University of Waterloo

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Chemical Fact Sheets

Compressed Gas Standard

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Introduction:

Compressed gases can cause significant injury and property damage when handled inappropriately. When released, some of these gases can be immediately dangerous to life or health, can react with metals and other substrates in a dangerous way and ignite/explode in the presence of air.

This standard contains guidance on the controls required when using compressed gases at the University of Waterloo. It includes information such as:

- Considerations when performing a risk assessment of processes or activities involving compressed gases
- Required training for individuals using and individuals working in proximity to compressed gases
- The appropriate controls required when these gases are being used, stored, and handled
- A generic emergency procedure for individuals using compressed gases on campus

Scope

This standard is applicable to the use of any compressed gas on campus. A listing of the most commonly used toxic, pyrophoric and corrosive gases at UWaterloo is provided in Appendix 4. Cryogens are considered in the UWaterloo Cryogens standard.

Training

Compressed Gas Users

Before an individual can use a compressed gas, they must successfully complete the following training:

1. Cryogenic and compressed gas safety – SO1030 (Online)
2. Laboratory Safety – SO1010 (Online)
3. Read and understand this standard
4. Read and understand the MSDS/SDS for the gas
5. Specific training by the Principal Investigator (PI) or Lab Manager on the gases the person will be using. This includes training on SOPs for:
    a. Set-up
    b. Cylinder change-out
    c. Emergency release of gas

Non-users in Labs using Compressed Gases

Any individual not directly working with a compressed gas, but working in a laboratory where compressed gases are being used must complete the following training:

1. Laboratory Safety – SO1010 (Online)
2. Read and understand this standard

3. Training by PI on response to hazardous gas releases (What to do if….)

Hazard Assessment

Prior to ordering a compressed gas, the lab user should perform a hazard assessment to determine what controls are required to minimize risk. The following steps provide a generic method of assessing risk:

- Determine which hazard category(ies) the gas falls into (See Appendix 2 for gas classifications)
- How good are the warning properties of this gas (odour, colour, etc…)?
- Identify the volumes of gas used, and the result of a catastrophic failure of a cylinder or process
- Identify where in your process is the most likely point of failure
- Answer the following questions:
  - How will I know 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 assessment is completed, you need to identify how you can control these hazards. This will include a combination of Engineering, Administrative, and Personnel Protective Equipment. The next section in this document outlines the most common hazards associated with compressed gas use. Following that is a section on the required controls for various gases.

Hazards

There are two categories of hazards you 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.
2. **Chemical Hazards:** Hazards associated with the actual material inside the cylinder should it be released in an uncontrolled fashion.

To prevent against mechanical hazards you need to ensure you understand how a cylinder and its components can become damaged, and how proper handling and storage procedures can be used to minimize this risk. To prevent against chemical hazards you need to understand the properties of the gas and how it can cause harm, and how it interacts with various substrates and the environment.

Mechanical Hazards – Causes and Controls

- Determine which hazard category(ies) the gas falls into (See Appendix 2 for gas classifications)
- How good are the warning properties of this gas (odour, colour, etc…)?
- Identify the volumes of gas used, and the result of a catastrophic failure of a cylinder or process
- Identify where in your process is the most likely point of failure
- Answer the following questions:
  - How will I know 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 assessment is done, you should identify how you can control these hazards. This will include a combination of Engineering, Administrative, and Personnel Protective Equipment. The next section outlines the required and recommended controls for various types of gases that are used on campus.

Hazards:

There are two categories of hazards you 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.
2. **Chemical Hazards:** Hazards associated with the actual material inside the cylinder should it be released in an uncontrolled fashion.
3. **Unique Pressure Hazards:** When a gas under high pressure is directed toward an opening in the skin (cut, open wound, etc…), an air bubble could form in the blood stream. This is termed an embolism and is a very serious condition.

Mechanical Hazards – Causes & Controls

To prevent against mechanical hazards, it is important to understand how a cylinder and its components can become damaged and how proper handling and storage procedures can be used to minimize this risk.

View the picture below for a summary of the ways in which a cylinder can become damaged:

Figure 1: The four ways in which a compressed gas cylinder can be physically damaged.

- Heat – heat will do two things, first it will weaken a cylinder's walls, and second it will expand the gas inside creating added pressure against the walls. Both of these effects together can lead to rupture of the cylinder and a dangerous way (explosion). Any cylinder exposed to a heat source like a flame should be removed from service.

  To avoid heat damage keep cylinders away from heat sources and ignition sources. At a minimum, a compressed gas cylinder should be stored at temperatures below 49^{0}C.

- Electrical arcs can significantly weaken the integrity of the cylinder where the contact happened. Again, the cylinder can rupture, and therefore it should be taken out of service.

  To avoid electrical arcing damage, keep cylinders away from electrical panels and from becoming part of an electrical circuit.

- Impact damage – impact damage can occur if the cylinder falls or is struck by something. The area particularly susceptible to damage is the cylinder valve.

  To protect from impact damage cylinders should only be moved using appropriate cylinder carts, the cylinder cap should always be on if the cylinder is not in use (and during transport), and cylinders must always be securely chained to a fixed object when put in a process or stored. Lastly, store away from high traffic areas such as exit routes, doorways, elevators or stairs.

- Corrosion – corrosion can happen to a cylinder if it is stored in conditions with excessive moisture, or in areas that have corrosive gases.

  To avoid corrosion, cylinders should not be stored in corrosive atmospheres, or areas of high humidity or moisture. If stored outdoors, they should be on a raised concrete pad (away from sitting in water) and should be protected from rain and snow. (Cylinders) that contain corrosive gases have specific storage requirements which will be viewed later in this document.

Best Practices for Cylinder Use, Handling and Storage:

Use:

If a manufacturer's instructions or guidance conflicts with this document, please contact the Safety Office for clarification. In most cases, this is general information, and the supplier information will be used as guidance.

- HARD copies of MSDSs/SDSs for all compressed gases in use must be readily available
- ONLY use cylinders that are in an upright position and that have been securely fastened to a fixed object.
- NEVER use cylinders who's contents are unknown
- ALWAYS wear safety glasses, a face shield or goggles when using compressed gases
- ALWAYS consult the manufacturer's guidance documentation for the appropriate regulator for your application
- DO NOT force cylinder connections. If it does not open, contact the supplier for guidance.
- NEVER force a cylinder valve open. If you cannot open it by hand, contact the supplier for instructions
- NEVER use a flame to thaw a valve frozen with ice. Instead use warm water (not boiling) and only if gas is NON-REACTIVE
- REGULATORS and PRESSURE GAUGES should only be used with the gases for which they have been designed

- DO NOT modify connections
- NEVER open a cylinder valve if a valve outlet is pointing at someone. Clear area before opening.
- DO NOT empty a cylinder completely. Leave about 25 psi in the cylinder to prevent backflow.
- NEVER use oil or grease on oxygen cylinder systems
- TEST cylinders for leaks using an appropriate leak test solution every time you use them (see image to right ->)
- TOXIC, CORROSIVE, FLAMMABLE, and OXIDIZING gases must have emergency plans before you are allowed to use them. You must have a specific procedure describing actions to take should the cylinder rupture or leak for each type of gas.
- OXYGEN and ACETYLENE gases must have purge procedures for use. Purge before use.
- FLAMMABLE gases require grounding the valve before bleeding.
- USE the cylinder valve for turning gas off, not the regulator valve.
- BEFORE removing a regulator ensure the cylinder valve is off
- ALWAYS use a trap between the regulator and a reaction vessel to prevent contamination when carrying out chemical reactions
- TURN off the cylinder valve then the regulator after work is done. Pressure gauges should be brought to zero

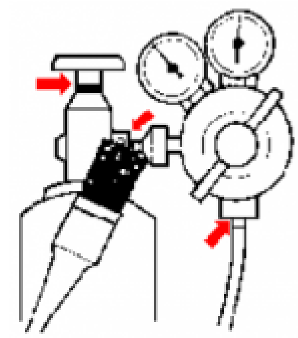
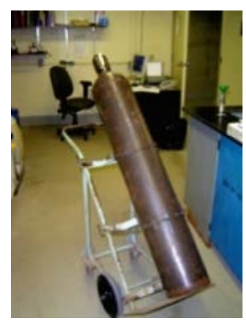


Figure 2: Schematic of a compressed gas cylinder components.

Handling:

Large gas cylinders can easily reach 100 kg, with some reaching a mass of 1,000 kg (Chlorine) therefore you must follow proper handling protocols to move and transport a compressed gas cylinder. Follow these guidelines or contact the Safety Office for more information:

- ONLY move cylinders using appropriate cylinder handling carts (see image on right ->)
- ALWAYS keep the cylinder valve in place when transporting a cylinder
- NEVER drag a cylinder, if needed you may roll a cylinder on its edge to position it
- AVOID dropping or allowing cylinders to strike objects or each other
- EMPTY cylinders should be handled as if they are full – there should be a residual pressure in them
- DO NOT tamper with cylinder safety devices
- NEVER refill a cylinder. Refilling requires special equipment and techniques.
- NEVER mix gases in a cylinder
- USE safety gloves and safety shoes when transporting or moving cylinders



Storage:

- STORE and SECURE cylinders in an upright position
- STORAGE areas must be well ventilated

- DO NOT store flammable substances in the same area
- OXDIZING gases (like oxygen) must be separated from FLAMMABLE (like hydrogen) gases by at least 6 m or by a 1.5 m high fire-resistant wall with a rating of at least 30 minutes.
- STORE cylinders out of direct sunlight and in temperatures below 49^{0}C. Cylinders with fusible plugs (pressure release device) will release contents at 65^{0}C or greater.
- SEPARATE and MARK clearly empty cylinders from full ones
- ALWAYS put valve cap in place when a cylinder is not in use
- NO sources of ignition should be present in a compressed gas storage area
- STORE propane tanks greater than 5 lbs. outside.

Proper storage	Improper Storage
 	  

Figure 3: Differences between proper and improper storage.

Laboratory Use

- REMOVE empty cylinders as soon as possible
- TOXIC gases must be placed in vertical ventilated cabinets
- KEEP SDS for cylinder accessible in the lab

Table 1: Laboratory cylinder limits based upon gas type.

	Flammable or oxidizing gases	Liquefied flammable gases	Gases with health hazard rating of 3 or 4 (LC_{50} 3000 ppm) stored in ventilated cabinet
Number of cylinders per 500 ft^2	3	2	3

Chemical Hazards:

The hazards associated with each chemical are specific to its properties. In general compressed gases come in the following categories:

- Inerts
- Flammables
- Oxidizing
- Corrosive

- Toxic

The most common gases found at the University of Waterloo have been categorized and identified in Appendix 4.

Inerts

An 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.

Flammables

A flammable gas is a substance that has a Lower Flammability Limit (LFL) of less than 13% or a flammability range that is greater than 12%, regardless of the LFL. A substance with a large flammability range is considered more hazardous than one with a smaller range. The image on the right illustrates the flammability range of some common gases.

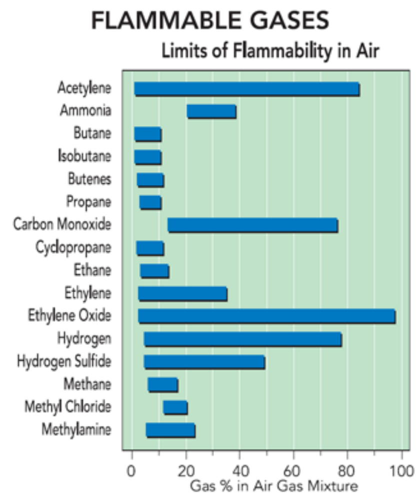


Figure 4: An illustration depicting the upper and lower flammability limits for various flammable gases.

The main hazard with a flammable gas is when released it can rapidly accumulate to a concentration that could ignite and cause a fire or even flashback to the cylinder – resulting in an explosion.

To prevent this you should:

- ALWAYS check the compressed gas system for leaks before beginning work
- USE non-sparking tools
- USE system safety devices like flash arrestors and check valves
- GROUND the regulator valve before bleeding the system
- USE and STORE in an area with appropriate ventilation
- STORE and use away from ignition sources, hot objects, electrical equipment and equipment that is not intrinsically safe.
- CREATE an emergency plan outlining the steps required to deal with a leaking flammable gas system

Oxidizers

An oxidizing gas is one that facilitates a chemical reaction. The most common oxidizing gas is oxygen. Other examples of oxidizing gases include: chlorine, nitrogen oxide, nitrous oxide, and nitric oxide. Gas mixtures can also be classified as an oxidizer. Any gas mixture with an oxygen content of greater than 23.5% is considered an oxidizer.

The main hazards associated with oxidizing gases:

- Lower flammability range of flammable substances
- Can “enrich” combustibles so they combust easier and with greater vigor (examples – clothing, gloves, fabrics, paper, cardboard, etc.…).
- Fires involving oxidizers are much more difficult to put out

To prevent this you can:

- KEEP oxidizing gases at least 6 m away from flammable gases
- NEVER store combustible items near oxidizing gas cylinders
- NEVER use greases or oils or lubricants for oxygen compressed gas systems. The combination of friction, combustibles and an oxidizing gas can cause ignition – contact manufacturer or supplier for details on how to properly set up your system.
- NEVER use oxygen to purge lines or valves or to enrich the air in an area.
- MONITOR storage areas for leaks

Corrosive Gases

Corrosive gases attack and chemically destroy metals, fabrics, certain plastics and even human tissue. In extreme conditions a corrosive gas that is released or leaking can lead to mechanical failure, destruction of infrastructure, and/or serious health problems (such as asthma).

Examples include Ammonia, Hydrogen Chloride, and Sulphur Dioxide

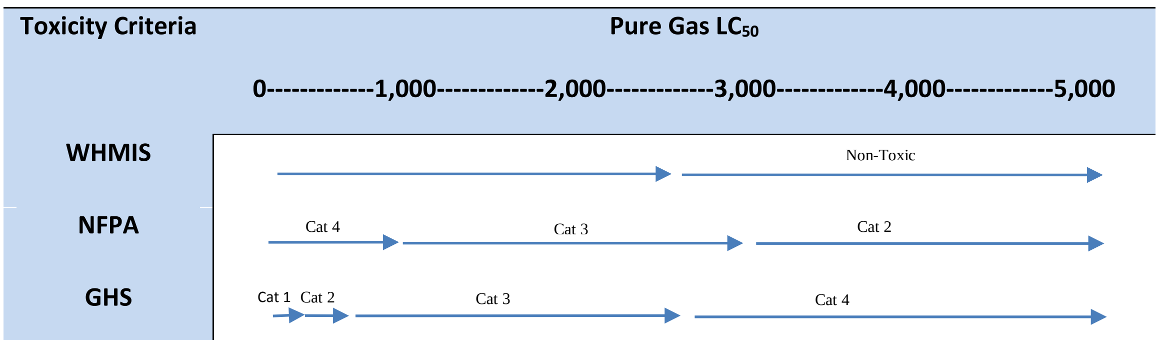
To handle corrosive gases safely, the following precautions must be observed:

- ALL users must have specific hands on training on the safe handling, use, and storage of corrosive gases. This should also include training on what do to in case of an accidental release.
- DEVELOP two person cylinder change out procedures for corrosive gases before they are used
- REGULATORS must contain a bonnet vent. Connect the bonnet vent to an exhaust duct (normally in a fume hood or gas cabinet).
- PURGE regulator and system with an inert gas after each use
- EYEWASHES and SHOWERS are required for any area or lab using a corrosive gas
- EMERGENCY ACTION PLANS are required before using any corrosive gases. Each emergency plan should be written for the specific process and location the process is taking place in.
- WORK can only take place in a continuously vented fume hood or toxic gas cabinet
- NOTIFY all individuals in area that corrosive gases are used. They must be made aware of the emergency plan.
- INSPECT corrosive gas cylinders:
  - For damage on a regular basis (prior to each use, or at least once per day)
  - To ensure cylinder valve is not frozen (open and close)
- STORE corrosive gases for no more than 6 months preferably only 3 months
- DISCHARGING a toxic gas requires one or more of the following controls to prevent backflow:
  - Flow through a liquid

   - Check valves; or,
   - Vacuum break device
- SERIOUS consideration should be given to the use of continuous monitoring (< 5 min. intervals) and fail-safe automatic closing valves for corrosive gas systems
- UNATTENDED use of corrosive gases is prohibited
- USE of corrosive gases can only occur during normal business hours (8 am to 4:30 pm)

Toxic Gases

Toxic gases are defined by their Lethal Concentration 50 values (LC50). An LC50 is the concentration of a chemical in air at which 50% of an exposed test population will die within a set period of time (usually 4 hours).



Notes:

- WHMIS criteria will likely align to GHS in 2018
- NFPA – Category 4 and 3 gases are highly toxic, whereas category 2 gases are toxic
- GHS – Category 1 (0 - 200 ppm) and 2 (200–500 ppm) gases are considered highly toxic, whereas category 3 (500 – 2,500 ppm) gases are considered toxic.

Figure 5: Toxicity criteria for gases based upon the LC50.

Below are general best practices for use with toxic compressed gases.

- ALL users must have specific hands on training on the safe handling, use, and storage of toxic gases. This should also include training on what do to in case of an accidental release.
- DEVELOP two person cylinder change out procedures for toxic gases before they are used
- REGULATORS must contain a bonnet vent. Connect the bonnet vent to an exhaust duct (normally in a fume hood or gas cabinet).
- EYEWASHES and SHOWERS are required for any area or lab using a toxic gas
- EMERGENCY ACTION PLANS are required before using any toxic gases. Each emergency plan should be written for the specific process and location the process is taking place in.
- NOTIFY all individuals in area that toxic gases are used. They must be made aware of the emergency plan.

- INSPECT toxic gas cylinders and systems for corrosion or damage on a regular basis (prior to each use, or at least once per day)
- DO NOT STORE toxic gases in laboratories. Their use should be on-demand. Temporary storage can be a fume hood or gas cabinet (temporary means 1 week or less).
- DISCHARGING a toxic gas requires one or more of the following controls to prevent backflow:
    - Flow through a liquid
    - Check valves; or,
    - Vacuum break device
- WORK can only take place in a continuously vented fume hood or toxic gas cabinet
- SERIOUS consideration should be given to the use of continuous monitoring (< 5 min. intervals) and fail-safe automatic closing valves for toxic gas systems
- UNATTENDED use of toxic gases is prohibited
- USE of toxic gases can only occur during normal business hours (8 am to 4:30 pm)

Toxic Gas By-Products

The release of toxic gas by-products can cause serious harm to individuals or area infrastructure. It is important to have keep an emergency plan should a toxic gas by-product be released. Below are the two most common ways in which a toxic gas by-product can be produced:

1. Interaction between water and a solid compound
2. Incompatible reactions

Table 2 below summarizes some common incompatibilities and the toxic gases they produce.

Table 2: Reactions causing toxic gas releases.

Material 1 +	Material 2 →	Toxic Gas Produced
Arsenic Compounds	Any reducing agent	Arsine
Azides	Acidic compounds	Hydrogen azide
Cyanides	Acidic compounds	Hydrogen cyanide
Hypochlorites	Acidic compounds	Chlorine or hypochlorous acid
Nitrates	Sulfuric Acid	Nitrogen dioxide
Nitric Acid	Copper, brass, any heavy metals	Nitrogen dioxide (nitrous fumes)
Nitrites	Acidic compounds	Nitrous fumes
Phosphorus	Caustic alkalis or reducing agents	Phosphine
Selenides	Reducing agents	Hydrogen selenide
Sulfides	Acidic compounds	Hydrogen sulfide
Tellurides	Reducing agents	Hydrogen telluride

Pyrophoric Gases

A pyrophoric gas is a gas that will ignite upon contact with air or moisture. Furthermore, all pyrophoric gases are toxic by inhalation. In order to use a pyrophoric gas, the following requirements should be observed:

- ALL users must have specific hands on training on the safe handling, use, and storage of pyrophoric gases. This should also include training on what do to in case of an accidental release.
- DEVELOP two person cylinder change out procedures for pyrophoric gases before they are used
- EYEWASHES and SHOWERS are required for any area or lab using a pyrophoric gas
- EMERGENCY ACTION PLANS are required before using any pyrophoric gases. Each emergency plan should be written for the specific process and location the process is taking place in.
- NOTIFY all individuals in area that pyrophoric gases are used. They must be made aware of the emergency plan.
- DO NOT STORE toxic gases in laboratories. Their use should be on-demand. Temporary storage can be a fume hood or gas cabinet (temporary means 1 week or less).
- WORK can only take place in a continuously vented fume hood or toxic gas cabinet
- CONTINUOUS monitoring (< 5 min. intervals) and fail-safe automatic closing valves shall be used for pyrophoric gas systems
- UNATTENDED use of pyrophoric gases is prohibited
- USE of pyrophoric gases can only occur during normal business hours (8 am to 4:30 pm)

Hazard Assessment

Prior to ordering a compressed gas, the lab user should perform a hazard assessment to determine what controls are required to minimize risk.

You can use these basic steps to complete your hazard assessment:

- Determine which hazard category(ies) the gas falls into (See Appendix 4 for gas classifications)
- How good are the warning properties of this gas (odour, colour, etc…)
- Identify the volumes of gas used, and the result of a catastrophic failure of a cylinder or process
- Identify where in your process is the most likely point of failure
- Answer the following questions:
    - How will I know 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 assessment is done, you should identify how you can control these hazards. This will include a combination of Engineering, Administrative, and Personnel Protective Equipment. The next section outlines the required and recommended controls for various types of gases that are used on campus.

Required and Recommended Controls

Controls used to minimize risk of an uncontrolled release can be categorized into 3 categories. These include:

- ***Engineering Controls*** - consist of devices that are designed to vent, warn, signal, monitor or shut-off uncontrolled releases of toxic gases. The engineering controls required for various gases are outlined in Table 1 below. A description of each engineering control is provided in Appendix 1.
- ***Administrative Controls*** – are operational safety practices associated with using and handling the hazardous gases. The administrative controls required for various gases are outlined in Table 1 below. A description of each administrative control is provided in Appendix 2.
- ***Personal Protective Equipment (PPE)*** – The PPE required for various situation is described in Table 1 below. A description of the most commonly used PPE is provided in Appendix 3.

A well designed process will utilize some portions of all three types of controls. However, when they are implemented, they should be implemented in the order of effectiveness, namely:

1. Engineering
2. Administrative
3. PPE

PPE requires the most involvement by the user which is why it is the most ineffective type of control. Administrative controls are somewhat better than PPE, but also rely on the user. Engineering controls are normally automated, and therefore tend to be the most reliable and effective type of control.

Table 3 below outlines the various required and recommended engineering and administrative controls for the various types of compressed gases used at UWaterloo.

Table 3: Required/recommended Engineering and Administrative Controls. If a gas has multiple hazards, use the classification with most stringent requirements. Detailed descriptions of each control is provided in Appendix 1.

Engineering Control Requirements	Highly Toxic & Toxic	Pyrophoric	Flammable	Corrosive	Oxidizer
Exhausted enclosures (other than a gas cabinet)			R	X	
Gas cabinet	X	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	Not allowed!				

Table Notes:

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

Storage of Compressed Gases

Compressed gases not in use should not be stored in laboratories. If a hazardous gas cylinder is almost empty and will soon need to be changed (within 5 days) an extra cylinder may be stored in the lab.

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:

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

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)
2. Barricade or seal of the local area of release (place signs and caution tape)
3. Call UW Police Services at extension 22222 and indicate what has happened, the location, and any other questions they may ask. They will meet the fire department at the main entrance of the University and direct to the release area.
4. Call Central Plant and request building be put on 100% fresh air
5. Obtain MSDS/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:

1. Move exposed person to fresh air
2. Perform first aid
3. For eye exposure – flush eyes
4. For skin exposure, remove clothing and flush skin

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

Appendix 1: Definitions for Engineering Controls

1. Exhausted enclosures

- Operate at negative pressure in relation to the surrounding area
- Connect to an approved exhaust system
- Be certified annually by manufacturer or equivalent for proper air flow

2. Gas cabinet

- Operate at negative pressure in relation to the surrounding area
- Be provided with self-closing limited access ports or non-combustible windows to give access to equipment controls
    - Average face velocity at the face of the access ports or windows shall not be less than 200 feet per minute (1.01 m/s) with a minimum of 150 feet per minute (0.76 m/s) at any 1 point of the access port or window
- Connect to an approved exhaust system
- Be provided with self-closing doors
- Be constructed of not less than 0.097 –inch (2.46 mm) (12 gage) steel
- Not contain more than 3 cylinders in a single gas cabinet
    - Exception: Cabinets containing cylinders not exceeding 1 pound (0.4536 kg) net contents each shall not exceed 100 cylinders.
- Be seismically restrained
- Be certified annually by manufacturer or equivalent for proper air flow

3. **Treatment Devices:**

Treatment systems must be designed to reduce the maximum allowable discharge concentration of the gas to 1/2 IDLH (Immediately Dangerous to Life and Health) at the point of discharge to the atmosphere. This is normally done by using dilution with an inert gas or air.

When more than 1 gas is emitted to the treatment system, the treatment system must be designed to handle the worst-case release based on the release rate, the quantity, and the IDLH for all the gases stored or used.

Treatment devices are not required where the gas is monitored AND a failsafe automatic detecting self-closing valve is used.

4. **Flow Limiting Devices:**

Use a flow-limiting device to restrict hazardous gas flow rates to just over maximum flow required (e.g., flow restricting orifice). To be effective, these devices are installed immediately downstream of each gas cylinder.

For small scale experiments, such as fume hood use, a needle valve is sufficient.

For large cylinders, a flow restricting orifice must be installed by the gas supplier in the cylinder valve or installed in the gas purge panel.

5. **Documented Maintenance Records:**
   Records of all maintenance (preventative and unplanned) should be kept for a minimum of 3 years.

6. **Purge System:**
   The ability to purge the area between the cylinder valve and the regulator with an inert gas prior to maintenance or cylinder change out is required. Inert gases used for this purpose must be used solely for this purpose and no other operation.

7. **Detector System:**
   A continuous gas-detection system is required to detect the presence of gas at or below the permissible exposure limit or ceiling limit. The detection system must:

   - Initiate a local alarm and transmit a signal to a constantly attended control station (exceptions may apply)
   - Be capable of monitoring the room or area in which the gas is stored at or below the permissible exposure limit or ceiling limit and the discharge from the treatment system at or below 1/2 IDLH (Immediately Dangerous to Life and Health) limit.

     The alarm must be both inside and outside the storage area. The audible alarm must be distinct from all other alarms. An oxygen sensor *may* be required if it is determined that the location where this compressed gas is being used or stored presents a risk of asphyxiation. Contact Plant Operations for guidance on appropriate systems to use.

   Note: Exceptions to detection systems may exist… contact the Safety Office for more information.

8. **Emergency Alarms (warning signs)**
   If an alarm system is present, signs must be posted with information outlining the following:

   - What the alarm states mean
   - What actions to take
   - Who to contact

9. **Welded Compatible Piping**
   Piping and tubing must:

   - Have welded or brazed connections throughout unless an exhausted enclosure is provided
   - Not be located in any portion of a corridor unless otherwise approved by the Local Fire Department

See the section on "Compatible piping" above for addition information

10. Local shut-off

Personnel must be able to shut the system off at the source.

11. Interlocks

An automatic shutdown of gas flow must be initiated when any of these conditions occur:

- Hazardous condition is detected
- Seismic disturbance
- Loss of power – see the "Emergency power" section for more information
- Excess-flow-triggered shut-off – Where gases are carried in pressurized piping above 15 psig (103.4 kPa), excess flow control must be provided
- Loss of vacuum, cooling or ventilation

12. Emergency Power

Emergency power must be provided for these systems:

- Exhaust ventilation (including the power supply for treatment systems)
- Gas cabinet ventilation
- Gas-detection
- Emergency alarm

13. Monitored Secondary Containment

Any secondary containment system must have a detection system.

14. Auto-shutoff

When a short-term hazard condition is detected, the gas detection system must automatically close the shut-off valve at the source on gas supply piping and tubing related to the system being monitored for which gas is detected.

15. **Exhaust flow alarm**

Should ventilation become inadequate, an audible and visual alarm must be available.

16. Cylinder Safety Devices

A pressure relief device is one that will allow the release of excess pressure should it develop within a cylinder or other portion of a compressed gas system. There are several types of pressure relief devices:

a. Rupture disk – non-reclosing pressure relief device actuated by static pressure that is designed to function by the bursting of the disk. It is designed to burst at a pre-determined pressure. The pressure rating of the device is usually stamped on the face of the device.

b. Fusible plug – non-reclosing pressure relief device actuated by the melting of a fusible metal. These are designed to protect a cylinder from over-pressurization due to heat only.

c. Combination Rupture Disk and Fusible Plug – Pressure will not be relieved unless both the rupture disk bursts (pressure) and the fusible plug melt (heat).

d. Pressure relief Device – This is a re-closing pressure relief device that is spring loaded. It functions to temporarily relieve pressure, then reseats once pressure has returned to an acceptable value. This type of device is found on propane cylinders

For a full discussion on pressure relief devices, please open the following link: Pressure relief devices – Safetygram 15

17. Cylinder Valves

Most compressed gas cylinders have at least one cylinder valve present. The three most common types of valves are the pressure seal valve, the packed valve, and the diaphragm valve. These will described here:

- ***Pressure seal valve:***
  - Best use – inert gases, hydrogen, and oxygen
  - Use in fully open condition – partially open conditions do not have as good a seal as in the fully open condition
  - Very reliable, and can be used for pressures up to 6,000 psi
- ***Packed valve:***
  - Best used for corrosive and reactive gases
  - Can come in two forms, wrench operated, or hand-wheel operated
  - Wrench operated valve has a specific torque set by manufacturer
  - Wrench operated valves should only be opened ¼ or ½ turn – do not fully open
  - Hand operated valves can be turned more – 1 full turn to 2 full turns when being operated – do not fully open
- ***Diaphragm Valve***
  - Best used for highly toxic, pyrophoric and high purity gases
  - Hand wheel operated valve

For a full discussion on cylinder valve types, please open the following link: Safetygram 23 – Cylinder valves

18. **Regulators**

Regulators allow for the controlled release of gas from a compressed gas cylinder. It normally reduces the pressure that can be used for various everyday tasks.

- Single stage regulators - Constant adjustment of the delivery knob is required to ensure the gas delivery pressure remains constant.

- Two-stage regulators – Constant adjustment of the delivery knob is not required to ensure gas delivery pressure remains constant.

For a complete discussion on regulators and their selection, please open the following link: Regulators – Safetygram 12.

19. **Line Safety Devices**

Line safety devices are devices used to either prevent the hazardous mixing of gases, backflow of gases, or the propagation of a flame through a line. These types of devices include flash arrestors and check valves.

a. Flash Arrestors - A flash arrestor is a device put in line with a compressed gas system regulator. The arrestor consists of a series of small pathways or holes. As a flame travels through it this multitude of paths (or holes) the flame separates and its energy dissipates thus quenching the flame.

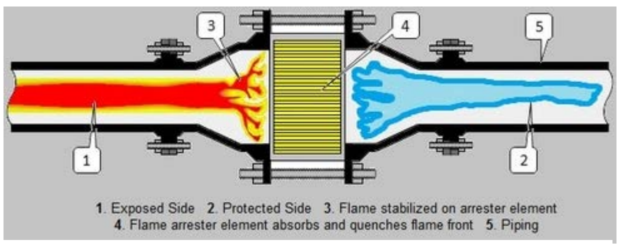


Figure 6: Schematic representation of how a flash arrestor works.

b. Check Valves - A check valve is a simple device that allows a gas to flow in only one direction. They are required in processes that require multiple types of gas to feed the same process. It prevents the hazardous mixing of gases.

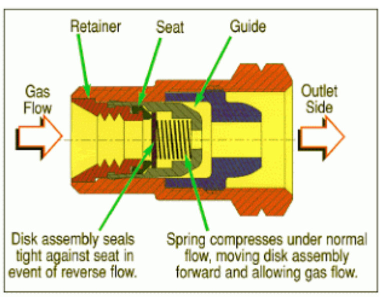


Figure 7: Schematic representation of how a check valve works.

Appendix 2 – Definitions for Administrative Controls

1. **Leak Checking:**

   Gas systems must be leak tested at the following intervals:

   - Upon receipt
   - At installation
   - Periodically during operation
   - At disconnect / shipping

It is critical that these gases also be leak tested prior to removal from their exhausted enclosures and subsequent to transport, or if you have reason to believe that the system has been compromised.

2. **Emergency Response Plans:**
   Your emergency response plan should be specific to the gases used in your lab. You must outline what would happen should an unplanned or accidental release of gas occur, who would be contacted, what PPE is required, evacuation plans, communication plans, and how the situation could be remedied.

3. **Training:**
   Training is required for all individuals using these gases, and for any individuals who are present in the lab when work with these gases occurs, but do not directly use these gases. Please review the training section above.

Appendix 3 - Personal Protective Equipment (PPE)

The following are a PPE commonly used to reduce the risk of compressed gas use.

Eye Protection – Safety glasses with side shields, safety goggles, or face shields should be worn when operating systems involving compressed gases. The type of eye protection should be based on the hazard assessment.

Skin Protection – Long pants, shirts and closed-toed and closed-heeled shoes must be worn at all times.

Hand Protection – Leather or cut-resistant gloves should be used when handling gas cylinders to protect against cuts and pinch point hazards. Chemical resistant gloves are required if contact with the gas or its liquefied state is anticipated (like when connecting a regulator/pressure gauge assembly). The type of hand protection should be based upon the hazard assessment.

Steel-toed shoes – recommended when moving compressed gas cylinders

Respiratory Protection – usually not required or not permitted as a permanent means of protection. Inhalation hazards should be controlled through engineering controls first. Respiratory protection should only be used for cylinder change outs and in case of an uncontrolled or accidental release of gas.

Appendix 4: Commonly used gases and their properties

Table 4: Most commonly used gases exposure properties and risk category.

Gas	Molecular Formula	CAS No.	Hazards	TLV (ppm)	PEL (ppm)	LC50 (ppm)	IDLH (ppm)
Acetylene	C_2H_2	74-86-2	Flammable, unstable, reactive, asphyxiant	N/A	N/A	N/A	N/A
Ammonia	NH_3	7664-41-7	Corrosive	25	50	7338	300
Argon	Ar	7440-37-1	Inert				
Arsine	AsH_3	7784-42-1	Highly Toxic, Flammable, Pyrophoric	0.05	0.05	178	3
Boron Tribromide	BBr_3	10294-33-4	Toxic, Corrosive	1	1	380	50
Boron Trichloride	BCl_3	10294-34-5	Corrosive	5	5	2541	25
Boron Trifluoride	BF_3	7637-07-0	Toxic, Corrosive	1	1	864	25
Bromine	Br_2	7726-95-6	Highly toxic, corrosive, oxidizer	0.1	0.1	113	3
Carbon Dioxide	CO_2	124-38-9	Inert (asphyxiant)	5000	5000		4000
Carbon Monoxide	CO	630-08-0	Toxic, flammable	25	25	3760	1200
Chlorine	Cl_2	7782-50-5	Toxic, corrosive, oxidizer	0.5	1	293	10
Chlorine Dioxide	ClO_2	10049-04-4	Toxic, oxidizer	0.1	0.1	250	5
Chlorine Trifluoride	ClF_2	7790-91-2	Toxic, oxidizer, corrosive	0.1	0.1	299	50
Diborane	B_2H_6	19278-45-7	Highly toxic, flammable, pyrophoric	0.1	0.1	80	15
Dichlorosilane	SiH_2Cl_2	4109-96-0	Toxic, corrosive, flammable	2	5	314	50
Ethane	C_2H_6	74-84-0	Flammable	N/A	N/A	N/A	N/A
Ethylene	C_2H_4	74-85-1	Flammable	200	N/A	N/A	N/A
Ethylene oxide	C_2H_4O	75-21-8	Toxic, flammable	1	1	2900	800
Fluorine	F_2	7782-41-4	Highly toxic, corrosive, oxidizer	0.1	0.1	185	25

Chemical Fact Sheets
Compressed Gases – Hazardous Gas Standard

Gas	Molecular Formula	CAS No.	Hazards	TLV (ppm)	PEL (ppm)	LC50 (ppm)	IDLH (ppm)
Germane	GeH_4	7782-65-2	Highly toxic, flammable, pyrophoric	0.2	0.2	620	ND
Helium	He	7440-59-7	Inert (asphyxiant)	N/A	N/A	N/A	N/A
Hydrogen	H2	1333-74-0	Flammable	N/A	N/A	N/A	N/A
Hydrogen bromide	HBr	10035-10-6	Toxic, corrosive	3	3	2860	30
Hydrogen chloride	HCl	7647-01-0	Toxic, corrosive	5	5	2810	50
Hydrogen cyanide	HCN	74-90-8	Highly toxic, flammable,		4.7	40	50
Hydrogen fluoride	HF	7664-39-3	Toxic, corrosive	0.5	3	1300	30
Hydrogen iodide	HI	10034-85-2	Toxic, corrosive			2860	
Hydrogen selenide	H_2Se	7783-07-5	Highly toxic, flammable	0.05	0.05	51	1
Hydrogen sulfide	H_2S	7783-06-4	Toxic, flammable, corrosive	10	10	712	100
Krypton	Kr	7439-90-9	Inert (asphyxiant)	N/A	N/A	N/A	N/A
Methane	CH_3	74-82-8	Flammable	N/A	N/A	N/A	N/A
Methyl bromide	CH_3Br	74-83-9	Toxic, flammable	1	1	850	250
Methyl chloride	CH_3Cl	74-87-3	Flammable	50	50		2000
Methyl isocyanate	CH_3NCO	624-83-9	Highly toxic, flammable	0.02	0.02	22	3
Methyl mercaptan	CH_3SH	74-93-1	Toxic, flammable	0.5	0.5	1350	150
Neon	Ne	7440-9-1	Inert (asphyxiant)	N/A	N/A	N/A	N/A
Nickel carbonyl	$Ni(CO)_4$	13463-39-3	Highly toxic, flammable	0.001	0.001	18	2
Nitric oxide	NO	10102-43-9	Highly toxic, oxidizer, corrosive	25	25	115	100
Nitrogen	N2	7727-37-9	Inert (asphyxiant)	N/A	N/A	N/A	N/A
Nitrous Oxide	N_2O	10024-91-2	Oxidizer	50	5	115	20

Chemical Fact Sheets
Compressed Gases – Hazardous Gas Standard

Gas	Molecular Formula	CAS No.	Hazards	TLV (ppm)	PEL (ppm)	LC50 (ppm)	IDLH (ppm)
Nitrogen dioxide	NO_2	10102-44-0	Highly toxic, oxidizer, corrosive	3	5	115	20
Oxygen	O_2	7782-44-7	Flammable	N/A	N/A	N/A	N/A
Ozone	O_3	10028-15-6	Highly toxic, oxidizer	0.05	0.1	9	5
Phosgene	$COCl_2$	75-44-5	Highly toxic	0.1	0.1	5	2
Phosphine	PH_3	7803-51-2	Highly toxic, flammable, pyrophoric	0.3	0.3	20	50
Phosphorus oxychloride	$POCl_3$	10025-87-3	Highly toxic	0.1	N/A	N/A	N/A
Phosphorus pentafluoride	PF_5	7647-19-0	Toxic, oxidizer, corrosive	N/A	N/A	261	N/A
Phosphorus trichloride	PCl_3	7719-12-2	Toxic, corrosive	0.2	0.2	208	25
Propane	C_3H_8	74-98-6	Flammable	N/A	1000	N/A	N/A
Selenium hexafluoride	SeF_6	7783-79-1	Highly toxic, corrosive	0.05	0.05	50	2
Silane	SiH_4	7803-62-5	Pyrophoric	5	5	N/A	N/A
Silicon tetrachloride	$SiCl_4$	10026-04-7	Toxic, corrosive	2	5	750	100
Silicon tetrafluoride	SiF_4(HF)	7783-61-1	Toxic, corrosive	3.2	3.2	922	30
Stibine	SbH_3	7803-52-3	High toxic, flammable	0.1	0.1	178	5
Sulfur dioxide	SO_2	7446-09-5	Toxic, corrosive	2	5	2520	100
Sulfur hexafluoride	SF_6	2551-62-4	Inert (asphyxiant)	N/A	N/A	N/A	N/A
Sulfuryl fluoride	SO_2F_2	2699-79-8	Toxic, corrosive	5	5	3020	1000
Tellurium hexafluoride	TeF_6	7783-80-4	Highly toxic, corrosive	0.02	0.02	25	1
Titanium tetrachloride	$TiCl_4$	7550-45-0	Highly toxic, corrosive	N/A	1.3	119	1.3
Tungsten hexafluoride	WF_6(HF)	7783-82-6	Toxic, corrosive	N/A	30	218	30
Vinyl bromide	C_2H_3Br	593-60-2	Toxic, flammable	N/A	0.1	N/A	N/A
Vinyl chloride	C_2H_3Cl	75-01-4	Toxic, flammable	N/A	N/A	N/A	150
Xenon	Xe	7440-63-3	Inert (asphyxiant)	N/A	N/A	N/A	N/A
Xenon Difluoride	XeF_2	13709-36-9	Toxic, corrosive, oxidizer	N/A	250	445	250