ENVIRONMENT, HEALTH & SAFETY
UNIVERSITY OF MICHIGAN

Compressed Gas Use Program

Guideline

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Applies To: Personnel that order, use, handle, or store compressed gas cylinders.

The topics in the body of this document pertain to all compressed gases and compressed gas cylinders. Additional information about control measures for corrosive, flammable, oxidizing, pyrophoric, and toxic compressed gases are located in the appendices.

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Compressed Gas Use Policy Statement

All University of Michigan (U-M) employees ordering, handling, using, or storing *compressed gases* and cylinders (cylinders) **must** comply with the requirements contained in this document and complete all required training.

All employees ordering, handling, using, or storing compressed gases and cylinders **must** adhere to the roles and responsibilities listed in the Academic Laboratory and Research Safety Policy.

Compressed Gas Use Program

The Compressed Gas Use Program is derived from government regulations, the U-M Academic Laboratory and Research Safety Policy, and the Restricted Hazardous Gas Approval Process. It provides guidance for safe handling of compressed gases and cylinders and a template for *standard operating procedures* (SOP) that laboratory directors, supervisors, and shop managers can customize, then implement in their department.

Related Compressed Gas Use Program Documents

- Restricted Hazardous Gases Authorization Form
- Compressed Gas Standard Operating Procedure
- Lab Emergencies SOP
- Safety Data Sheets

Potential Hazards

The purpose of the Compressed Gas Use Program is to protect employees from the potential hazards of compressed gases and their associated cylinders, which are as follows:

- Fire and explosion hazards of *flammable*, *pyrophoric*, or reactive gases.
- Health hazards of *toxic*, corrosive, or *asphyxiant* gases.
- Pressure hazards due to the high pressures within most cylinders that can result in rapid release and subsequent violent pin wheeling or propulsion (rocketing) of the cylinder.
- Safety hazards, due to the weight of the cylinders, during handling and storage operations.

Training Requirement

All U-M personnel **must** follow the best practices written for your department.

All research laboratory personnel working in a laboratory that uses hazardous materials **must** successfully complete the EHS_BLS025w General Laboratory Safety Training course. In addition, they **must** read and follow the standard operating procedures written for the lab regarding safe use of compressed gases.

Restricted Hazardous Gases

Restricted hazardous gases present an increased risk to personnel and for the University of Michigan; therefore, personnel **must** obtain EHS approval before ordering the following gases:

- Carbon monoxide

- Pyrophoric gases (e.g. arsine, disilane, diborane, germane, phosphine, silane)
- Flammable gases (e.g. Hydrogen >5%)
- Toxic and highly toxic gases per NFPA 55
- Oxidizers (e.g. liquid oxygen, gaseous oxygen >25%, chlorine, fluorine)
- Corrosive gases (e.g. ammonia)

For more information, refer to the Restricted Hazardous Gases Authorization Form on the EHS Web site.

Maximum Allowable Quantity

National Fire Protection Association (NFPA) 55 and International Fire Code have established a maximum allowable quantity (MAQ) of compressed gas that can be used and stored within a building. Therefore, use the following best management practices to minimize the amount of compressed gas located in your workplace.

- Substitute, if possible, with a gas that is less hazardous.
- Limit the amount of hazardous compressed gas to that which is deemed necessary.
- Minimize the quantity of compressed gases on hand using the following strategies:
  - Maintain the smallest quantities of compressed gases as possible
  - Have no more than one back up cylinder of each gas
  - Use just-in-time delivery
- Record all compressed gases in your lab's chemical inventory, including non-hazardous gases

The Restricted Hazardous Gas Policy controls the quantity of hazardous gases in a building. MAQs vary based factors such as the floors above grade, quantity and type of gas used and stored, fire control zones, and sprinkler protection.

Contact EHS at (734) 647-1143 to assist you and the facilities manager to determine the MAQ for your lab or workspace.

Compressed Gas Cylinder Labels

Do not accept a cylinder from the gas supplier without a proper label. Cylinders **must** be legibly marked by stenciling, stamping, or labeled with at least the chemical name (or commonly accepted name of the material contained) and the primary hazard associated with the chemical (such as "flammable").

In addition, the cylinders **must** bear the approved markings of the *Department of Transportation (DOT)* stamped in the metal at the top of the cylinder.

NOTE: Do not rely on the color of the cylinder for identification of contents as colors may vary with supplier. Look at the official label on the cylinder, not the color of the cap.

Use

When using, transporting, moving, and storing compressed gases cylinders, follow these best practices:

- Cylinders **must** not be refilled except by authorized suppliers.
- Repair or alteration of a cylinder is prohibited.
- Only properly trained employees should handle and use compressed gas cylinders.

Using Compressed Gases

- Never use an open flame or smoke in areas where oxygen or flammable gases are used.
- Never heat a cylinder to raise the pressure of the gas.
- Never leave pressure on a hose or line that is not being used.
- Leave some positive pressure (a minimum of 20 *psig*) in empty cylinders to prevent "suck back" and contamination.
- Never use compressed gas to dust off equipment or clothing.

Transporting Cylinders

- Use a gas cylinder hand *cart* and the proper restraining devices to move cylinders more than one meter.
  NOTE: Never drag, slide, or roll a cylinder.
- Transport a cylinder with its protective cap in place.
- Do not use a valve cover to lift a cylinder.
- Never drop, bang, or strike cylinders against each other or other objects.

Inspecting Cylinders

Cylinders and their associated equipment **must** be inspected before each use.

- Cylinders
  - The cylinder label **must** identify the gas or gas mixture and the primary hazard associated with that chemical (flammable, oxidizer, etc). **Do not** accept a cylinder without a proper label; contact your supplier.
  - The cylinder **must** be free of corrosion, pitting, cuts, gouges, bulges, neck defects and general distortion.
- Associated equipment
  - The cylinder mounting and restraining devices **must** not show any signs of damage or loss of integrity.
  - Use only the regulator designed for the gas being used. Do not force corrections.
  - Do not use Teflon tape on any CGA valve connection threads. Tape will prevent the bullet-nose CGA to fully contact the mating surface inside the cylinder valve, increasing the chance of a gas leak.
  - Valves and regulators **must not** show signs of damage (cracks, corrosion, etc).
  - Cylinder regulators and connections **must** be tested for leaks.
    - For argon, nitrogen, hydrogen, or air, use a soapy water solution to test for leaks.
    - For other gases, leak test the lines and equipment with an inert gas before using.

When inspecting cylinders and associated equipment after use, verify the following actions have been taken:

- Valves are closed and tightened.
- Any remaining residual gas has been safely released from the line.
- Valve protection caps are securely fastened during long-term storage.

NOTE: Any problem with pressure-relief devices should be immediately reported to your supplier. **Never** tamper with pressure-relief devices in valves or cylinders. Only qualified gas supplier personnel should service pressure-relief devices.

Responses to Identified Problems

If at any time you notice a problem with a cylinder or its associated equipment, contact the supplier for technical advice, replacement, or both.

If you identify a leak that you cannot fix and the cylinder contains a hazardous material, call DPS at 911 and evacuate the area.

Engineering Control Measures

The following engineering controls **must** be implemented when using, transporting, moving, and storing compressed gas cylinders:

- Secure cylinders and *lecture bottle*s in an upright position using the appropriate restraining devices. **NOTE**: Securing devices for various sizes and shapes of compressed gas cylinders can be purchased from gas suppliers or safety equipment companies.
- Ventilate (typically six air changes per hour) areas where the cylinders are used and stored.
- Install, where required, the following engineering control measures:
  - Continuously exhausted gas cabinets or enclosures.
  - Gas detection systems, alarms, etc.
  - Nitrogen purge system.
  - Automatic shut-off valves.
  - Flashback arrestors.
- Place and tighten the valve protection cap on the compressed gas cylinder when the cylinder is not in use.
- If using flexible (non-fixed) tubing, the tubing **must** be under 10 feet in total length.

Contact EHS at (734) 647-1143 to assist you and the facilities manager to determine the proper engineering controls for your lab or workspace.

Fixed Pressurized Piping

All compressed gases distributed in fixed pressurized piping **and** with any of the following properties (1) health hazard ratings of 3 or 4; (2) a health hazard rating of 2 without physiological warning properties, or (3) a reactivity rating of 3 or 4; **or are** (4) pyrophoric or flammable with a flammability class 4 rating **must** have the following engineering controls:

- Excess flow control devices.
- Continuous gas monitoring.
- Automatic shutoff valves:

NOTE: This information is for general guidance. Consult with your EHS representative to determine requirements for your particular usage. A code analysis may also be required.

Administrative Controls

The following administrative controls **must** be implemented when transporting, moving, and storing compressed gases cylinders.

- Replace or remove damaged or compromised cylinders or equipment.
- Use the associated equipment that is "assigned" to the compressed gas cylinder.
- Display the appropriate signs and labels in locations where cylinders are stored or used. Contact EHS at EHS-Labsafety@umich.edu to request hazard warning labels. To request a door sign, go to the EHS Door Sign Request Form.
- Be familiar with the U-M Chemical Hygiene Plan (CHP) and the lab's EHS Document Binder
- Write and implement SOPs about using, transporting, moving, and storing compressed gas cylinders in the work location.
- Never perform lab work alone with hazardous gases. Always implement a buddy system if work is conducted outside of normal business hours.
- Promptly return unneeded or excess gas cylinders to their vendor. Avoid stockpiling cylinders not needed for immediate use. Excessive storage can lead to fire code noncompliance and result in costly cylinder rental fees.

Personal Protective Equipment (PPE)

The following list of *personal protective equipment* (PPE) is required to help ensure your safety when using, transporting, moving, and storing compressed gases cylinders. For specific information, refer to the chemical's safety data sheet and your department's SOPs regarding PPE.

- Wear safety glasses or goggles for all work involving compressed gas cylinders.
- Wear steel toe shoes for frequent handling of compressed gas cylinders.
- Wear the proper protective clothing as stated in your department's SOP.
- Use the proper equipment as stated in your department's SOP.

Storage Requirements for Cylinders

Cylinders not "in use" **must** be stored in a location separate from the workspace. Per NFPA 45, a cylinder is considered to be “in use” if it complies with one of the following:

(1) Connected through a regulator to deliver gas to a laboratory operation
(2) Connected to a manifold being used to deliver gas to a laboratory operation
(3) A single backup cylinder secured alongside a cylinder that is connected through a regulator to deliver gas to a laboratory operation

For long-term storage of a cylinder, comply with the gas supplier's recommendation. In general, do not use a cylinder for more than three years at which point it **must** be returned to the supplier for testing and certification.

Other storage requirements are as follows:

- The storage location **must** be dry and well-ventilated (at minimum six air changes per hour).
- Cylinders **must** be grouped by the type of gas and segregated by compatibility.
- Full cylinders **must** be separated from empty cylinders with the empty cylinders marked with the word “Empty” or the lettering “MT.”
- *Flammable gases* **must** be stored away from flammable liquids, combustible materials, oxidizers, open flames, sparks and other sources of heat or ignition.
- Oxygen cylinders in storage **must** be separated from fuel-gas cylinders or combustible materials (such as grease) by a minimum distance of 20 feet or by a noncombustible barrier at least 5 feet high having a fire-resistance rating of at least one-half hour (i.e. a National Fire Protection Association-approved storage cabinet).
- Oxygen and flammable gases **must** be stored separate from locations where open flames and smoking are present. "No Smoking" and "No Open Flames" signs **must** be conspicuously posted in these areas.
- Cylinder valves **must** be closed when the cylinder is not in use.
- Removable caps **must** be on the cylinders at all times, except when cylinders are in use.
- Caps used for valve protection **must** be secured when the compressed gas cylinder is not being used and before moving the cylinder.
- Empty cylinders **must** be stored with the *valve protection cap* securely in place.
- Damaged or defective cylinders **must** be removed from service (contact the cylinder vendor or supplier for assistance).
- The temperature of the storage location **must** be maintained within the temperature range allowable for the cylinder as specified by the manufacturer (generally speaking, the temperature of gas cylinders **must** stay below 125◦F).
- Pyrophoric, toxic, and corrosive gases **must** be stored in a continuously mechanically exhausted ventilated enclosure. For more information, refer to Appendix D: Pyrophoric Gases and Appendix E: Toxic and Corrosive Gases.

Where NOT to Store Cylinders

Cylinders **must** be stored in locations that are free from clutter and where they are easily accessible.

DO NOT STORE CYLINDERS…	**TO PREVENT…**
Hallways, corridors, stairwells, near elevators, or any other high traffic areas.	Cylinders from being knocked over or tampered with.
Areas that are exposed to continuous dampness or areas that are used to store salt or other corrosive chemicals or fumes.	Cylinders from physical damage.
Outside unless they are appropriately sheltered or covered.	Cylinders from corroding.
In cold rooms or other unventilated spaces such as closets, lockers, trenches, tanks, and confined spaces. **NOTE**: An exception may be approved by EHS for *inert gases* when an oxygen monitor is in place. Contact EHS at (734) 647-1143 for more information.	• A build-up of gas in a storage location. • Oxygen deficiency.
• In direct sunlight • In excessive heat • Near sources of ignition (such as flames or sparks) • Near combustibles • Where they might become part of a electrical system	An increase of pressure inside a cylinder resulting in an explosion or fire.

Waste Disposal

In most cases, the compressed gas cylinder, including any unused gas, will be returned to the supplier from which the cylinder was purchased.

For gas cylinders that cannot be returned to the supplier, contact Environment, Health & Safety, Hazardous Materials Management (HMM) at 734-763-4568 to arrange for collection. Write “empty” on the outside of each cylinder and complete a hazardous waste manifest.

Appendix A: Hazards of Common Compressed Gases

The following table is a partial listing of some of the more common compressed gases and their associated hazards. Many gases exhibit more than one hazard. To provide the best protection to the user, a gas's most severe hazard has been designated with a "P" for primary. Any additional hazards for which added precautions are recommended have been designated with an "S" for secondary.

The hazards have been grouped into six general categories: flammable, asphyxiant, oxidizer, toxic, corrosive, and extreme cold. The following is a detailed description of each category and how a gas is classified.

- Toxic: In all cases, if a gas is toxic, this is the primary hazard. A toxic gas is any gas that has an LC50 less than or equal to 2000 ppm, but greater than 200 ppm. A **highly toxic** gas is any gas that has a LC50 in air of 200 ppm or less.
- Flammable: Any gas for which flammable limits in air are reported is considered flammable. However, if the gas were also toxic, then toxic would be the primary hazard with flammable **NOTED** as secondary.
- Asphyxiant: This category generally covers all the inert and *noble gases*. A gas that is listed flammable as primary would usually be listed with asphyxiant as secondary, especially if any reported toxicity approached oxygen-deficient levels.
- Oxidizer: This covers those gases that, in the presence of an ignition source and a fuel, support and may vigorously accelerate combustion. If the gas was also toxic, this would be listed as primary hazard with oxidizer as the secondary hazard. Some gases, such as fluorine, are as aggressive an oxidizer as they are toxic, so both hazards are listed as primary.
- Corrosive: Primarily, most gases in the absence of water are not corrosive. However, since most sources refer to the gas properties in moist air, corrosive is listed as a mostly secondary hazard where appropriate.
- Extreme Cold: If a gas is shipped as a liquefied gas under pressure, extreme cold would generally be listed as a secondary hazard, assuming there are more significant (primary) hazards. However, an inert cryogenic liquid is listed with extreme cold as its primary hazard.
- Other – Other hazards are included in this category. If a gas has pyrophoric properties, severe decomposition hazards, or other types of reactivity hazards, they are referenced in this column. A description of the numbers found in this column is located at the end for this table.

NOTE: The user is cautioned that other classification systems exist, particularly from regulatory agencies that may result in a different assessment of the hazard. In addition, there may be additional health hazards that are not reported here, so the user should consult the gas supplier's SDS for specific information.

GAS / CAS NUMBER	FLAMMABLE	ASPHYXIANT	OXIDIZER	TOXIC	CORROSIVE	EXTREME COLD	OTHER*	DOT CLASS 2
Acetylene / 74-86-2	P	S					1	2.1
Air, Compressed / NA								2.2
Ammonia / 7664-41-7	S				P	S		2.3, 8
Argon / 7440-37-1		P						2.2
Argon (Liquid) / 7440-37-1		P				S		2.2

GAS / CAS NUMBER	FLAMMABLE	ASPHYXIANT	OXIDIZER	TOXIC	CORROSIVE	EXTREME COLD	OTHER*	DOT CLASS 2
Arsine / 7784-42-1	S			P				2.3, 2.1
Bromochlorodifluoromethane (R12B1) / 353-59-3		P						2.2
1,3-Butadiene / 106-99-0	P	S				S	3	2.1
Butane / 106-97-8	P	S				S		2.1
1-Butene / 106-98-9	P	S				S		2.1
Carbon Dioxide / 124-38-9		P						2.2
Carbon Dioxide (Liquid) / 124-38-9		P				S		2.2
Carbon Monoxide / 630-08-0	S			P				2.3, 2.1
Chlorine / 7782-50-5			S	P	S			2.3, 8
Chlorine Trifluoride / 7790-91-2			P	P	S		2	2.3, 5.1, 8
1-Chloro-1,1 –difluorethane (R142b)/ 75-68-3	P	S				S		2.1
Chlorodifluoromethane (R22) / 7545-6		P				S		2.2
Chlorotetraflurorethane (R124) / 2837-89-0		P				S		2.2
Chlorotrifluoromethane (R13) / 75-72-9		P				S		2.2
Cyanogen / 460-19-5	S			P	S			2.3, 2.1
Cyclopropane / 75-19-4	P	S				S		2.1
Diborane / 19287-45-7	S			P			4	2.3
Dichlorodifluoromethane (R12) / \75-71-8		P				S		2.2
Dichlorofluoromethane (R21) / 75-43-4		P				S		2.2
Dichlorosilane / 4109-96-0	S			P	S		5	2.3, 2.1, 8
1,2 – Dichlorotetrafluoroethane (R114a) / 76-14-2		P				S		2.2
Diethylamine / 109-89-7	P							3, 8
Dimethylamine / 124-40-3	P	S			S			2.1
Disilane / 1590-87-0	P						5	2.1
Ethane / 74-84-0	P	S				S		2.1
Ethylene / 74-85-1	P	S				S	6	2.1
Ethylene Oxide / 75-21-8	P			P		S	7	2.3, 2.1
Fluorine / 7782-41-4			P	P				2.3, 5.1, 8
Germane / 7782-65-2	S			P			6	2.3, 2.1
Helium / 7440-59-7		P						2.2
Helium (Liquid) / 7440-59-7		P				S		2.2
Hydrogen / 1333-74-0	P	S						2.1
Hydrogen (Liquid) / 1333-74-0	P	S				S		2.1

GAS / CAS NUMBER	FLAMMABLE	ASPHYXIANT	OXIDIZER	TOXIC	CORROSIVE	EXTREME COLD	OTHER*	DOT CLASS 2
Hydrogen Bromide / 10035-10-6				P	S			2.3, 8
Hydrogen Chloride/ 7647-01-0				P	S			2.3, 8
Hydrogen Cyanide / 74-90-8	S			P				6.1, 3
Hydrogen Sulfide / 7783-06-4	S			P	S			2.3, 2.1
Isobutane / 72-28-5	P	S				S		2.1
Krypton / 7439-90-9		P						2.2
Liquefied Petroleum Gas (LPG) / 68476-85-7	P	S				S		2.1
Methane / 74-82-8	P	S						2.1
Natural Gas / NA	P	S						2.1
Neon / 7440-01-9		P						2.2
Neon (Liquid) / 7440-01-9		P				S		2.2
Nickel Carbonyl / 13463-39-3	S			P			8	6.1, 3
Nitric Oxide / 10102-43-9			S	P				2.3
Nitrogen / 7727-37-9		P						2.2
Nitrogen (Liquid) / 7727-37-9		P				S		2.2
Nitrogen Dioxide / 10102-44-0			P	P	S			2.3, 5.1, 8
Nitrous Oxide / 10024-97-2		P	S					2.2, 5.1
Oxygen / 7782-44-7			P					2.2, 5.1
Oxygen (Liquid) / 7782-44-7			P			S		2.2, 5.1
Ozone / 10028-15-6			P	P				2.2
Pentaborane / 19624-22-7	S			P			5	4.2, 6.1
Phosgene / 75-44-5				P	S			2.3, 8, 4.2
Phosphine / 7803-51-2	S			P				2.3, 2.1
Propane / 74-98-6	P	S				S		2.1
Propylene Oxide / 75-56-9	P			S			9	3
Silane / 7803-62-5	P						5	2.1
Sulfur Dioxide / 7446-09-5				P	S	S		2.3, 8
1,1,1,2-Tetrachlorodifluoroethane (R112a) / 76-11-9		P						2.2
1,1,2,2-Tetrachlorodifluoroethane (R112) / 76-12-0		P						2.2
Tetrafluorohydrazine / 10036-47-2			P	P			10	1.1
Xenon / 7440-63-3		P						2.2

*Other Codes:

- May decompose violently in its free state under pressure in excess of 15 psig.
- Decomposes or reacts violently upon contact with water.
- Shipped with an inhibitor to avoid polymerization.
- Generally shipped pressurized with a diluent gas.
- Pyrophoric.
- May undergo explosive decomposition at elevated pressures when heated or ignited.
- Explosive decomposition on prolonged storage or hazardous polymerization may occur if contaminated.
- Thermally unstable; decompose violently at 140°F.
- Reaction with water may lead to a runaway reaction.
- Unstable in air for more than a few minutes.

[1] From: CGA P-1 2000. See Appendix D for a complete list.

[2] From: Department of Transportation Hazardous Materials Table 49 CFR 172.101:

- Class 1.1 = Explosive
- Class 2.1 = Flammable Gas
- Class 2.2 = Non-flammable, nonpoisonous compressed gas - including compressed gas, liquefied gas, pressurized cryogenic gas, compressed gas in solution, asphyxiant gas and oxidizing gas
- Class 2.3 = Gas poisonous by inhalation
- Class 5.1 = Oxidizer
- Class 8 = Corrosive Liquid

Appendix B: Flammable Gases

Additional Information

Any gas for which flammable limits in air are reported is considered flammable. However, if the gas were also toxic, then toxic would be the primary hazard with flammable noted as secondary.

When using, handling, or storing a compressed gas that lists its primary and secondary hazard as flammable, incorporate the following controls into your standard operating procedures for using, handling, and storing compressed gases.

CONTROL	DESCRIPTION
Engineering Controls: All Quantities	• All lines and equipment associated with flammable gas systems **must** be grounded and bonded. • Flash arrestors are designed to prevent a flash-back, should it occur, in a line containing a flammable gas. • Portable fire extinguisher **must** available in the area where compressed gases and cylinders are used and stored. • Use spark- proof tools when working with flammable gas. • Do not use vessels, piping, or other materials that contain a significant amount of copper (usually considered to be more than 50% copper) with cylinders containing acetylene.
Engineering Control: Above the U-M MAQ	Flammable gas quantities above the U-M MAQ may be required to have the following engineering controls: • The workspace is equipped with a continuous gas detection system. • The gas detection system **must** initiate a local alarm that is both visible and audible. • The gas detection system **must** transmit a signal to a constantly attended control station. • Activation of the gas detection system **must** automatically shut off the flow of gas related to the system being monitored. • The gas detection system **must** detect the presence of gas at or below the Lower Explosive Limit (LEL). If the gas is also toxic, the system should detect the presence of gas at or below the OSHA permissible exposure level or ceiling limit of the gas in lieu of the LEL. • Emergency power **must** be provided for the exhaust ventilation, gas detection system, and alarm systems when required. • Sprinkler protection for gas cabinets and other protective features may be required. **NOTE**: This information is for general guidance. Consult with your EHS representative to determine requirements for your particular usage. A code analysis may also be required.
Administrative Controls	• Do not use acetylene at an operating pressure over 15 psig. • Do not leave flow experiments using flammable gases unattended.

Appendix C: Oxidizing Gases

Additional Information

Oxidizing gases that, in the presence of an ignition source and a fuel, support and may vigorously accelerate combustion. If the gas was also toxic, this would be listed as primary hazard with oxidizer as the secondary hazard. Some gases, such as fluorine, are as aggressive an oxidizer as they are toxic, so both hazards are listed as primary.

When using, handling, or storing oxidizing gases, incorporate the following controls into your standard operating procedures for using, handling, and storing compressed gases.

CONTROL	DESCRIPTION
Administrative Control	• All equipment used for *oxidizing gases* **must** be cleaned with oxygen-compatible materials free from oils, greases, and other contaminants. • Do not use oily hands or gloves when handling cylinders. The reaction between oxygen and hydrocarbons can be violent, even when small quantities are involved.

Appendix D: Pyrophoric Gases

Additional Information

When using, handling, or storing a compressed gas that is pyrophoric, incorporate the following controls into your standard operating procedures for using, handling, and storing compressed gases.

NOTE: This information is for general guidance. Consult with your EHS representative to determine requirements for your particular usage. A code analysis may also be required.

CONTROL	DESCRIPTION
Engineering Control: Lecture Bottles	Lecture bottles of *Pyrophoric* gases that are located workspaces **must** be kept in a continuously mechanically exhausted ventilated hood or other continuously mechanically exhausted ventilated enclosure:
Engineering Controls: Cylinders Greater than Lecture Bottle Size	Cylinders of pyrophoric gases (greater than lecture bottle size) **must** be kept in approved continuously mechanically ventilated, sprinklered gas cabinets and **must** be equipped with an excess flow control device.
Engineering Control: Above the U-M MAQ	• In addition to the requirements listed above, any quantity of Pyrophoric Gas above the U-M MAQ may be also required to have the following engineering controls upon consultation with your EHS representative: • The workspace **must** be equipped with a continuous gas detection system. • The gas detection system **must** initiate a local alarm that is both visible and audible. • The gas detection system **must** transmit a signal to a constantly attended control station. • Activation of the gas detection system **must** automatically shut off the flow of gas related to the system being monitored. • The gas detection system **must** detect the presence of gas at or below the Lower Explosive Limit (LEL). If the gas is also toxic, the system **must** detect the presence of gas at or below the OSHA permissible exposure level or ceiling limit of the gas in lieu of the LEL. • Emergency power **must** be provided for the exhaust ventilation, gas detection system, and alarm systems when required.

Appendix E: Toxic, Highly Toxic, and Corrosive Gases

Additional Information

In all cases, if a gas is toxic, this is the primary hazard. A toxic gas is any gas that has an *LC50* less than or equal to 2,000 ppm but greater than 200 ppm. A highly toxic gas is any gas that has a LC50 in air of 200 ppm or less. Requirements laid out in this section shall also apply to cylinders of carbon monoxide.

Primarily, most gases in the absence of water are not corrosive. However, because most sources refer to the gas properties in moist air, corrosive is listed as a mostly secondary hazard where appropriate.

Corrosive gases can chemically destroy exposed body tissue; therefore, avoid contact to skin and eyes.

When using, handling, or storing a compressed gas that lists its secondary hazards as corrosive, incorporate the following controls into your standard operating procedures for using, handling, and storing compressed gases.

When using, handling, or storing a compressed gas that is toxic, incorporate the following controls into your standard operating procedures for using, handling, and storing compressed gases.

NOTE: This information in the table is for general guidance. Consult with your EHS representative to determine requirements for your particular usage. A code analysis may also be required.

CONTROL	DESCRIPTION
Engineering Control: Lecture Bottles	Lecture bottles of toxic gas, highly toxic gas, or carbon monoxide and are located in workspaces **must** be kept in a continuously mechanically exhausted ventilated hood or other continuously mechanically exhausted ventilated enclosure.
Engineering Controls: Below the U-M MAQ	Departments using or storing toxic gas, highly toxic gas, or carbon monoxide cylinders (greater than lecture bottle size) in the workspace **must** comply with the following requirements as a minimum: • Cylinders **must** be kept in approved continuously mechanically ventilated gas cabinets. • The workspace **must** be equipped with a continuous gas detection system. **NOTE**: Gas detection may not be required where the physiological warning properties for the gas are at a level below the accepted permissible exposure level or ceiling limit of the gas. • The gas detection system shall initiate a local alarm that is both visible and audible.

CONTROL	DESCRIPTION
Engineering Controls: Above the U-M MAQ	Departments using a toxic gas, highly toxic gas, or carbon monoxide in quantities above the U-M MAQ in any size cylinder may be required to have the following engineering controls upon consultation with an EHS representative: • An approved continuously mechanically ventilated gas cabinet to store the cylinders. • A continuous gas detection system in the work place that meets the following requirements: **NOTE**: Gas detection may not be required where the physiological warning properties for the gas are at a level below the accepted permissible exposure level or ceiling limit of the gas. • It **must** initiate a local alarm that is both visible and audible. • It **must** transmit a signal to a constantly attended control station. • Activation of the gas detection system **must** automatically shut off the flow of gas related to the system being monitored. • It **must** detect the presence of gas at or below the OSHA permissible exposure level or ceiling limit of the gas. • Emergency power for the exhaust ventilation, gas detection system, and alarm systems when required. • Treatment systems for the exhaust. • Sprinkler protection for gas cabinets and other protective features.

Additional Controls for Corrosive Gases

CONTROL	DESCRIPTION
Engineering Control	Install an emergency shower and eyewash within 25 feet where corrosive materials are used. **NOTE**: This engineering control is required.
Administrative Controls	Check equipment and lines frequently for leaks. Metals become brittle when used in corrosive gas service.
PPE	Wear safety goggles, lab coat, and gloves as indicated by your workspace SOP.

Emergency Plan

EHS recommends that an emergency plan is written if the compressed gas used requires a continuously exhausted gas cabinet or enclosure or a gas detection system, alarm, etc.

For a template for writing an Emergency Plan, see Attachment 1.

Appendix F: Referenced Documents

- MIOSHA Part 69, Compressed Gases: Acetylene, Hydrogen, Oxygen, Nitrous Oxide
- MIOSHA Part 12 Gas Welding and Cutting standard
- Compressed Gas Association *CGA* P-20 (Classification of Toxic Gas Mixtures) and P-23 (Categorizing Gas Mixtures Containing Flammable and Nonflammable Components).
- Michigan State Fire Safety Board rules (Licensing and Regulatory Affairs)
- Compressed Gas Association documents:
  - Handbook of Compressed Gases, Compressed Gas Association, Inc.
  - CGA P-20 – 2009, Standard for Classification of Toxic Mixture, Compressed Gas Association, Inc.
  - CGA P-23 – 2008, Standard for Categorizing Gas Mixtures Containing Flammable and NonFlammalable Components, Compressed Gas Associations, Inc.
  - CGA P-1 – 2000, Safe Handling of Compressed Gases in Containers, Compressed Gas Association, Inc.
  - CGA C-6: Standards for Visual Inspection of Compressed Gas Cylinders, Compressed Gas Association, Inc.
  - CGA S-1.1, Pressure Relief Device Standards- Part 1-Cylinders for Compressed Gases, Compressed Gas Association, Inc.
  - CGA S-1.2, Pressure Relief Device Standards- Part 2- Portable Containers for Compressed Gases, Compressed Gas Association, Inc.
  - CGA S-1.3, Pressure Relief Device Standards- Part 3-Stationary Storage Containers for Compressed Gas, Compressed Gas Association, Inc.
  - CGA V-1, Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connection, Compressed Gas Association, Inc.
- National Fire Protection Association (NFPA) documents:
  - NFPA 45: Standard on Fire Protection for Laboratories Using Chemicals, 2019 Edition
  - NFPA 55: Compressed Gases and Cryogenic Fluids Code, 2020 Edition

Glossary of Terms

TERM	DEFINITION
Asphyxiant gas	A gas, including inert (noble) gases, 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. Examples include: argon (Ar), carbon dioxide (CO2), helium (He), and nitrogen (N2).
Cart	A gas cylinder cart or dolly **must** be used to transport gas cylinders. All gas cylinder carts or dollies **must** identify weight and have retaining straps or chains to hold cylinder in place.
CGA	Compressed Gas Association - An association that specifies cylinder valve outlet connections for specific gas services based on safety considerations.
Chemical Hygiene Plan (CHP)	A written policy, developed and implemented by lab management, which sets forth procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards associated with the use of hazardous chemicals. In essence, it is a lab safety manual.
Compressed Gas	Any gas or mixture of gases exerting in a container, a pressure exceeding 40.6 psia (280 kPa, abs) at 68°F (20°C). Also, any flammable liquid having an absolute vapor pressure exceeding 40.6 psia (280 kPa, absolute) at 100°F (37.8°C) as determined by ANSI/ASTM D323, American Standard Test Method for Vapor Pressure of Petroleum Products (Ried Method).
Corrosive Gas	Gases that can cause visible destruction of, or irreversible alterations in, living tissue (e.g., skin, eyes, or respiratory system) by chemical action when they come in contact, or do so in the presence of water, are classified as corrosive. It is essential that equipment used for handling corrosive gases be constructed of proper materials. Proper protective clothing and equipment **must** be used to minimize exposure to corrosive materials. Examples include: (acid gases), chlorine (Cl2), hydrogen bromide (HBr), hydrogen chloride (HCl), hydrogen fluoride (HF), and sulfur dioxide (SO2) and (alkaline gases) ammonia (NH3), monomethylamine (CH5N), dimethylamine (C2H7N) and trimethylamine (C3H9N).
DOT	(United States) Department of Transportation (oversees federal highway, air, railroad, and maritime and other transportation functions).
Flammable Gas	A gas is considered flammable when either a mixture of 13% or less (by volume) with air is ignitable at 14.7 psia (101.3 kPa) or has a flammable range with air of at least 12% regardless of the lower limit. (These limits shall be determined at 14.7 psia (101.3 kPa) of pressure and a temperature of 68°F (20°C).) Examples include: acetylene (C2H2), carbon monoxide (CO), ethane (C2H6), hydrogen (H2), methane (CH4), hydrogen

TERM	DEFINITION
	sulfide (H2S), phosphine (PH3), diborane (B2H6) and arsine (AsH3).
Highly toxic gas	A chemical that has a median lethal concentration (LC50) in air of 200 ppm by volume or less of gas or vapor, or 2 mg/L or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 0.44 lb and 0.66 lb (200 g and 300 g) each.
Inert Gas	A term used to describe a variety of gases which are chemically inactive. For instance, molecular nitrogen is often used as an inert gas in food packaging to ensure that food does not spoil in transit. Helium and neon are the only true elemental inert gases, because they do not form any true chemical compounds like the heavier noble gases do.
LC50	LC stands for lethal concentration. LC50 is the concentration of a material in air which causes the death of 50% (one half) of a group of test animals. The material is inhaled over a set period of time, usually 1 or 4 hours. The LC50 helps determine the short-term poisoning potential of a material. The value is expressed in g/kg or mg/kg of body weight.
Lecture Bottles	High pressure gas cylinders which are generally sold outright by the gas supplier and are not returnable to gas supplier. Lecture bottles may be purchased with flammable, corrosive and other hazardous material as defined in 49 CFR, Department of Transportation (DOT), and 29 CFR, Occupational Safety and Health Administration (OSHA). Lecture bottles have the designation "LB".
NFPA	National Fire Protection Association is a nonprofit organization, devoted to eliminating death, injury, and property loss due to fire, electrical and related hazards. The association delivers information through consensus codes and standards. U-M has adopted NFPA 45 and 55 as they relate to compressed gas use. All NFPA codes and standards can be viewed online for free.
Noble Gas	The noble gases are the chemical elements in group 18 (old-style Group 0) of the periodic table. This chemical series contains helium, neon, argon, krypton, xenon and radon. The noble gases were previously referred to as inert gases, but this term is not strictly accurate because several of them do take part in chemical reactions. Another older term was rare gases, although in fact they form a considerable part (0.93% by volume, 1.29% by mass) of the Earth's atmosphere.
Oxidizing Gas	Include oxygen (O2), nitrous oxide (NO) and gas mixtures containing a high percentage (> 23.5%) of oxygen. These gases can accelerate combustion and upon contact with combustible materials, may cause a fire or explosion. Therefore, this type of gas should be stored away from all combustible materials, potential sources of ignition and flammable gases.

TERM	DEFINITION
Personal Protective Equipment (PPE)	Devices worn by workers to protect against hazards in the environment. Examples include safety glasses, goggles, face shields, respirators, gloves, hard hats, steel-toed shoes, and hearing protection.
Pressure Relief Device (burst disk)	A pressure and/or temperature activated device used to prevent the pressure from rising above a predetermined maximum, thereby preventing rupture of a normally charged cylinder when subjected to a standard fire test.
Psia	Pounds per square inch, absolute.
Psig	Pounds per square inch, gauge.
Pyrophoric Gas	Materials that spontaneously ignite on contact with air at normal conditions. Examples include: silane (SiH4), disilane (Si2H6), dichlorosilane (SiCl2H2), diborane (B2H6) and phosphine (PH3)
Safety Data Sheets (SDS)	Chemical information sheets produced by the manufacturer accordance with the OSHA provisions of 29 CFR 1910.1200 containing the following information: identification and synonyms, hazardous components, physical data, fire and explosion data, toxicity data, health effects and first aid, reactivity, storage and disposal procedures, spill and leak procedures, and protective equipment. It also contains a contact number in case of emergency.
Standard Operating Procedure (SOP)	A concise document that gives safety instructions specific to the process and associated equipment.
Toxic Gas	A gas with a median lethal concentration (LC50) in air of more than 200 ppm but not more than 2000 ppm by volume of gas or vapor, or more than 2 mg/L but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 0.44 lb and 0.66 lb (200 g and 300 g) each. Examples include: arsine (AsH3), diborane (B2H6), nitric oxide (NO), nitrogen dioxide (NO2), phosgene (CCl2O), and phosphine (PH3).
Valve Protection Cap	A rigid removable cover provided for container valve protection during handling, transportation and storage.

Revision History

REVISION #	DATE	NOTES	REVISION #	DATE	NOTES
1	10/2/15		3	02/02/18	
2	6/24/16		4	06/29/18	
5	02/04/19	Updated web links	6	09/07/21	Added information regarding use of Teflon tape; Updated web links
7	6/30/2023	Updated links, revised restricted gases policy, updated code references			