large volumes of gas when they vaporize (at ratios of 600:1 to 1440:1, gas: liquid). This may create oxygen deficient conditions as cryogenic liquids displace oxygen from the air, as well as oxygen rich conditions as cryogenic liquids condense oxygen from the atmosphere. An oxygen deficient atmosphere presents a risk of asphyxia while an oxygen rich environment results in increased fire and explosion hazards as even non-flammable items may burn in an excess of oxygen. Pressure is also a hazard because of the large volume expansion ratio from liquid to gas that a cryogen exhibits as it warms and the liquid evaporates. This expansion ratio also makes cryogenic liquids more prone to splash and therefore skin and eye contact is more likely to occur.

Properties of Common Cryogenic Liquids

Gas	**Boiling Point °C (°F)**	**Liquid to Gas Volume Expansion Ratio**
Helium	- 268.9 (- 452)	1:757
Hydrogen	- 252.7 (- 423)	1:851
Nitrogen	- 195.8 (- 321)	1:696
Fluorine	- 187.0 (- 307)	1:888
Argon	- 185.7 (- 303)	1:847
Oxygen	- 183.0 (- 297)	1:860
Methane	- 161.4 (- 256)	1:578

Note: Absolute zero = - 273.15°C (- 459.67°F)

3.9.5.1. Handling

The following information applies to the use and handling of cryogenics:

- Appropriate PPE must be worn when handling cryogenic liquids. This includes special cryogen gloves, safety goggles, full-face shield, impervious apron or coat, long pants, and full coverage shoes. Gloves must be impervious and sufficiently large to be readily removed should a cryogen be spilled. Watches, rings, and other jewelry should NOT be worn to avoid bonding to the skin.
- Unprotected body parts must not come in contact with vessels or pipes that contain cryogenic liquids because extremely cold material may bond firmly to the skin and tear flesh if separation is attempted.

- Objects that are in contact with cryogenic liquid must be handled with tongs or proper gloves.
- All equipment should be kept clean, especially when working with liquid or gaseous oxygen.
- Work areas must be well ventilated.
- Transfers or pouring of cryogenic liquid must be done very slowly to minimize boiling and splashing.
- Cryogenic liquids and dry ice used as refrigerant baths must be open to the atmosphere. They must never be in a closed system where they may develop uncontrolled or dangerously high pressure.
- Liquid hydrogen must not be transferred in an air atmosphere because oxygen from the air can condense in the liquid hydrogen presenting a possible explosion risk.
- Keep liquid oxygen cylinders, piping, and equipment clean and free of grease, oil, and organic materials.
- All precautions should be taken to keep liquid oxygen from organic materials; spills on oxidizable surfaces can be hazardous.

3.9.5.2. Ventilation

Cryogenic liquids should be used and stored in well-ventilated areas. If large quantities of gases are present, risk can be mitigated through ventilation. Cryogenic liquids must not be stored or used in rooms that are not ventilated, such as cold rooms and warm rooms. It is recommended that laboratories with cryogenic liquids maintain a minimum air exchange of six air changes per hour. Hallways storage closets must not be used for human occupancy and must be used only for storage of cryogenic liquids and not for dispensing. If the air exchange rate is unknown in rooms at or above ground level, natural ventilation will typically provide one air change per hour.

3.9.5.3. Use and Storage

A cryogenic cylinder or dewar will release gas due to the normal evaporation of the cryogenic liquid over time. This information should be obtainable from the manufacturer however, it is typically 1-2% of the liquid capacity of the vessel over 24 hours. If cryogenic liquids are dispensed, this will increase the release of the cryogenic gas as compared to the natural evaporation rate from the cylinder. The expected loss during filling of a smaller, transfer dewar from a larger, storage cylinder is assumed to be 10%.

- Cryogenic liquids must be handled and stored in containers that are designed for the pressure and temperature to which they may be subjected. The most common container for cryogenic liquids is a double-walled, evacuated container known as a dewar. Thermoses are not approved.
- Containers and systems containing cryogenic liquids must have pressure-relief mechanisms.
- Coolers and Styrofoam boxes may be used for storage of small amounts of solid carbon dioxide (dry ice) only. Do not use coolers and Styrofoam boxes as the primary container for the transportation and storage of liquid cryogens.
- Cylinders and other pressure vessels such as dewars used for the storage of cryogenic liquids must not be filled to more than 80% capacity to protect against possible thermal expansion of the

contents and bursting of the vessel by hydrostatic pressure. If the possibility exists that the temperature of the cylinder may increase to above 30°C (86°F), a lower percentage (e.g., 60% capacity) should be the limit.

- Dewar flasks used for small volumes and transport should be shielded with tape or wire mesh to minimize flying glass and fragments should an implosion occur.
- Dewars must be labeled with the full cryogenic liquid name and should be labeled with hazard warning information.
- Work and storage areas must be well ventilated. Do not store cylinders or dewars in environmental chambers that do not have fresh air ventilation as leaks or venting from the container could cause an oxygen deficient atmosphere.
- Evaporation of liquid cryogens will displace oxygen in the room and may present an asphyxiation hazard. Air contains about 21% oxygen and breathing air with less than 19.5% is considered a dangerous oxygen deficient atmosphere. Concentrations of 18% can cause dizziness and result in unconsciousness and death.
  - Note: The cloud that appears when liquid nitrogen is exposed to air is condensed moisture in the atmosphere. Gaseous nitrogen is invisible.
- Do not store cryogenic dewars in walk-in refrigerators or cold rooms. These spaces typically only receive fresh air when the door is opened, thus evaporating liquid cryogens could displace enough air to create an oxygen deficient atmosphere.

3.9.5.4. First Aid Treatment for Cold-Contact Burns:

- Remove any clothing not frozen to the skin that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result.
- Place the affected part of the body in a 100-105°F warm water bath (not to exceed 44°C or 112°F).
- Never use dry heat.
- Obtain medical assistance as soon as possible.

3.9.5.5. Oxygen Monitoring and Depletion

An oxygen-monitoring device may add value and improve safety in some circumstances. A hazard assessment should be conducted by IUEHS for small or under-ventilated locations and other locations where there may be a possibility of an oxygen deficient hazard, to determine if oxygen alarms or other mitigation is needed. Oxygen alarms are not necessary in laboratories if the lab is appropriately sized and has sufficient continuous mechanical ventilation.

A hazard assessment must also be conducted for all bulk storage areas to determine the need for oxygen alarms or other mitigation. These spaces can be rooms with multiple liquid cylinders, multiple cylinders connected through manifolds, or multiple cylinders equal to or greater than 230 L in size. If there are additional concerns then IUEHS may perform monitoring during high risk procedures such as filling dewars from a large storage cylinder.

If the calculated room oxygen concentration from the normal evaporation of a cryogenic liquid during storage or when dispensing is 19.5% or less or a large external supply tank is used, then IUEHS will evaluate the space to determine if oxygen monitoring will be required. IUEHS will determine the type, location, and number of oxygen monitors needed.

Because the potential for catastrophic failure of a DOT-type cylinder is low, the natural evaporation rate is used to calculate the impact of cryogenic liquid storage on oxygen levels in a room. The new DOT-type cylinders are designed to withstand the standard DOT drop tests of four feet, so tipping or falling on their sides will unlikely release contents. Failures would most likely be due to human error or accidents like a forklift tine hitting the cylinder or another blunt force puncture of the double walled cylinder.

Liquid Nitrogen oxygen depletion during storage:

$$\%\ \boldsymbol{O_2\ depletion} = \frac{\mathbf{21 * 2 * 696}\ \boldsymbol{L} * \left(\frac{\mathbf{0.02} * \boldsymbol{V_{vessel}}}{\mathbf{24}\ \boldsymbol{hrs}}\right) * \frac{\mathbf{1}\ \boldsymbol{m^3}}{\mathbf{1000}\ \boldsymbol{L}}}{\boldsymbol{V_{room}} * \boldsymbol{ACH}}$$

Where:

21	= Normal % concentration of O_2 in air
2	= Doubling factor that accommodates the deterioration of vessel insulation
696	= N_2 liquid-to-gas expansion ratio (1 L liquid = ~696 L gas)
0.02	= Estimated evaporation from a vessel over 24 hours (2% total V_{vessel})
V_{vessel}	= Total volume of cryogenic vessel(s) in liters (L)
V_{room}	= Volume of the room (m^3)
ACH	= Air changes per hour (hr^{-1})

$$\%\boldsymbol{O_2\ concentration} = \mathbf{21}\% - \%\ \boldsymbol{O_2\ depletion}$$

Liquid Nitrogen oxygen depletion during transfer:

$$\%\ \boldsymbol{O_2\ depletion} = \frac{\mathbf{21} * \left[\boldsymbol{V_{room}} - \left(\mathbf{0.1} * \boldsymbol{V_{vessel}} * \mathbf{696}\ \boldsymbol{L} * \frac{\mathbf{1}\ \boldsymbol{m^3}}{\mathbf{1000}\ \boldsymbol{L}}\right)\right]}{\boldsymbol{V_{room}}}$$

Where:

21	= Normal % concentration of O_2 in air
696	= N_2 liquid-to-gas expansion ratio (1 L liquid = ~696 L gas)
0.1	= Estimated evaporation from a vessel while filling (10% total V_{vessel})
V_{vessel}	= Total volume of cryogenic vessel(s) in liters (L)
V_{room}	= Volume of the room (m^3)

3.9.5.6. Emergency Response

Any gas that has the potential to displace oxygen in sufficient quantities can cause asphyxiation. Only persons trained and qualified in the use of a SCBA with adequate backup shall respond to an inert gas leak or enter an area where an asphyxiant gas could be present. Shut off the source of the gas leak if there is no risk to personnel and ventilate the area. If a person has symptoms of asphyxiation, move the victim to fresh air and obtain proper medical attention.

3.9.6. Oxygen

Every user should understand that oxygen can be dangerous if not used correctly. Oxygen makes things burn more easily and can even explode. Following these safety guidelines will help reduce the potential risks associated with oxygen.

- Oxygen is not “compressed air”, it is oxygen. Never use oxygen as a substitute for “compressed air” to run pneumatic tools, in oil heating burners, to start internal combustion engines, to blow out pipelines, or to create pressure for ventilation.
- Keep oxygen cylinders secure at all times.
- Oxygen cylinder valves should be opened completely during use.
- Oxygen can ignite organics such as grease without a flame.
- Keep oxygen tanks (cylinders) away from all heat sources, including radiators, heat ducts, stoves, fireplaces, matches, and lighters.
- Do not permit open flames, sparks, or burning material in areas where oxygen is being used.
- Do not smoke when oxygen or fuel gases are present. Smoking can cause a fire or explosion.

3.9.7. Lecture Bottles

- Lecture bottles must be marked with a label that clearly identifies the contents.
- Lecture bottles must be stored according to their hazard classes.
- Lecture bottles that contain toxic gases must be stored in a ventilated cabinet.
- Lecture bottles must be secured to a fixed frame or structure during use and storage.
- Lecture bottles must not be stored near corrosives, heat, direct sunlight, or in damp areas.
- To avoid costly disposal fees, lecture bottles should only be purchased from suppliers that will accept returned bottles (full or empty). Contact the supplier before purchasing lecture bottles to ensure that they have a return policy.
- Lecture bottles must be dated upon initial use. It is advised that bottles be sent back to the supplier after one year to avoid accumulation of old bottles. They must be used or disposed of within 10 years of receipt.

4. TRAINING

All personnel affected by this program shall be trained in compressed gas safety by taking the online training, and laboratory personnel affected by this program must receive hands on training by the laboratory supervisor, or designee, before use of compressed gases/cryogenic liquids. The training shall include:

- Cylinder identification
- Cylinder inspection
- Cylinder handling, storage, and use
- Cylinder transportation

Retraining shall be performed when an incident or deficiency in knowledge is identified or suspected by the supervising department or IUEHS.

Compressed Gas Safety training records shall be recorded and maintained in accordance with the IUEHS Training and Training Records Program.

5. REFERENCES

- OSHA 29 CFR 1910.101
- Compressed Gas Association – "Safe Handling of Compressed Gases in Containers", 12th Edition, CGA P-1-2015

6. REVISIONS

Revised: October 2017
Revised: January 2022

APPENDIX A – GLOSSARY

Asphyxiant Gas – A gas that may cause suffocation by displacing the oxygen in the air necessary to sustain life, or is labeled by the DOT as Division 2.2.

Compressed Gas – A gas or mixture of gases having an absolute pressure exceeding 40 pounds per square inch (psi) at 70°F (21.1°C); or a gas or mixture of gases having an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F; or a liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72.

Corrosive Gas – A gas that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the point of contact or is labeled by the DOT as Division 2.3 and Division 8 (Corrosive).

Cryogenic Liquid – A refrigerated liquefied gas having a boiling point colder than - 90°C (130°F) at 14.7 psi, or for which the DOT requires the Division 2.2 label for non-flammable, non-poisonous compressed gas – including compressed gas, liquefied gas, pressurized cryogenic gas, compressed gas in solution, asphyxiant gas, and oxidizing gas.

DOT – Department of Transportation

Flammable Gas – A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less; or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air greater than 12% by volume, regardless of the lower limit; or one for which the DOT requires their red flammable gas label or is labeled as Division 2.1.

IU – Indiana University

IUEHS – Indiana University Environmental Health and Safety

OSHA – Occupational Safety and Health Administration

Oxidizer Gas – A gas that is non-flammable but can support and vigorously accelerate combustion in the presence of an ignition source and a fuel; or is labeled by the DOT as Division 2.2 and Division 5.1 (Oxidizer).

PPE – Personal Protective Equipment

PSI – Pound per Square Inch

SCBA – Self-Contained Breathing Apparatus

SDS – Safety Data Sheet

Toxic Gas – A gas that has a median lethal concentration in air of 2,000 parts per million or less by volume of gas; or gas for which the DOT requires the white poison label or is labeled as Division 2.3 “Gas poisonous by inhalation” because it is known to be so toxic to humans as to pose a hazard to health during transportation; or a gas that has a National Fire Protection Association (NFPA) Health Hazard Rating of 3 (Toxic) or 4 (Highly Toxic).