College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

Guide to Compressed or Liquefied Gases in Laboratories

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1.0 Introduction

Hazards can result from improper handling of gas cylinders and high pressure equipment. A leaking cylinder could produce an atmosphere that is toxic, anesthetic, asphyxiating, or explosive; and in the event of a rapid escape, the cylinder becomes a randomly directed missile. The main purpose of properly handling compressed gases is, therefore, to prevent uncontrolled escape of the gas.

A compressed gas is defined by the Department of Transportation (DOT) as “any material or mixture which exerts in the packaging an absolute pressure of 280 kPa (40.6psia) or greater at 20C (68F).”

2.0 General Precautions

- Never drop cylinders or permit them to strike each other violently.
- Do not expose cylinders to temperatures higher than 50° C. Some rupture devices on cylinders release at about 65° C.
- Never tamper with pressure relief devices in valves or cylinders.

- Before using cylinders, read all label information and Safety Data Sheet associated with the gas being used.
- Always use a cylinder dolly when moving cylinders.

2.1 Types of Compressed Gas Cylinders

There are three major groups of compressed gases stored in cylinders.

- Liquefied gases are partially liquid at normal temperature and charge pressure. Examples: chlorine, propane, nitrous oxide.
- Non-liquefied gases are entirely gaseous at normal temperatures regardless of charge pressure. Examples: argon, oxygen, nitrogen. The standard 5 foot gas cylinders supplied by gas vendors at a pressure of 2,200 – 2,400psi, contain an average of 250 cu. ft. of gas at normal temperature.
- Dissolved gases are dissolved in a liquid phase solvent. Dissolved gas cylinders are packed with an inert, porous filter saturated with the solvent which stabilizes the volatile gas. Acetylene is the only common dissolved gas.

Some gases, such as carbon dioxide, are commonly used in both a liquid and gas form. Cylinders designed for liquid phase dispensing have a siphon, or "dip", tube.

2.2 Securing Cylinders

Keep cylinders secured to the bench or wall and to keep the caps on when they are not in use. Cylinders may be chained to the wall, secured by bench straps, or held by commercial floor stands. ***Bungee cords, zip ties, ropes or wires are not acceptable means of securing cylinders.***

2.3 Lecture Bottles

In addition to standard precautions, the following special rules apply to work with lecture bottles in the laboratory:

- Lecture bottles do not have pressure-relief devices to prevent rupturing or a transport cap.

- Unlike larger cylinders, lecture bottles all have identical valve threads, irrespective of the gas contained within.
- If labels and valve tags do not agree or if there is any question as to the contents of a lecture bottle, return the unused bottle to the supplier. Whenever possible, purchase lecture bottles from suppliers who will accept the return of empty or partially empty bottles.
- When transporting lecture bottles, use a cart and block the bottles to prevent rolling and falling.

2.4 Storage

Maximum allowable storage quantities vary depending on building, floor, control area, fire rated design and type of gas. Contact the College of Engineering Director for Safety for assistance with determining allowable storage in your lab. When a cylinder is not in use, close the main cylinder valve tightly and add the protective cap.

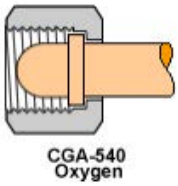
Promptly remove the regulator from an empty cylinder, replace the protective cap, and label the cylinder by using an "empty" tag or writing on the side of the cylinder with chalk. Never bleed cylinders completely empty; leave a slight pressure to keep contaminants out. Empty cylinders shall be promptly removed.

2.5 Return and Transport

When returning empty cylinders leave some positive pressure in the cylinder. Transport using a wheeled cylinder cart or cylinder dolly with the capped cylinder strapped securely to the cart/dolly. When returning empty cylinders to the loading dock, always chain the cylinders in the marked locations. Ensure the return tag clearly lists the lab specific contact.

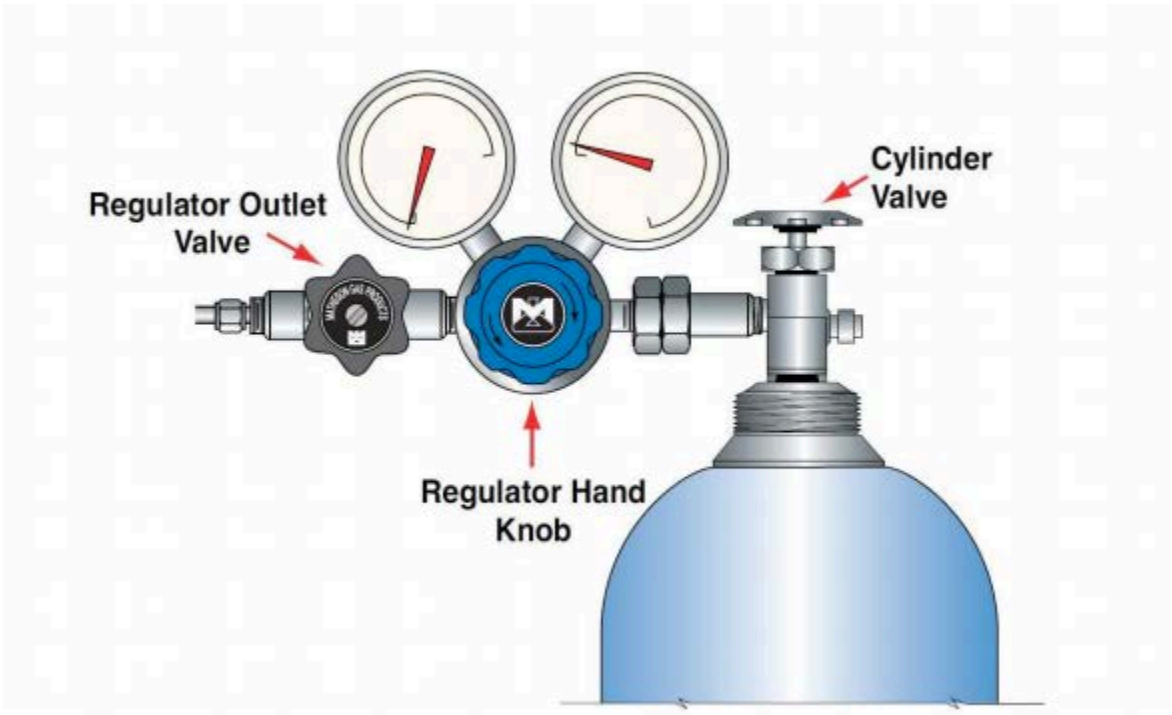
2.6 Connections

Threads on cylinder-valve outlet connections have been standardized by the Compressed Gas Association and are not the same on all cylinders.



This prevents accidental mixing of incompatible gases from an interchange of connections. Left hand fittings for fuel gases have a cut mark through the nut.

Never lubricate, modify, force, or tamper with cylinder valves. Especially do not put oil or grease on the high-pressure side of a cylinder containing oxygen, chlorine, or another oxidizing agent. An auto ignition or explosion could result. Unlike larger cylinders, lecture bottles all have identical valve threads, irrespective of the gas contained within.



Regulators are gas-specific which limits interchange and adds safety. Special installation processes, not mentioned here, are used for toxic or high purity gases. Always make sure that the regulator and valve fittings are compatible.

To select the appropriate regulator:

1. Determine the gas pressure needed
2. Determine the maximum pressure the system might require
3. Select a delivery pressure range so the required pressures are in the 25%-90% range of the regulator delivery pressure
4. Check with the gas supplier about compatible connections and regulators

Check cylinder outlet and regulator inlet connections for debris or contamination before connecting. Some gases, such as carbon dioxide, require a gasket. Insure that a required gasket is in place before assembling the regulator onto the cylinder.

Tighten connecting nut with a smooth jaw wrench. Back out the adjusting knob or key on the regulator. Open the cylinder valve just enough to indicate pressure on the regulator gauge (no more than one full turn). Check connections checked with a soap solution for leaks. Never use oil or grease on the regulator of a cylinder valve.

All compressed gas regulators should, at a minimum, be checked for external leakage and internal leakage (creep or crawl) regularly. Regulators should be removed from service at least every five years (more frequent in some cases) and returned to the manufacturer, or a competent agent to be inspected and/or refurbished as necessary. Regulators should also be tagged or labeled to identify the last date of inspection. Users should consult the manufacturer for specific procedures on how to check for external

and internal leakage as well as the recommended frequency of the tests. Regulators are continuously exposed to high stresses due to cylinder pressures. In addition to that, the materials of construction are attacked internally by both mildly and severely corrosive gases. External corrosive environments can cause gauges and springs to corrode. Argon, helium and nitrogen regulators (CGA 580) will, under a given set of conditions, have a longer service life than regulators used for hydrogen chloride and hydrogen sulfide (CGA 330) simply because the gas service is more severe (corrosive).

The most common type of regulator failure is the internal leak, sometimes called creep or crawl. This can occur when the seat becomes damaged or displaced due to a foreign particle such as a metal chip or other material. When the seat cannot close completely, delivery pressure will not be maintained and regulator pressure cannot reach a state of equilibrium. Downstream or delivery pressure will continue to climb until the safety relief mechanism on the regulator is activated (usually a relief valve or a diaphragm burst hole). Checking for this type of failure is relatively easy if the device has a gauge that reads regulated pressure. The gauge pressure will start to rise above the set point and continue upward. This creates a potentially hazardous condition where any downstream equipment would be subjected to pressures beyond the rated limit. Regulators should be visually checked for this type of failure. Excessive flexing of metal regulator diaphragms can cause a radial crack, which allows gas to escape to the atmosphere through the vent hole in the bonnet.

3.0 Piping and Manifolds

Piping, tubing, valves and fittings conveying hazardous materials shall be designed and installed in accordance with ASME B31 (Reference IFC 2012 – 5003.2.2). The system's weakest component determines the overall pressure limit.

4.0 Toxic Gases

Flow-restricting orifices are recommended on cylinders of toxic gases. All portable tanks and cylinders must be marked to indicate the orifice (inches) on the certification tags and the vessel themselves. Toxic-gas cylinders shall be stored in continuously mechanically ventilated enclosures with an extinguishing system (IFC 2012 – Section 6004.1.2). If the net toxic gas content exceeds one pound per cylinder no more than three cylinders of toxic gas are allowed per enclosure (gas cabinet). Any new laboratory construction shall require vented gas cabinets for storage of highly toxic gases. Gas cylinder cabinets for toxic gases must have a fire extinguishing system (IFC 2012 – 6004.1.2). Purchase of diluted toxic gas, if feasible below a concentration known to be dangerous, will serve to reduce exposure risk.

Waste toxic gases shall be treated by absorption, wet or dry scrubbing, combustion, or condensation via refrigeration, before being vented to chemical fume hoods or other local exhaust arrangements. The safe venting of pressure-relief devices should be considered. (IFC 2012 – Section 6003.1.3 Treatment Systems)

If the physiological warning properties for the toxic or highly toxic gas(es) are above the PEL an emergency alarm system is required (IFC 2012 – 6004.2.2.10); consult with the UW Environmental Health and Safety Office regarding this determination. Consult the emergency plan for the given lab area to determine the action expected during a leak situation. The Office of Environmental and Occupational Health (EOH) and Occupational Medicine shall be contacted for information on selection, fit testing, and training if respirators or Self Contained Breathing Apparatus (SCBA) have been provided. No one may

use respirators on the job without prior medical approval, fit testing, and training. Any required leak detection system shall send all alarm signals to University Police as part of a mutually agreed upon emergency response plan.

5.0 Flammable Gases

Purchase of diluted flammable gas, if feasible below the explosive range, will serve to reduce the explosion risk.

Where gases or liquids having a NFPA 704 hazard ranking of Flammability Class 4 are carried in pressurized piping above 15 pounds per square inch gauge (psig), an approved means of leak detection and emergency shutoff or excess flow control shall be provided. (Reference: IFC 2012 - 5003.2.2.1).

Any required continuous atmosphere detection system shall send all alarm signals to University Police as part of a mutually agreed upon emergency response plan.

Oxygen/fuel gas system for welding, brazing or glass blowing shall follow OSHA CFR 1910.253. This requires the use of Grade T welding hose color coded red/green for all oxygas welding applications and the installation of flash arresters on hydrogen and acetylene cylinders.

Flammable gas cylinders must be stored 20ft away from oxidizers and oxygen gas cylinders or separated by a fire rated wall.

5.1 Acetylene

The in house transfer, handling, storage, and utilization of acetylene in cylinders shall be in accordance with Compressed Gas Association Pamphlet G-1-2015. Acetylene cylinders have a porous filler material filled with acetone and dissolved acetylene. The cylinder must only be used in the upright position. If a cylinder has been handled in a non-upright position, do not use it until it has sat upright for at least 30 minutes.

Some tubing materials, such as copper and lead solder, form explosive acetylides.

Never exceed the delivery pressure limit of 15psig indicated by the warning red line of an acetylene pressure gauge. The use of an excess flow control valve is not recommended. Install a flash arrestor downstream from the regulator and check valves wherever backflow needs to be prevented.

5.2 Hydrogen

Individual hydrogen gas cylinders should contain less than 400scf. Larger hydrogen gas vessels may require a laboratory designed with explosion control and other safety measures. The installation of a flash arrestor is required and the installation of an excess flow control valve is recommended. When piping hydrogen, use stainless steel tubing to prevent the buildup and potential spark from static electricity.

6.0 Cryogenic Liquids and Liquefied Gases

The hazards of cryogenic liquids include fire or explosion, pressure buildup, embrittlement of structural materials, asphyxiation, and destruction of living tissue on contact. Liquid helium, argon or nitrogen may displace air and create an atmosphere without sufficient oxygen. Portable cylinders of cryogens must only be stored in well ventilated areas. Storage of cryogenic liquids (i.e. liquid nitrogen) or liquefied gases (i.e. carbon dioxide) in cold rooms or other rooms without external ventilation is prohibited. Fire or explosion may occur when the liquid form of flammable gases, such as hydrogen, is used without proper management of the gaseous phase. Liquid oxygen may produce an enriched oxygen atmosphere, which increases the flammability of ordinary combustible materials. Enriched oxygen levels may also cause some nonflammable materials, such as carbon steel, to burn readily.

Contact with cryogenic liquids generally causes tissue freezing and frostbite. Even brief contacts may be intense and painful. Prolonged contact may result in blood clots. Appropriate protective clothing, gloves, and eye protection — preferably a face shield — shall be worn when cryogenic liquids are handled. Choice of personal protective equipment (PPE) should be carefully evaluated, as gloves not designed for use with cryogenic liquids can saturate and cause more extensive cold damage to the skin.

6.1 Dewars and Transfer Equipment

Use a phase separator or special filling funnel to prevent splashing and spilling when transferring liquid nitrogen into or from a dewar. The top of the funnel should be partly covered to reduce splashing. Use only small, easily handled dewars for pouring liquid. For the larger, heavier containers, use a cryogenic liquid withdrawal device to transfer liquid from one container to another. Be sure to follow instructions supplied with the withdrawal device. The receiving vessel must be raised so the delivery tube is immediately above the mouth of the vessel (i.e., the cryogenic liquid should never be allowed to fall through air to reach the receiving vessel). When a warm tube is inserted into liquid nitrogen, liquid will spout from the bottom of the tube due to gasification and rapid expansion of liquid inside the tube. Wooden or solid metal dipsticks are recommended; avoid using plastics that may become very brittle at cryogenic temperatures.

6.2 Monitoring for Oxygen Deficiency

Indoor areas where bulk inert gas systems are newly installed shall be continuously monitored with an atmosphere monitoring system. The system shall provide an audible and visual alarm (red light) when the oxygen level drops to 19.5%. The audible and visual alarm shall be located inside the area and immediately outside of all entrances to the indoor area. Any required atmosphere monitoring system shall send all alarm signals to University Police.

6.3 Minimum Ventilation Rate

Natural or mechanical ventilation shall be provided when bulk inert gas systems are installed in buildings, rooms, or any indoor confined area. Ventilation shall be provided throughout the space at the rate of not less than 1.0 cu. foot per minute per square foot of floor area determined by the area enclosed. (Reference: IFC2012 – 5004.3.1)

7.0 Quantity Limits on Campus

The scope of this section generally applies to areas constructed for business occupancy (B). For quantity limits for all other occupancies, especially High Hazard Group (H) contact the UW Environmental Health and Safety Office.

Building users on the UW Campus generally have to comply with the limits according to the International Building Code (IBC) and the International Fire Code (IFC). Groups of research laboratories within a building may be subdivided into fire control areas. For more specific information regarding laboratory design and fire control specification contact the UW Environmental Health and Safety Office.

The total quantities of flammable or combustible liquids allowed in a fire control area (laboratory or suite of laboratories) are limited by the location in the building and the construction specifications.

7.1 IFC Maximum Allowable Quantities in Storage per Building - Sprinklered Fire Control Area

Hazardous Material	Below grade/basement	1st floor/grade	2nd floor	3rd floor	4th to 6th floor
Cryogenic flammable	67 gal	90 gal	67 gal	45 gal	11 gal
Cryogenic Oxidizing	67 gal	90 gal	67 gal	45 gal	11 gal
Flammable gas (gaseous)	1,500 cu. ft.[a]	2,000 cu. ft.[a]	1,500 cu. ft.[a]	1,000 cu. ft.[a]	250 cu. ft.[a]
Oxidizing gas (gaseous)	2,250 cu. ft.[a]	3,000 cu. ft.[a]	2,250 cu. ft.[a]	1,500 cu. ft.[a]	375 cu. ft.[a]
Oxidizing gas (liquefied)	112 pounds[a]	150 pounds[a]	112 pounds[a]	75 pounds[a]	18.7 pounds[a]
Pyrophoric (needs EHS approval)	37 cu. ft.[a]	50 cu. ft.[a]	37 cu. ft.[a]	25 cu. ft.[a]	6 cu. ft.[a]
Corrosive	1,215 cu. ft.[a]	1,620 cu. ft.[a]	1,215 cu. ft.[a]	810 cu. ft.[a]	202 cu. ft.[a]
Highly toxic (needs EHS approval)	15 cu. ft.[b]	20 cu. ft.[b]	15 cu. ft.[b]	10 cu. ft.[b]	2 cu. ft.[b]
Toxic	1,215 cu. ft.[a]	1,620 cu. ft.[a]	1,215 cu. ft.[a]	810 cu. ft.[a]	202 cu. ft.[a]

a. Quantities shall be increased 100% when stored in approved cabinets, gas cabinets, or exhausted enclosures as specified by the International Fire Code. Maximum quantities shall be increased 100% for buildings equipped throughout with an automatic sprinkler system. Where both are present, the increase shall be applied accumulatively.
b. Allowed only when stored in approved exhausted gas cabinets or exhausted enclosures.

Unsprinklered College of Engineering Buildings

Flammable Gas Maximum Allowable Quantity and Control Areas

	Higher Than 9 1 Control Area Allowed	Maximum Allowable Quantity 5% 1st Floor Qty 50 cuft
	7-9th Floor 2 Control Areas Allowed	Maximum Allowable Quantity 5% 1st Floor Qty 50 cuft
	4-6th Floor 2 Control Areas Allowed	Maximum Allowable Quantity 12.5% 1st Floor Qty 125 cuft
	3rd Floor 2 Control Areas Allowed	Maximum Allowable Quantity 50% 1st Floor Qty 500 cuft =
	2nd Floor 3 Control Areas Allowed	Maximum Allowable Quantity 75% 1st Floor Qty 750 cuft =
	1st Floor 4 Control Areas Allowed	Maximum Allowable Quantity 1000 cuft =
Grade		
	Basement 3 Control Areas Allowed	Maximum Allowable Quantity 75% 1st Floor Qty 750 cuft =

Flammable Gas Maximum Allowable Quantity and Control Areas w/Gas Cabinets (Increase 100%)

	Higher Than 9 1 Control Area Allowed	Maximum Allowable Quantity 5% 1st Floor Qty 100 cuft =
	7-9th Floor 2 Control Areas Allowed	Maximum Allowable Quantity 5% 1st Floor Qty 100 cuft =
	4th Floor 2 Control Areas Allowed	Maximum Allowable Quantity 12.5% 1st Floor Qty 250 cuft =
	3rd Floor 2 Control Areas Allowed	Maximum Allowable Quantity 50% 1st Floor Qty 1000 cuft =
	2nd Floor 3 Control Areas Allowed	Maximum Allowable Quantity 75% 1st Floor Qty 1500 cuft =
	1st Floor 4 Control Areas Allowed	Maximum Allowable Quantity 2000 cuft =
Grade		
	Basement 3 Control Areas Allowed	Maximum Allowable Quantity 75% 1st Floor Qty 1500 cuft =

Note: Source - IFC Hazardous Materials - General Provisions Tables 2703.1.1(1) and 2703.8.3.2