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# Compressed Gas Safety Program

## Contents

## Introduction and Purpose

University of California, Riverside (UCR) persistently endeavors to provide a learning, teaching, and research environment free from recognized hazards. The University requires the safe handling, use, and storage of compressed gas cylinders to protect employees and students from potential physical and health hazards associated with using compressed gases in laboratories or other locations that are part of the University.

## 1. Scope and Application

This program specifies minimum requirements for safe storage, use, and handling of compressed Gas, toxic and highly toxic gas at UCR. This document also:

• summarizes the health and safety risks associated with toxic and highly toxic gas use and handling;

• identifies exposure control methods to protect employee's safety and health and the environment;

• outlines regulatory and university requirements related to this work;

• specifies emergency response procedures for addressing toxic gas issues; and

• provides resources for further information.

## 2. References

Title 8, California Code of Regulations, § 4649, 4650

Compressed Gas Association (CGA) requirements

International Fire Code 2003 Edition

National Fire Protection Association (NFPA) requirements 13, 45, 55, 72, 101

## 3. Potential Hazards

Compressed gas cylinders can present a variety of hazards due to their pressure and/or contents. This program covers recommendations which should be followed for the use of all compressed gases. In addition to the general work practices for toxic gases, flammable and inert gases. The compressed gas safety program applies to the storage, use, and handling of gases in pressurized portable containers and gas systems, its primary focus is on single gas uses and systems. For multiple gas use in single controls area and/or building additional requirements may be applied. Please See Appendix? for a guide to compressed gas hazard assessment and evaluating risk.

## 4. Definitions

**Anesthetic gas:** A gas that may cause loss of sensation with or without the loss of consciousness.

**CGA:** Compressed Gas Association

**Ceiling Limit:** The maximum exposure limit, which cannot be exceeded for any length of time

**DOT:** United States Department of Transportation. Responsible for promulgating regulations controlling the transport of toxic gases.

**IDLH:** Immediately Dangerous to Life or Health. "An atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere" (California Code of Regulations, Title 8, Section 5192).

**Inert Gas:** is one that is non-reactive and very stable. Inert gases are non-toxic and do not burn, explode, or corrode materials, but they are still hazardous because when released they displace oxygen. Displacing oxygen will make the atmosphere in the local area not able to support human or other life.

**Manometer:** An instrument for measuring pressure. A U-tube partially filled with a liquid that indicates the pressure exerted on the instrument by displacement of the liquid.

**Leak Test:** Testing pressurized apparatus by a reliable method. This may include coating all non-welded joints with a soap solution which is capable of forming bubbles at leak points, a pneumatic leakdown test using accurate gauges, or other effective measures. Gas systems must be leak tested at the following intervals: upon receipt, at installation, periodically during operation & at disconnect / shipping

**LEL (Lower Explosive Limit)**: LEL is the lowest concentration of a gas or vapor in the air that can produce ignition or explosion

**Magnehelic:** A diaphragm-type pressure differential sensor with a direct reading gauge.

**MAQ (Maximum Allowable Quantity):** The California Fire Code establishes the maximum allowable quantities (MAQ) of flammable or combustible liquids which are permitted in a control area (laboratory or suite of laboratories). The MAQ defines what the total aggregate volume of liquids can be inside of a particular control area.

**NFPA:** National Fire Protection Association.

**PEL:** Permissible Exposure Limit: The maximum concentration of an airborne contaminant to which a worker may be exposed for an 8-hour shift. PELs are established and enforced by Cal/OSHA (California Occupational Safety and Health Administration).

**RMPP:** Risk Management and Prevention Program. A Risk Management Prevention Program is required to anticipate and prevent circumstances that could result in accidental releases of acutely hazardous materials (AHMs) if used in amounts greater than the threshold planning quantity (TPQ). The RMPP includes a hazard and operability study, offsite consequence analysis, and seismic analysis.

**RFO:** Restricted Flow Orifice. An in-cylinder device that reduces the maximum gas release rate.

**STEL:** Short Term Exposure Limit. A maximum time weighted exposure that should not be exceeded for any 15-minute period during a workday.

**TLV-TWA:** The threshold limit value time weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

**Toxic Gas:** Toxic gases, for the purpose of this program, are gases that may cause significant acute health effects at low concentrations. Health effects may include severe skin or eye irritation, pulmonary edema, neurotoxicity, or other potentially fatal conditions. The criteria used to establish the list for this guideline are: **(1)** A National Fire Protection Association (NFPA) health rating of 3 or 4; **(2)** An NFPA health rating of 2 with poor physiological warning properties; (3) Pyrophoric (self-igniting) characteristics or; (4) Extremely low occupational exposure limits in the absence of an NFPA health.

## 5. Responsibilities

### Chairs

Chairs are responsible for establishing and implementing department information and training programs for their respective areas. Delegation of this responsibility to the Principle Investigator (PI), laboratory supervisor, manager and/or safety committee is acceptable. It is the responsibility of the Chair to:

- Understand the processes and hazards in the respective work area;
- Ensure that University policies are enforced and safe work practices are followed; and
- To provide for and acquire adequate instruction in the use and maintenance of compressed gas cylinders for employees.

### Principal Investigator

- Maintains primary responsibility for toxic gas safety in the laboratory
- Includes written safety procedures (SOP) in their laboratory Chemical Hygiene Plan
- Provides and maintains gas safety equipment in good working order
- Conducts and documents laboratory safety self-assessment inspections at regular intervals
- Provides documented training to toxic gas users
- Establishes purchasing specifications (quantity minimization, needed concentrations, etc.)
- Ensures toxic gas program compliance within the laboratory
- Arranges the return of gas cylinders when gas use is completed
- Provides updates to Environmental Health & Safety (EHS) upon any changes to the laboratory chemical inventory
- Determines the minimum amount of a toxic gas needed for the research
- Assures that proper SDS sheets are in the laboratory

### Environmental Health & Safety (EHS)

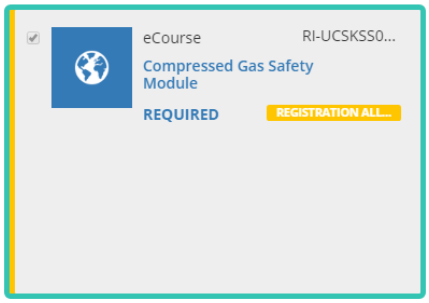
- Ensures that University Compressed Gas Safety programs and safe work practices are used
- Determines health hazard classifications for previously unlisted gases, including: acute and chronic toxicity, carcinogenicity, flammability, pyrophoricity and corrosivity
- Provides gas system planning guidance related to new construction and renovation
- Assists, advises, and provides training as necessary
- Reviews and approves procedures for all controlled, highly toxic, or hazardous gases
- Assists, advises, and instructs UCR employees in the care and handling of compressed gas cylinders and gas systems

### Departmental Purchasing Unit, Material Management

- Reviews toxic gas purchase requests and ensures that toxic gas requests are approved by EHS prior to placing orders
- Informs users of policies regarding toxic gas purchasing

## 6. Training Requirements

UCR personnel (this includes faculty, staff, researchers, and part-time employees) who physically transports and makes connections to compressed gas systems for use at UCR must complete compressed gas safety training approved by EHS. Lab specific training is considered adequate for the connections of tubing and adjustments of valves. EHS provides a web-based training, all personnel working with toxic and highly toxic gases must also complete the proper training prior to their first contact with these materials.




This course will establish the needed elements for an effective compressed gas safety program. The content in this course is designed to comply with the intent of the applicable regulatory requirements.

UCR faculty members who are sponsoring graduate students, visiting researchers, or other personnel not identified above as qualified licensed contractors will follow this program. Please consult with EHS (951-827-5528) for other training programs taken elsewhere to verify equivalency. The training program

will be provided by the PI, a Lab Manager or EHS and will include operational training on specific compressed gas cylinder hazards on campus.

UCR Employees will require refresher training under any of the following conditions:

- Changes in the workplace rendering previous training obsolete
- Changes in the types of cylinder systems or equipment used that would render previous training obsolete
- Observation of unsafe work practices and/or violations of safety rules involving the use of compressed gas cylinders or equipment, or observed behavior indicating that the employee has not retained the required training and retraining may be recommended.

## 7. Labeling Requirements

Compressed gas cylinders shall be legibly marked for the purpose of identifying the gas content with either the chemical or the trade name of the gas. Such marking shall be by means of stenciling, stamping, or labeling, and shall not be readily removable. Whenever practical, the marking shall be located on the shoulder of the cylinder (OSHA Standard 8 CCR §4649 (d))

In addition:

- A durable label should be provided that cannot be removed from the compressed gas cylinder.
- Compressed gas cylinders that do not clearly identify its contents by name should not be accepted for use
- Color-coding is not a reliable means of identification; cylinder colors vary from supplier to supplier, and labels on caps have no identification value because many caps are interchangeable
- Tags should be attached to the gas cylinders on which the names of the users and dates of use can be entered

If the labeling on the gas cylinder becomes unclear or defaced so that the contents cannot be identified, the cylinder should be marked “contents unknown” and the manufacturer must be contacted regarding appropriate procedures for removal.

## 8. General 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

## 9. Proper Storage of Compressed Gas Cylinders

All compressed gas cylinders must be properly stored in compliance with OSHA and NFPA code requirements. Cylinders internal pressure can reach over 2,000 psi. In the event of a container breach, the cylinder becomes a potential projectile.

Signage required at compressed gas cylinder storage locations may include any one of the following (Fig 1 & 2 respectively). Specific requirements will be identified by the UCR Campus Fire Marshal.


**Fig 1.** No smoking flammable gas signage

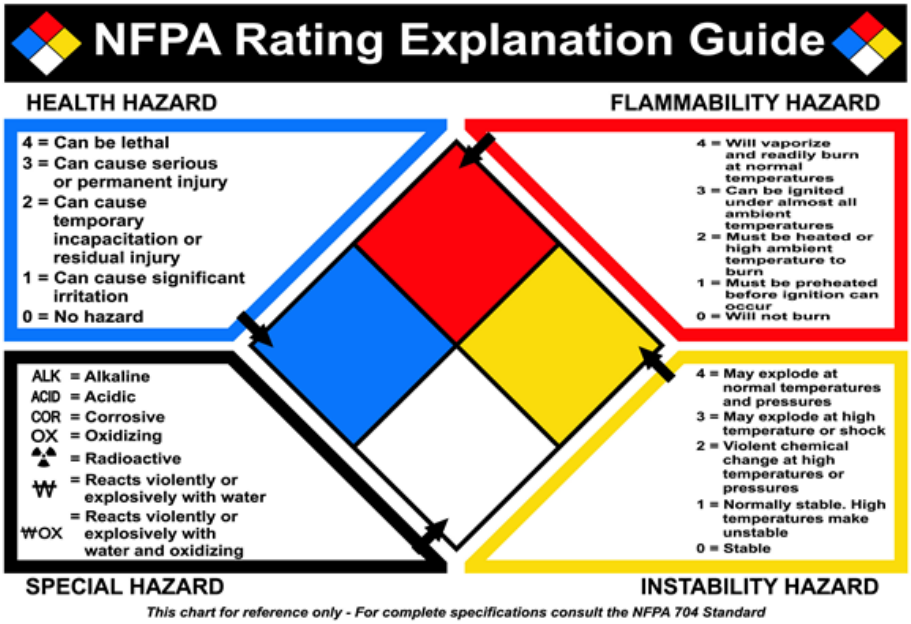



**Fig 2**. National Fire Protection Association (NFPA) rating

It is recommended the following precautions be taken for the storage of compressed gas cylinders.

- Cylinders must be stored in a dry, cool, well-ventilated, secure area

- All cylinders whether empty or full must be stored upright and secured by chains, straps or in racks to prevent them from falling
- Segregated cylinders by contents. For example, flammable gases must be stored separately from oxidizing gases by a distance of 20 feet or a 5 foot high, one-hour fire-rated wall (Fig 3)

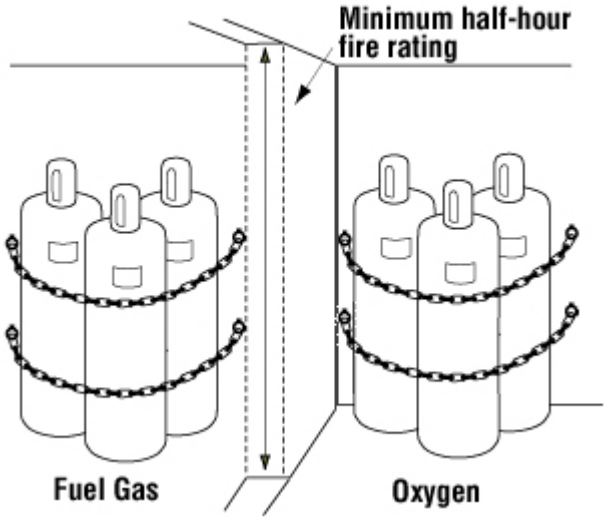



**Fig 3.** Flammables and oxidizer segregation

- Prevent smoking or open flames in oxidizer or flammable gas storage areas
- Do not expose cylinders to corrosive materials such as corrosive gas or other combustible materials
- Segregate full and empty cylinders, use "first in first out" inventory control method
- Store cylinders away from heavily traveled areas and emergency exits
- Provide adequate access for cylinder handling and material handling carts
- Visually inspect stored cylinders on a routine basis, look for indication of leakage
- All cylinder storage areas, outside or inside, shall be protected from extreme heat and cold and from access by unauthorized personnel.

## 9.1 Securing Compressed Gas Cylinders

Cylinders should be secured in one or more of the following ways:

- By a noncombustible, two-point restraint system (e.g. chains) that secures the cylinder
- By a noncombustible rack, framework, cabinet, approved strapping device, secured cylinder cart, or other substantial assembly that prevents the cylinder from falling
- Straps should surround the cylinder approximately 1/3 to 2/3 the height of the cylinder measured from the floor
- Gas cylinders must be secured to prevent falling due to accidental contact or vibration

- Compressed gas cylinders must be protected from sources of heat while stored in a well-protected, well ventilated and dry location away from highly combustible materials.

### 9.1.1 Methods of Securing Compressed Gas Cylinders

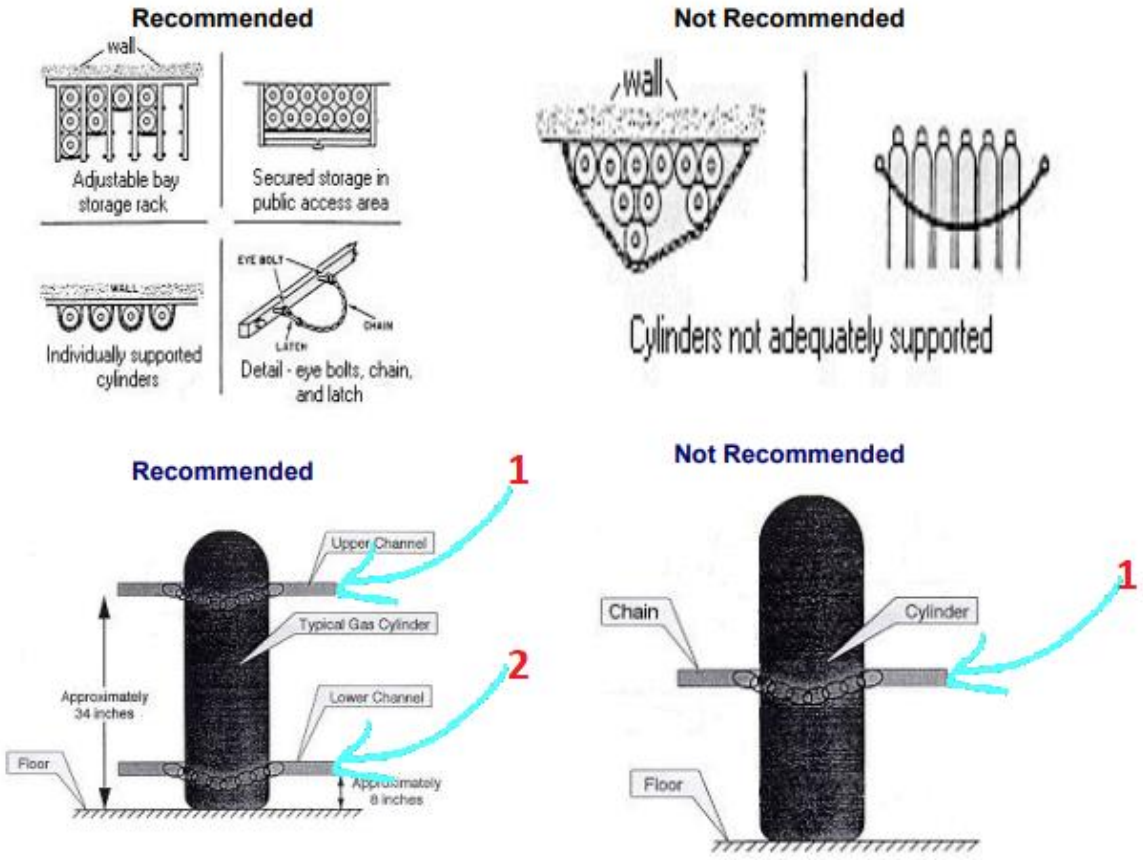



**Fig 4**. Recommended methods for securing compressed gas cylinder

## 9.3 Proper Handling of Compressed Gas Cylinders

Compressed gas cylinders should be handled only by those familiar with the hazards and who can demonstrate safety precautions working with cylinders. Cylinders are heavy and awkward to move and improper handling can result in sprain, strain, falls, bruised, or broken bones. Other hazards such as fire, explosion, chemical burns, poison, and cold burns could occur due to mishandling. Eye protection and appropriate footwear should always be used when transporting compressed gas cylinders. It is advised to always push cylinder carts and not pull.

The following precautions must be taken when handling compressed gas cylinders:

- Wear the appropriate personal protective equipment when handling cylinders
- Cylinders must always be transported on wheeled cylinder carts with retaining straps or chains
- Do not roll or drag a cylinder over a few feet necessary to position the cylinder
- Compressed gas cylinders must be transported with protective caps in place. Do not lift the cylinder by the protective cap
- Avoid dropping the cylinder; do not tamper with pressure-relief devices or remove any product label or shipping hazard labels
- Don't try to catch a falling cylinder
- Do not allow grease or oil to come in contact with oxygen cylinder valves, regulators, gauges or fittings; an explosion or fire can result. Oxygen cylinders and apparatus must be handled with clean hands and tools
- Open cylinder valve slowly, directed away from your face
- Do not attempt to refill compressed gas cylinders; this is only to be done by qualified manufacturer of compressed gases.

## 9.4 Proper Use of Compressed Gas Cylinders

Take the following precautions to prevent injuries caused by the improper use of compressed gases:

- Know and understand the gases associated with the equipment being used
- Use regulators approved for the specific gas
- Do not mix gases in a cylinder
- Do not permit cylinders to become part of an electrical circuit
- Use non-sparking tools (brass) when working with flammable/explosive materials.
- Prevent sparks and flames from contacting cylinders
- Never strike an arc on a cylinder. Never introduce another product into the cylinder
- Do not discharge the contents from any gas cylinder directly towards any person
- Do not force cylinder valves connections that do not fit
- Open cylinder valve slowly and carefully after the cylinder has been connected to the process. Use check valves to prevent reverse flow into the cylinder
- Close the cylinder valve and release all pressure from the downstream equipment. Disconnect the cylinder anytime there an extended non-use period is expected. Cap the cylinder when not in use
- Follow storage and handling requirements
- Never use a compressed gas in any confined space
- Never work alone when using compressed gas.

- Never use compressed gas to dust off clothing. This could cause injury to the eyes or body and create a fire hazard. Clothing can become chemically saturated and burst into flames if touched by an ignition source such as a spark or cigarette.

If the cylinder's valve does not operate properly, do not attempt to force the valve to turn. The cylinder should be returned to the vendor or UCR campus storehouse. Employees must not attempt to repair cylinders or cylinder valves or to force stuck or frozen cylinder valves.

### 9.4.1 Piping Connections and Tubing

Hazardous gases must be dispensed using systems that are properly cleaned and compatible with the gas in use. "Burst pressure" of tubing and piping must be twice the maximum pressure on the second stage regulator. Exceptions to this requirement may be made for short sections of tubing when it and the compressed gas cylinder are completely enclosed in a fume hood and low pressures and flow rates are used. It is recommended to:

- Use "hard" piping (such as copper and stainless steel tubing) whenever possible (as opposed to flexible or plastic tubing). Avoid using cast iron pipe or fittings
- Never use Teflon tape on cylinder connections or tube-fitting connections. Use Teflon tape only on pipe threads where the seal is made at the threads. All other connections have metal to metal face seals or gasket seals
- Select tubing compatible with the chemical and pressure properties of the gas being used in the system. Avoid the use of flexible tubing for highly toxic gases. Flexible tubing should only be used within "line of sight." Do not run flexible tubing through walls, ceiling spaces, doorways, or other non-visible pathways if chafing is likely to occur
- Always clamp flexible tubing connections. Use a clamp approved for the maximum allowable pressure that the connection is subject to. Never use wire, which may cut the flexible tubing.
- Understand most flexible tubing deteriorates with age or exposure to chemicals or UV light. Replace old flexible tubing before it deteriorates
- Always leak-check (leak-test) tubing or piping connections when using hazardous gases.
- Secure and support tubing or piping to keep it in place and to prevent "whipping" if a connection fails under pressure
- Use appropriately rated flexible lines are suitable for manifold/cylinder connections.

### 9.4.2 Regulators

Regulators reduce high pressure gas on a cylinder or process line to a lower usable level. Regulators provide additional safety measures by preventing fire/explosions, chemical or cold burns, poisoning and system over-pressurization. Safety considerations include materials of construction to ensure chemical compatibility, and never use any regulator for gases other than

those for which it is intended. Care must also be taken when using left-handed treaded connectors. Do not force connected or over tighten a connection. Check the bolt for hash marks indicating a left-handed treaded connection.

### 9.4.3 Valves on Compressed Gas Cylinders

Most compressed gas cylinders require the installation of at least one valve. This valve allows the cylinder to contain gases and allows gas to be filled into or emptied from the cylinder. The cylinder valve is the most vulnerable part of the compressed gas cylinder. Leaks can also occur at the regulator, cylinder stem and at the hose connection. Precautions to consider while using valves are:

- Open valves slowly to control pressure surges and heat of compression
- Inspect the valve for damage and foreign materials before connecting to the cylinder
- Never use a damaged valve where integrity may have been affected. Discontinue using a valve that operates abnormally, i.e., becomes noisy or progressively harder to operate
- Never tamper with regulatory or attempt to tighten or loosen the valve into or out of the cylinder
- Never use an automatic operator, adapter, wrenches, or other tools to obtain a mechanical advantage on hand wheel-operated valves without reviewing all safety requirements
- Never lubricate valves or their connections
- Never drag, lift, or move a cylinder using the valve or the hand wheel as a handle
- Use the cylinder valve to regulate flow or pressure
- Never move cylinders without the transport cap installed.

### 9.4.4 Restrictive Flow Orifices (RFOs)

Restrictive Flow Orifices are installed in the cylinder valve outlet and provides significant safety benefits for uses of hazardous gases like toxic and highly toxic gases. Consult the EHS Office for additional information on RFOs.

### 9.4.5 Vacuum Pumps

Hydrocarbon based vacuum pump oil is incompatible with strongly oxidizing and many reactive gases. New vacuum pumps that have inert lubricants and never contained oil-based lubricants must be used with oxidizing and reactive gases.

Vacuum pumps must be securely vented to a fume hood or other approved local exhaust system with tubing that is compatible with the gases used. Exhaust lines must be as short as feasible. Vented enclosures may be required for vacuum pumps depending on the toxicity of the gases used.

## 9.5 Engineering Control Measures

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

• Secure cylinders and lecture bottles 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.

• Ensure appropriate ventilation is available in 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, it is recommended the tubing stay under 10 feet in total length. Contact EHS @ 951-827-5528 to assist you and the facilities manager to determine the proper engineering controls for the laboratory or workspace.

### 9.5.1 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

should 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.

## 9.6 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.
- Display the appropriate signs (e.g ePlacard) and labels
- Be familiar with the UCR Chemical Hygiene Plan (CHP) and the Laboratory Safety Manual
- Write and implement SOPs about using, transporting, moving, and storing compressed gas cylinders in the work location.

## 9.7 Personal Protective Equipment

For personnel and environmental protection against the potential exposure to toxic and highly toxic gases the following personal protective equipment should be used by personnel:

- Laboratory coats or gowns must be worn at all times in the toxic or highly toxic gas area;
- Appropriate hand protection must be used when handling toxic and highly toxic gases;
- Safety goggles must be worn at all times in the toxic or highly toxic gas area;
- When employee exposure exceeds the Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV) (whichever is lower), respiratory protection will be required.

**NOTE:** You must be enrolled in EHS Respiratory Protection program before wearing respiratory protection to enroll please contact EHS Industrial Hygienist x22964

## 9.8 Specific Requirements of Compressed Gas Cylinders

Read the label on the cylinder and identify the contents before using. If the label is illegible or missing, return the cylinder to the vendor or UCR campus storehouse. Don't rely on stenciling or the color of the cylinder. Do not use a cylinder with unidentified contents. All cylinders must be permanently labeled as to their contents and if they are full or empty (example - an empty cylinder may be marked “MT” alternatively “empty” is also appropriate). Empty cylinders must also be separated from full cylinders. Know the hazards of the contents and follow appropriate safe use practices for the material inside. Refer to the specific Safety Data Sheet (SDS) for further information.

## 9.9 Emergency Response Guidelines

All laboratories are required to have an emergency response plan for the hazardous gases they use. These plans should outline what should be done should an uncontrolled release of a gas occur. The severity of the release will be determined by the following factors:

- Amount of local and general exhaust in location
- Types of controls in place
- Gas concentrations and warning properties of the released gas

Most leaks occur at the valve and valve stem fitted on the top of the cylinder. Leakage here is frequently due to dirt in the connection, damaged connections or washers where required. Such leaks are easily rectified, attempt to tighten the connection

### Uncontrolled Release

Once a highly toxic or toxic gas has been released the user should be able to determine if the flow can be shut off safely either by using an emergency shutoff button or by manually closing the shutoff valve. If this is not possible, the following general actions should be taken:

1. Activate the fire alarm – evacuate building and local area of release (laboratory), turn off all ignition sources (if time permits), evacuate the area immediately and close the door.
2. Barricade or seal of the local area of release (place signs and caution tape)
3. Call UCPD on a **campus phone** @ 9-911 to arrange for medical attention for exposed personnel and to report the incident, identify where and what has happened. UCPD will provide the scene control of the release area.
4. Call Facilities (951) 827-4214 for assistance in placing the requested building on 100% fresh air
5. Obtain SDS and follow emergency release instructions – unless the specific emergency response plan developed by the lab is more detailed and appropriate

Once the area is evacuated and isolated, only trained Emergency Response Personnel with proper PPE and monitoring equipment will be authorized to the enter the release area.

### Personnel Exposure

If there is a personnel exposure, the first aid actions on your emergency release procedure should be followed. The basic treatment for any exposure is:

- In the event of personnel skin contamination, wash with soap and water and remove contaminated clothing.
- In the event of personnel eye contamination immediately flush the exposed area using an eye wash or water for 15 minutes.
- In the event of personnel exposure via inhalation, remove to fresh air

The specific actions and order will be determined by your specific emergency procedure

**NOTE:** When medical attention is needed, the SDS sheet for the toxic or highly toxic gas should be brought to the hospital to assist in treatment. Please also inform EHS (951-827-5528) about exposure

# APPENDICES

## Appendix A: Purchase Approval Process

The toxic gas purchase approval process applies to new uses of toxic gases, as well as changes in volume, use, or location for existing uses as of **06/04/2018**. The purchasing process is diagrammed in **Fig 5**. Renewal purchase requests for gas uses that have been previously approved will be expedited through the purchase process.

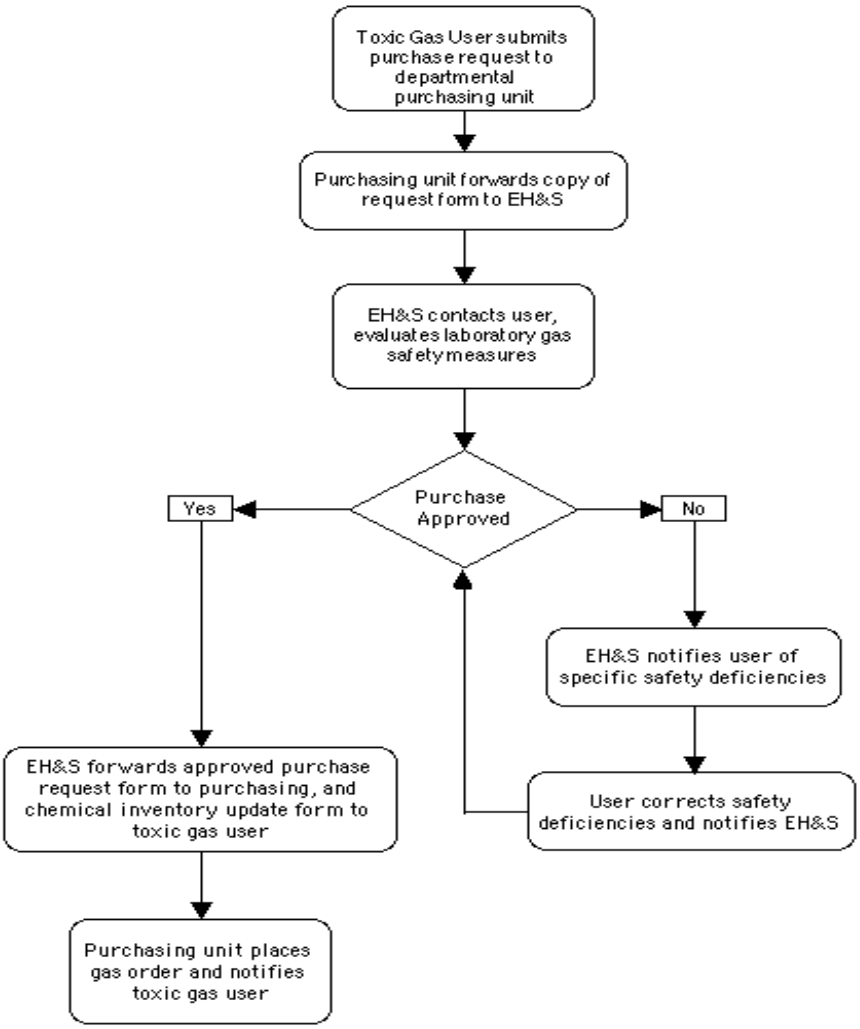



**Fig 5**. Pathway for toxic gas approval

The toxic gas user shall first present a purchase request to their departmental purchasing unit. The purchasing unit shall then send the purchase request to the Office of Environment, Health & Safety (EHS). EHS will then contact the toxic gas user to discuss safety issues related to the proposed use. An evaluation of a toxic gas purchase request may involve interviewing the gas user or laboratory safety

officer, a laboratory visit, modeling of a laboratory gas release, and/or specific recommendations for gas use safety. The criterion for toxic gas purchase approval is the ability to provide a safe working environment and advance provision for proper handling and disposal.
If the proposed toxic gas purchase will result in a change in the laboratory's Occupancy Use Classification (as defined in the California Building Code), the current California Fire Code requirements will be applied. If these requirements are not feasible, the PI will work with EHS to propose alternate means of providing adequate protection for review and approval by the Campus Fire Marshal. In existing labs where the purchase will not result in an Occupancy Use Classification change, EHS will ensure that currently enforced safety and environmental regulations are properly addressed, and may require additional precautionary measures applicable to the proposed use.

Upon EHS approval of the gas purchase, notification will be sent to the departmental purchasing unit and to the toxic gas user. The purchasing unit will then proceed with the gas ordering process. If the toxic gas use plans are not approved, EHS will notify the toxic gas user of specific deficiencies and will work with the toxic gas user to implement any needed safety modifications. Unapproved purchase requests that cannot be resolved may be appealed to the Vice Chancellor of Research (VCR) for an acceptable resolution. If the toxic gas is not in the laboratory's current chemical inventory, the user shall amend the chemical inventory within fifteen (15) days of receiving the gas.

As part of the ordering process, the toxic gas user is responsible for obtaining vendor information regarding chemical compatibility for process equipment, manifold specifications, and the availability of restricted flow orifices. Restricted flow orifices shall be used where feasible.

## Appendix B: Types of Compressed Gases

The types of compressed gas can be divided into three categories, each with unique characteristics.

- ✓ Non-Liquefied Gas
- ✓ Dissolved Gas
- ✓ Liquefied Gas

**Non-Liquefied Gas:** is also a compressed, pressurized or permanent gas. These gases do not become liquid when they are compressed at normal temperatures or even very high pressures. Common examples are oxygen, nitrogen, helium, and argon.

**Dissolved Gas:** can also be compressed. A common example of dissolved gas is acetylene. Care should be taken when using acetylene or welding. Consult your supervisor before using acetylene.

**Liquefied Gas**: can become liquid at normal temperatures when they are inside a cylinder under pressure. When gas is removed from the cylinder, enough liquid evaporates to replace it, keeping the pressure in the cylinder constant. Common examples include anhydrous ammonia, chlorine, propane, nitrous oxide, and carbon dioxide.

# Appendix C: Hazard Assessment

A hazard assessment for compressed gas can be used to determine what controls are required to minimize risk. To evaluate risk, please use these broad methods:

- Determine which hazard categories the gas falls into (See Appendix B for gas types)
- How good are the warning properties of this gas (odor, color)?
- Identify the volumes of gas used, and the result of a catastrophic failure of a cylinder or process
- Identify where the most likely point of failure in the process is
- Answer the following questions:
    - How will it be known if a gas is released?
    - How quickly will the gas be released should a failure occur?
    - Are there any incompatibles close by?
    - What steps must be taken if the gas is released?
    - Who needs to be notified and how will they be notified?

Once the evaluation is completed, how to control these hazards should be identified. This will include a combination of Engineering, Administrative, and Personnel Protective Equipment. The next section in this document summarizes the most common hazards associated with compressed gas use

## Hazards

There are two categories of hazards and a third unique that must be aware of prior to using any compressed gas.

**1. Mechanical Hazards**: Hazards associated with physical damage to a cylinder or its components causing the uncontrolled release of the gas. To prevent against mechanical hazards an understanding of how a cylinder and its components can become damaged, and how proper handling and storage procedures can be used to minimize this risk

**2. Chemical Hazards:** Hazards associated with the actual material inside the cylinder should it be released in an uncontrolled fashion. To prevent against chemical hazards the properties of the gas, its severity and how it interacts with various substrates and the environment must be understood as well.

**3. Unique pressure Hazards**: Abrade skin or eyes due to blown shavings, chips and/or filings. Airborne contaminants can be a respiratory hazard. And finally, on rare occasions, some of the compressed air can enter the blood stream through a break in the skin or a body opening causing an embolism; the consequences of even a small quantity of air or other gas in the blood can quickly be fatal.

**Table 2**: Required/recommended Engineering and Administrative Controls. If a gas has multiple hazards, use the classification with most stringent requirements.

| Engineering Control Requirements | Highly Toxic & Toxic | Pyrophoric | Flammable | Corrosive | Oxidizer |
|---|---|---|---|---|---|
| Exhausted enclosures (other than a gas cabinet) | | | R | X | |
| Gas Cabinet | X | | | R | |
| Treatment to ½ of IDLH atmospheres | R[1] | R[1] | | R[1] | |
| Flow limiting device | X | X | | X | |
| Sprinkled space | X | X | X | | |
| Dedicated Purge system | X | X | R | X | |
| Gas Detector system | R[1] | R[1] | | R[1] | |
| Emergency alarms | X | X | | X | |
| Welded, compatible piping | X | X | | X | |
| Coaxial piping | X | X | | R | |
| Local shut-off | X | X | X | X | |
| Remote shut-off | X | X | R | X | |
| Interlocks with exhausted enclosure | X | X | R | R | |
| Emergency power (alarm, detector, ventilation) | X | X | R | R | |
| Monitored secondary containment | X | X | R | X | |
| Failsafe Auto shut-off (detector triggered) | R[1] | R[1] | R | R[1] | |
| Exhaust flow alarm | X | X | R | X | |
| Cylinder safety devices | X | X | X | X | X |
| Line safety devices | X | X | X | X | X |
| **Administrative Control Requirements** | **Highly Toxic & Toxic** | **Pyrophoric** | **Flammable** | **Corrosive** | **Oxidizer** |
| Emergency response plan, team, and drills | X | X | X | X | X |
| Leak checks (at initial set-up and after complete) | X | X | X | X | X |
| Documented monthly inspections | X | X | X | X | X |
| Recommended size of cylinders | Use smallest cylinder available. Avoid lecture bottles as they are extremely expensive to dispose of | | | | |
| Lab Storage of Cylinders | As minimal as possible | | | | |

Table Notes:
- X - Required
- R - Recommended
- R[1] – Treatment systems not required if the following are installed:
  - o Gas detection system to measure the gas concentration point of discharge; and,
  - o An automatic fail-safe closing valve

## Appendix D: Toxic and highly toxic gases

Toxic and highly toxic gases may cause significant acute health effects at low concentrations. Health effects may include severe skin or eye irritation, pulmonary edema, neurotoxicity, or other potentially fatal conditions. The criteria used to establish the materials addressed by this program are:

- A National Fire Protection Association (NFPA) health rating of 3 or 4
- An NFPA health rating of 2 with poor physiological warning properties
- Pyrophoric (self-igniting) characteristics, OR
- An extremely low occupational exposure limits in the absence of an NFPA health rating.

**Table 1** identifies common gases that meet the criteria of toxic or highly toxic, though it is not exhaustive.

**Table 1 – Common Toxic and Highly Toxic Gases**

| | | |
|---|---|---|
| allene | Dichlorosilane | nitric oxide |
| ammonia | Dimethylamine | nitrogen dioxide |
| arsenic pentafluoride | Disilane | nitrogen trifluoride |
| arsine | Fluorine | phosgene |
| boron trichloride | fluorine mixtures | phosphine |
| boron trifluoride | germane (GeH4) | phosphorous pentafluoride |
| bromine pentafluoride | hydrogen bromide | phosphorous trichloride |
| bromine trifluoride | hydrogen chloride | phosphorous trifluoride |
| 1,3 butadiene | hydrogen cyanide | silicon tetrafluoride |
| carbon tetrafluoride | hydrogen fluoride | stibene (SbH3) |
| carbon monoxide | hydrogen selenide | sulfur tetrafluoride |
| carbonyl sulfide | hydrogen sulfide | sulfuryl fluoride |
| chlorine | methyl bromide | tungsten hexafluoride |
| chlorine trifluoride | methyl chloride | vinyl chloride |
| cyanogen | methyl silane | |
| cyanogen chloride | Monomethylamine | |
| diborane | nickel carbony | |

Certain dilute toxic gases are exempt from this program if worst case release modeling of an accidental acute release indicates that the gas concentrations will not result in exposures to laboratory personnel exceeding any of the following:

- The OSHA Short Term Exposure Limit (STEL)
- The Threshold Limit Value-ceiling (TLV-C)
- Any recognized full shift exposure standard if there is no STEL or TLV-C for the material
- One half of the concentration established as Immediately Dangerous to Life or Health (IDLH)

**ALL exemptions on the basis of dilution will be made on a case-by-case basis by the Office of the Environmental Health & Safety (EHS).**

## Exposure Control Methods

### A. Engineering Controls

For personnel and environmental protection against the potential exposure to toxic and highly toxic gases, the following engineering controls are required:

1. All toxic and highly toxic gas cylinders and reaction vessels/chambers shall be kept and used in a chemical fume hood, gas cabinet or exhausted enclosure that meets the following minimum requirements:

**Fume hoods shall:**

• Be certified for chemical use by EHS within the last year (as indicated by a certification sticker on the fume hood)

• Be used for all manipulations. If the use of a fume hood is impractical, other ventilations shall be provided

• Have airflow measuring devices and visual and audible alarms that signify low airflow conditions

• Be located in rooms that are exhausted and negative in pressure to surrounding areas.

**Gas cabinets shall:**

• Be located in rooms that are exhausted and operate at negative pressure in relation to surrounding areas

• Have self-closing limited access ports or non-combustible windows to give access to equipment controls

• Provide and average velocity at the face of access ports or windows not less than 200 feet per minimum with a minimum of 150 feet per minute at any point (call EHS @ 951-827-5528 to have air flows measured)

• Be connected to an exhaust

• Have self-closing doors

• Be sprinkled

• Be constructed of not less than 12 gauge steel

• Have airflow measuring devices and visual and audible alarms that signify low airflow conditions

• Be installed through the Facilities or vendor.

**Exhausted enclosures shall:**

• Operate at negative pressure in relation to surrounding areas;

• Provide and average velocity at the face of access ports or windows not less than 200 feet per minimum with a minimum of 150 feet per minute at any point (call EHS @ 951-827-5528 to have air flows measured);

• Have airflow measuring devices and visual and audible alarms that signify low airflow conditions

• Be located in rooms that are exhausted and negative in pressure to surrounding areas

2. All exhaust lines or ducts carrying purged or exhausted emissions of toxic gases must be connected to a mechanical exhaust system that discharges to a safe location (i.e. presents no potential for re-entrainment into any building supply air intake or occupied area). Exhaust wall ducts shall be chemically resistant to degradation by the toxic gas in use.

### B. Work Practice Controls

For personnel and environmental protection against the potential exposure to toxic and highly toxic gases, the following work practice controls should be used:

**Handling:**

The following work practice controls must be used when handling toxic and highly toxic gases:

• Safety Data Sheets (SDS) must be reviewed prior to working with any toxic or highly toxic gas

• Standard Operating Procedures (SOP) must be developed for the gas(es) in use

At a minimum, SOPs shall contain:

- Safety precautions for the storage, handling and use/delivery of the gases
- Identification of all PPE that will be worn
- Description of toxic gas monitoring systems
- Emergency response procedures
- Consult EHS (951-827-5528) for SOP review and/or development

• All cylinders shall be immediately leak tested with a leak indicating solution and must be clearly labeled with content and hazard information

• All work with toxic or highly toxic gases must be conducted in a working chemical fume hood to prevent exposure by inhalation

• Proper personal protection equipment (PPE) must be worn at all times to prevent eye and skin contact

• No work with toxic or highly toxic gases shall be performed alone

• Do not drag, roll, slide or drop cylinders. A suitable hand truck, to which the cylinder is secured, must be used for cylinder movement.

• When transporting gases outside the lab, the protective cap shall be in place and shall cover the valve.

• Never attempt to lift a cylinder by its cap.

• Secure cylinders at all times while in use and during transport.

• Only use approved regulators and valves. Consult your gas supplier for approved regulators and valves.

• Once cylinder has been connected to process, open valve slowly and carefully. If experiencing difficulty opening cylinder valve, discontinue use and contact supplier. Forced freeing of "frozen" or corroded valves should NOT be attempted.

• Regulators and valves should be kept free of moisture. Systems should be purged with dry inert gas (e.g. helium, nitrogen, argon, etc.) before the product is introduced and when system is out of service.

• The main valve on all toxic and highly toxic gas cylinders must be closed at all times when the cylinder is not in use

In addition to protocol for hazardous gases piping and tubing **section 14**, toxic and highly toxic gases shall:

• be identified to indicate the material conveyed and arrows shall indicate the direction of flow

• have readily accessible manual or automatic remotely activated fail-safe emergency shutoff valves installed on supply tubing at the point of use and the source

• have emergency shutoff valves identified and the location shall be clearly visible and indicated by means of a sign

• have backflow-prevention or check valves when backflow of hazardous materials could create a hazardous condition of caused the unauthorized discharge of hazardous materials

• have excess flow control when gas is carried in pressurized piping above 15 psi. The excess flow control shall be located in the source exhausted enclosure

**Disposal:**

The following work practice controls must be used when disposing of toxic and highly toxic gas cylinders:

• All empty toxic and highly toxic gas cylinders shall be labeled as empty

• Toxic gases should only be purchased by vendors who will agree to take back the empty cylinder

• Any cylinders that will or cannot be removed by the vendor must be disposed of through EHS.

### C. Personal Protective Equipment

For personnel and environmental protection against the potential exposure to toxic and highly toxic gases the following personal protective equipment should be used by personnel:

- laboratory coats or gowns must be worn at all times in the toxic or highly toxic gas area
- Appropriate hand protection must be used when handling toxic and highly toxic gases
- Safety goggles must be worn at all times in the toxic or highly toxic gas area
- When employee exposure exceeds the Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV) (whichever is lower), respiratory protection will be required.

**NOTE:** Personnel must be enrolled in EHS Respiratory Protection program before wearing respiratory protection. To enroll please contact EHS Industrial Hygienist x22964

### D. Toxic Gas Monitors

Electronic toxic gas monitors shall be installed and continuously operated whenever a toxic or highly toxic gas is used or stored. All gas monitoring systems shall have:

- Audible and visible alarms located in gas supply locations, gas use locations, and outside the gas use room
- An alarm status and gas concentration readout panel located outside the gas room;
- Local audible and visual alarms specific and distinct from fire alarm bells. The alarm's sound should be significant in meaning and require personnel action
- The toxic gas alarm level set-point set at the Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV), whichever is lower
- Connection to an emergency power source
- Locks or enclosures that protect power connections and control switches that affect the detection system operation.

## Appendix E: Pyrophoric Gases

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, Call EHS @ (951) 827-5528.

| 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 UCR MAQ | In addition to the requirements listed above, any quantity of Pyrophoric Gas above the UCR MAQ may be also required to have the following engineering controls upon consultation with your EHS representative:<br>• The workspace must be equipped with a continuous gas detection system.<br>• The gas detection system must initiate a local alarm that is both visible and audible.<br>• The gas detection system must transmit a signal to a constantly attended control station.<br>• Activation of the gas detection system must automatically shut off the flow of gas related to the system being monitored.<br>• 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.<br>• Emergency power must be provided for the exhaust ventilation, gas detection system, and alarm systems when required. |

## Appendix F: Oxidizing Gases

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<br>• 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 G: Flammable Gases

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.<br>• Flash arrestors are designed to prevent a flash-back, should it occur, in a line containing a flammable gas.<br>• Portable fire extinguisher must available in the area where compressed gases and cylinders are used and stored.<br>• Use spark- proof tools when working with flammable gas.<br>• 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 |
| **Administrative Controls** | • Do not use acetylene at an operating pressure over 15 psig.<br>• Do not leave flow experiments using flammable gases unattended. |
| **Engineering Control:** Above the UCR MAQ | Flammable gas quantities above the UCR MAQ may be required to have the following engineering controls:<br>• The workspace is equipped with a continuous gas detection system.<br>• The gas detection system must initiate a local alarm that is both visible and audible.<br>• The gas detection system must transmit a signal to a constantly attended control station.<br>• Activation of the gas detection system must automatically shut off the flow of gas related to the system being monitored.<br>• 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.<br>• Emergency power must be provided for the exhaust ventilation, gas detection system, and alarm systems when required.<br>• Sprinkler protection for gas cabinets and other protective features may be required.<br>**NOTE:** This information is for general guidance. Consult with your EHS representative to determine requirements for your particular usage. (951) 827-5528 |