University of Nebraska Lincoln

Safe Operating Procedure

(Revised 7/08)

COMPRESSED GAS CYLINDERS IN LABORATORIES

(For assistance, please contact EHS at (402) 472-4925, or visit our web site at http://ehs.unl.edu/)

Improper handling of compressed gas cylinders can result in adverse physical or health effects. In addition to general procedures for handling and using compressed gases, certain facility related requirements will apply, depending on the type and amount of gases in use.

General Safety Procedures

- Prior to ordering and receiving any gas, review the MSDS and other literature from the manufacturer and Compressed Gas Association (CGA) to: (1) acquaint yourself and other laboratory personnel with the hazards posed by the gas; (2) assess ancillary systems, equipment, and piping to ensure that the gas is compatible; (3) determine if the intended use location is adequately equipped to safely use the gas; (4) determine if the size of the laboratory is adequate for the maximum volume of cylinders that will be in use (see Table 1 at the end of this SOP) and segregation of incompatible gases can be maintained (see Figure 1 at the end of this SOP). The summary of gas data in Table 2 provides general information, but is not a substitute for the MSDS and/or literature from the CGA.

- Prior to ordering, determine if the gas may be subject to provisions of the United States Department of Homeland Security ***Chemical Facility Anti-Terrorism Standards***, 6 CFR Part 27. Contact EHS prior to ordering and receiving any of the gases in Table 3 (at the end of this SOP), since possession totals may be cumulative per location/area without regard to quantities possessed by individuals.

- Airflow for compressed gas use and storage locations should be negative to adjacent areas. Use and storage locations should be mechanically ventilated (preferably with exhausts located low and high since gases have differing densities), free of combustible materials, away from open flames (25' separation distance), and protected from ambient temperature that could exceed 125º F. In addition, cylinders should not be stored in contact with pooled water or corrosive atmospheres (to prevent corrosion and damage to the cylinder), and away from areas where they could become part of an electrical circuit.

- Provide training to users on the dangers of pressurized systems; physical and health hazards of the gas in use, and; proper installation, specifications, and use of fittings, valves, regulators, and other ancillary equipment.

- Inspect all cylinders upon delivery for valve protection and hydrostatic test date. Cylinders should be stamped to indicate testing within the past 5 years. The hydrostatic test date will be stamped into the cylinder. A stamp of "2MM84+" indicates that the cylinder was tested in February of 1984; "MM" are the initials of the inspector; and "+" indicates that the cylinder is authorized for charging up to 10% in excess of the marked service pressure. Other stampings will appear on the opposite side of the collar of the cylinder, an example of which is provided below. In this example, "DOT 3AA2265" indicates that the cylinder meets the United States Department of Transportation Specification 3AA and that it has a service pressure of 2265 psig at 70º F. The "K161110" is the manufacturer's assigned serial number for the cylinder. The "BTWECO" is the manufacturer's unique symbol.

  DOT 3AA2265
  K161110
  BTWECO

- Do not use a compressed gas cylinder unless the cylinder is clearly marked or labeled with the cylinder's content. Never rely on the color of a cylinder to identify its contents.

- Piping systems should be marked with the name of the gas and direction of flow arrows. Marking should be at each critical process control valve, at each wall, floor, or ceiling penetration, at each change of direction, and at every 20' of continuous piping run.

- Always don appropriate eye and/or face protection when working on or near compressed gas cylinders and systems. Chemical goggles are recommended when using corrosive, irritating, or toxic gases. Goggles, face shield, hand and body protection are recommended when handling cryogenic gases.

- Use a hand-truck specifically designed to move cylinders. Strap the cylinder onto the hand truck before moving, and ensure that the cylinder valve cap is securely in place before moving (do not attempt to move a cylinder with the regulator attached or valve cap removed). Do not roll cylinders or permit them to drop.

- During use and storage, secure full and empty cylinders from tipping over and in an upright manner. If storing multiple cylinders, segregate incompatible gases (refer to Figure 1). Do not store cylinders in egress areas or hallways. Do not remove the cylinder valve cap until the cylinder has been secured at the point of use. Securing means to use a rack, cage, strap or chain securely affixed to an immovable object (i.e., wall, counter, etc.). If a strap or chain is used it should be positioned above the midpoint but below the shoulder of the cylinder.

- After removing the cylinder valve cap and prior to opening, inspect the valve assembly for damage. Hand pressure should be all that is necessary for cylinder caps and hand wheel supply valves; tools should not be necessary or used to

remove caps or open valves. Return the cylinder to the manufacturer if damage is noted. Do not use the cylinder.

- Do not use the laboratory or adjacent hallways for storage of excess gas cylinders (full or empty). If necessary, one reserve cylinder may be maintained next to the cylinder that is in use.

- Inspect ancillary connections, valves, regulators, tubing, and other devices used with compressed gases regularly (including leak testing each time a cylinder is changed). Replace when signs of damage or deterioration are noted. Ensure that fittings and tubing are compatible with the gas and designed for that use. For example, copper fittings are incompatible with acetylene and can form explosive deposits; standard hose clamps do not take the place of compression fittings. Oxidizing gases are particularly hazardous when in contact with oil, grease, or other organic substances.

- All compressed gas cylinders must be used with a regulator that is designed for the gas and pressures involved. Two-stage regulators are generally recommended for laboratory operations.
    - The regulator must be marked for the maximum cylinder pressure; and the cylinder pressure should not exceed 75% of the maximum rated pressure for the regulator.
    - The regulator must be equipped with two gauges; one to show the cylinder pressure and the other to show the outlet pressure. The exception is for single stage regulators that are designed for use with corrosive gases.
    - If the delivery cylinder is located outside of the laboratory or away from the point of operation, there must be a station regulator and gauge installed at the point of use to show the outlet pressure. In addition, a manual shut off valve should be installed at the point of use when the source cylinder is located away from the point of operation.
    - Never use an adapter between the regulator and the source cylinder.
    - Never use an aid, such as pipe dope or Teflon tape to connect a regulator to a cylinder.

- After attaching a pressure-reducing regulator to a compressed gas cylinder:
    (1) Turn the regulator adjustment screw out (counterclockwise) until it feels loose.
    (2) Stand behind the cylinder with the valve outlet facing away from you.
    (3) Observe the high-pressure gauge on the regulator from an angle; do not pressurize a gauge while looking directly at the glass or plastic faceplate.
    (4) Open the valve handle on the compressed gas cylinder S-L-O-W-L-Y, until you hear the space between the cylinder valve and regulator gently fill the gas. (You can also watch the pressure rise on the high-pressure gauge. If you turned the regulator adjustment screw back properly, there should be no gas flow out of the regulator or pressure rise on the low-pressure gauge.)

(5) When you are ready to use the compressed gas cylinder, fully open the cylinder valve until you feel it stop. Then, close it one-quarter turn.
(6) Verify that leaks are not present with an electronic detector, soap solution, or other suitable means. Never use a flame to check for leaks.
(7) If using a cylinder that does not come equipped with a hand wheel operated valve, leave the wrench that is used to open the cylinder in place while using the cylinder to allow for quick closing in the event of a leak.
(8) Use the following practices on acetylene cylinders to allow quick closing of the valve in the event of an emergency:
    (a) Open acetylene cylinder valves no more than one and one-half turns.
    (b) Leave the wrench on the valve spindle when the cylinder is being used, if the acetylene cylinder has a T-wrench instead of a hand-wheel valve.

- Use backflow check valves where incompatible gases are connected to a common piece of equipment, or where low- and high- pressure gases are connected to a common set of piping. Use a flame arrestor when using flammable and oxidizing gases in applications where there is potential for flashback.

- Always close the cylinder valve of an apparently empty cylinder before disconnecting the regulator; and when the cylinder is not in use. Do not leave pressure on the regulator when the cylinder is not in use.

- Mark all empty cylinders as "empty" or "MT." Secure the valve cap on all stored full or empty cylinders. Ensure that the cylinder valve on empty cylinders is closed.

- Use only non-sparking tools with flammable gas systems.

- Do not purposely vent a cylinder. Should there be a suspected leak, close all regulator valves and tighten the packing nut. If the leak continues, initiate the following procedures:
    - If the leak is minor, secure the cylinder next to a fume hood.
    - If the leak is major, evacuate individuals from the area and call the University Operator. Observe appropriate procedures for personal injury or fire as provided in UNL's *Centrex.*
    - Notify the supplier (if local).

Facility Requirements

- A continuously mechanically ventilated hood or other continuously mechanically ventilated enclosure is required for the storage and use of <u>lecture sized bottles</u> of the following types of gases:
    - Gases that have health hazard ratings of 3 or 4.

- Gases that have a health hazard rating of 2 without physiological warning properties
- Pyrophoric gases.

- At a minimum, a continuously mechanically ventilated gas cabinet is required for the above gases in cylinders that exceed a lecture-bottle size. The gas cabinet must be sprinklered if the gas is pyrophoric. Additional requirements will apply:
  - If the quantities in table 4 are exceeded; or
  - At the discretion of the Authority Having Jurisdiction (Nebraska State Fire Marshal's Office). Consult with UNL FMP (Richard Firebaugh) when contemplating using the above gases in cylinders that are larger than a lecture bottle size. UNL FMP will obtain the SFM's determination regarding specific requirements.

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Table 1 – Maximum internal cylinder volume per laboratory

Class	Labs less than 500 sq.ft.	Labs greater than 500 sq.ft.
Liquefied flammable gases	1.2 sft^3	0.0018 ft^3 per sq.ft. of lab space
Flammable gases	6.0 sft^3	0.012 ft^3 per sq.ft. of lab space
Oxidizing gases	6.0 sft^3	0.012 ft^3 per sq.ft. of lab space
Toxic gases	0.3 sft^3	0.0006 ft^3 per sq.ft. of lab space
Corrosive gases	0.3 sft^3	0.0006 ft^3 per sq.ft. of lab space

* A maximum of 25 lecture bottles of all gases combined is specified for any laboratory area.

Table 2 – Data Summary for Common Gases

	NFPA Health Rating (HMIS Rating)	NFPA Fire Rating (HMIS Rating)	NFPA Reactivity Rating	NFPA Special Conditions	Other considerations
Acetylene	0 (2)	4 (4)	2		Flammability range in air = 2.5 – 81%. Forms explosive acetylides with certain metals (i.e., copper). Do not use at pressures exceeding 15 psig.
Air	0 (0)	0 (0)	0		
Anhydrous ammonia	3 (3)	1 (1)	0		Flammable range in air = 1.5 – 28%. TLV = 25 ppm. Corrosive.
Argon (gas)	0 (0)	0 (0)	0		
Argon (liquid)	3 (3)	0 (0)	0		Cryogen (Boiling point = -302.6 F). Expansion ratio = 840
Carbon Dioxide (gas)	1 (1)	0 (0)	0		TLV = 5000 ppm.
Carbon Dioxide (liquid)	1 (1)	0 (0)	0		Cryogen (Boiling point = - 109 F). Expansion ratio = 553 TWA = 5000 ppm
Carbon Monoxide	2 (1)	4 (4)	0		Flammable range in air = 12.5 – 74%. TLV = 50 ppm.
Chlorine	4 (3)	0 (0)	0	Oxidizer	TWA = 0.5 ppm. Corrosive.
Deuterium	0 (0)	4 (4)	0		Flammable range in air = 4.9 – 75%.
Disilane	1 (1)	4 (4)	2		Pyrophoric. Flammable range = 0.2% – unknown. Does not need an ignition source. TWA = 5 ppm.
Ethylene	2 (1)	4 (4)	2		Flammable range in air = 3.1 – 42%. No occupational exposure limits established.
Fluorine	4 (3)	0 (0)	4	Water reactive Oxidizer	Toxic (TWA = 0.1 ppm). Corrosive.
Helium (gas)	1 (1)	0 (0)	0 (0)		Inert
Helium (liquid)	3 (3)	0 (0)	0 (0)		Cryogen (Boiling point = -452.1 F). Liquid helium is the coldest liquefied gas. Expansion ratio = 754
Hydrogen (gas)	0 (0)	4 (4)	0		Flammable range in air = 4.0 – 75%.
Hydrogen	3 (3)	4 (4)	0		Extremely flammable.

(liquid)					Cryogen (Boiling point = -423 F). Expansion ratio = 848.
Hydrogen chloride	3 (3)	0 (0)	1		Poison (Ceiling limit = 5 ppm). Corrosive.
Hydrogen sulfide	4 (2)	4 (4)	0		Poison (TLV = 10 ppm). Deadens olfactory nerves (does not have good warning properties). Flammable range in air = 4.3 – 45%.
Isobutane (2-Methylpropane)	1 (0)	4 (4)	0		Flammable range in air = 1.8 – 8.4%. Mildly anesthetic. TWA = 800 ppm. Liquefied petroleum gas.
Methane	0 (0)	4 (4)	0		Flammable range in air = 5.0 – 15.0%
Nitrogen (gas)	0 (0)	0 (0)	0		
Nitrogen (liquid)	3 (3)	0 (0)	0		Cryogen (boiling point = -320.4 F). Expansion ratio = 695
Nitrous Oxide	2 (1)	0 (0)	0	Oxidizer	NIOSH exposure limit = 25 ppm. Mildly anesthetic.
Oxygen (gas)	0 (0)	0 (0)	0	Oxidizer	Ventilation must ensure that oxygen enriched environments above 23% do not occur.
Oxygen (liquid)	3 (3)	0 (0)	0	Oxidizer	Cryogen (Boiling point = -297.3 F). Expansion ratio = 860. Ventilation must ensure that oxygen enriched environments above 23% do not occur.
Propane	1 (1)	4 (4)	0 (0)		Flammable range in air = 2.1 – 9.5%. TWA = 1000 ppm Liquefied petroleum gas.
Silane	1 (0)	4 (4)	2		Pyrophoric. Flammable range = 1.4 – 96%. TWA = 5 ppm.
Sulfur Hexafluoride	1 (1)	0 (0)	0		TLV = 1000 ppm. Liquefied compressed gas (not cryogenic).
Xenon	0 (0)	0 (0)	0		Cryogen (Boiling point = -162 F)

Table 3: Gases in a Laboratory Setting that are Regulated Under the United States Department of Homeland Security *Chemical Facility Anti-Terrorism Standards*

Arsine (15 pounds or more of pure or any mixture containing 0.67% or more)	Boron trifluoride (45 pounds or more of pure or any mixture containing 26.87% or more)
Carbonyl fluoride (45 pounds or more of pure or any mixture containing 0.67% or more)	Chlorine pentafluoride (15 pounds or more of pure or any mixture containing 4.07% or more)
Chlorine trifluoride (45 pounds or more of pure or any mixture containing 9.97% or more)	Cyanogen (45 pounds or more of pure or any mixture containing 11.67% or more)
Cyanogen chloride (15 pounds or more of pure or any mixture containing 2.67% or more)	Diborane (15 pounds or more of pure or any mixture containing 2.67% or more)
Dichlorosilane (45 pounds or more of pure or any mixture containing 10.47% or more)	Dinitrogen tetroxide (15 pounds or more of pure or any mixture containing 3.8% or more)
Fluorine (15 pounds or more of pure or any mixture containing 6.17% or more)	Germane (45 pounds or more of pure or any mixture containing 20.73% or more)
Germanium tetrafluoride (15 pounds or more of pure or any mixture containing % or more)	Hexafluoroacetone (45 pounds or more of pure or any mixture containing 15.67% or more)

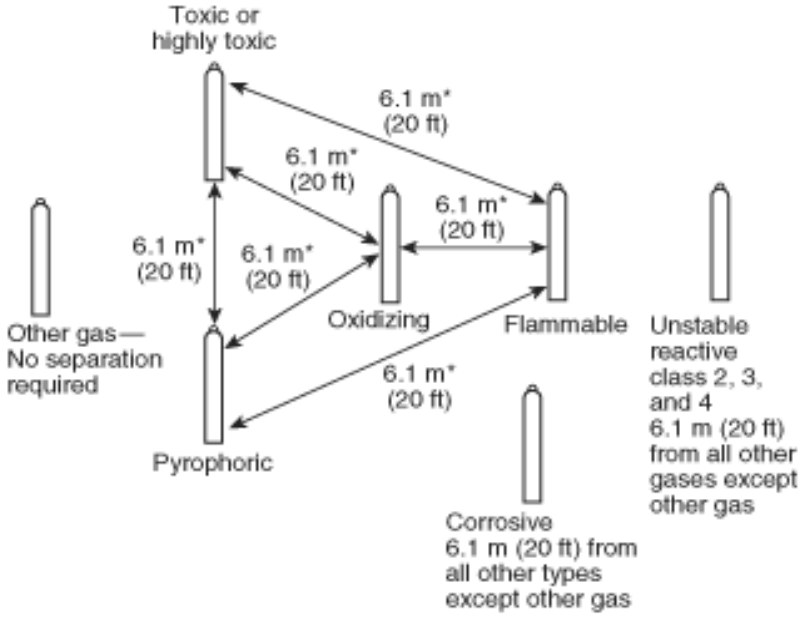
Hydrogen cyanide (15 pounds or more of pure or any mixture containing 4.67% or more)	Hydrogen fluoride, anhydrous (45 pounds or more of pure or any mixture containing 42.53% or more)
Hydrogen selenide (15 pounds or more of pure or any mixture containing 0.07% or more)	Hydrogen sulfide (45 pounds or more of pure or any mixture containing 23.73% or more)
Methylchlorosilane (45 pounds or more of pure or any mixture containing 20% or more)	Nitric oxide (15 pounds or more of pure or any mixture containing 3.83% or more)
Oxygen difluoride (15 pounds or more of pure or any mixture containing 0.09% or more)	Perchloryl fluoride (45 pounds or more of pure or any mixture containing 25.67% or more)
Phosgene (45 pounds or more of pure or any mixture containing 0.17% or more)	Phosphine (15 pounds or more of pure or any mixture containing 0.67% or more)
Selenium hexafluoride (15 pounds or more of pure or any mixture containing 1.67% or more)	Silicon tetrafluoride (45 pounds or more of pure or any mixture containing 15% or more)
Stibine (15 pounds or more of pure or any mixture containing 0.67% or more)	Sulfur tetrafluoride (15 pounds or more of pure or any mixture containing 1.33% or more)
Tellurium hexafluoride (15 pounds or more of pure or any mixture containing 0.83% or more)	Trifluoroacetyl chloride (45 pounds or more of pure or any mixture containing 6.93% or more)
Tungsten hexafluoride (45 pounds or more of pure or any mixture containing 7.10% or more)	The information in parenthesis provides the cumulative total regulatory threshold and the minimum concentration of gas mixture that is subject to counting toward the regulatory threshold

Table 4 – Quantity Limitations Triggering Additional NFPA 55 Storage/Use/Facility Requirements

	Unsprinklered Area	Sprinklered Area
	Gas Cabinet, Gas Room or Exhausted Enclosure	Gas Cabinet, Gas Room or Exhausted Enclosure
Corrosive Gas		
Liquefied	136 kg (300 lb)	272 kg (600 lb)
Non-Liquefied	46 m^3 (1620 ft^3)	92 m^3 (3240 ft^3)
Cryogenic Fluid		
Flammable	170 L (45 gal)	170 L (45 gal)
Oxidizing	340 L (90 gal)	681 L (180 gal)
Flammable Gas		
Liquefied	227 L (60 gal)	454 L (120 gal)
Non-Liquefied	28 m^3 (2000 ft^3)	56 m^3 (4000 ft^3)
Highly Toxic Gas		
Liquefied	2.3 kg (5 lb)	4.5 kg (10 lb)
Non-Liquefied	0.6 m^3 (20 ft^3)	1.1 m^3 (40 ft^3)
Nonflammable Gas		
Liquefied	No Limit	No Limit
Non-Liquefied	No Limit	No Limit
Oxidizing Gas		
Liquefied	114 L (30 gal)	227 L (60 gal)
Non-Liquefied	85 m^3 (3000 ft^3)	170 m^3 (6000 ft^3)
Pyrophoric Gas		
Liquefied	0 kg	3.6 kg (8 lb)
Non-Liquefied	0 m^3 (0 ft^3)	2.8 m^3 (100 ft^3)
Toxic Gas		
Liquefied	136 Kg (300 lb)	272 Kg (600 lb)
Non-Liquefied	46 m^3 (1620 ft^3)	92 m^3 (3240 ft^3)
Unstable Reactive (Detonable) Gas, Class 3 or Class 4		

Liquefied	0 kg	1 kg (2 lb)
Non-Liquefied	0 m^3 (0 ft^3)	0.6 m^3 (20 ft^3)
Unstable Reactive (Nondetonable) Gas, Class 3		
Liquefied	2 kg (4 lb)	4 kg (8 lb)
Non-Liquefied	3 m^3 (100 ft^3)	6 m^3 (200 ft^3)
Unstable Reactive, Class 2		
Liquefied	227 L (60 gal)	454 L (120 gal)
Non-Liquefied	43 m^3 (1500 ft^3)	85 m^3 (3000 ft^3)
Unstable Reactive, Class 1		
Liquefied	No Limit	No Limit
Non-Liquefied	No Limit	No Limit

Figure 1 – Compatible Gas Storage (Separation)



* The 6.1m (20 ft) distance can be reduced without limit when separated by a barrier of noncombustible materials at least 1.5 m (5 ft) high that has a fire-resistant rating of at least ½ hour.

NFPA Definitions

Corrosive Gas. A gas that causes visible destruction of or irreversible alterations in living tissue by chemical action at the site of contact.

Cryogenic Fluid. A fluid with a boiling point lower than -90°C (-130°F) at an absolute pressure of 101.325 kPa (14.7 psia).

Flammable Gas. A material that is a gas at 20°C (68°F) or less at an absolute pressure of 101.325 kPa (14.7 psia), that is ignitable at an absolute pressure of 101.325 kPa (14.7 psia) when in a mixture of 13 percent or less by volume with air, or that has a flammable range at an absolute pressure of 101.325 kPa (14.7 psia) with air of at least 12 percent, regardless of the lower limit.

Flammable Liquefied Gas. A liquefied compressed gas that, when under a charged pressure, is partially liquid at a temperature of 20°C (68°F) and is flammable.

Highly Toxic Gas. A chemical that has a median lethal concentration (LC50) in air of 200 ppm by volume or less of gas or vapor, or 2 mg/L or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 g and 300 g (0.44 lb and 0.66 lb) each.

Inert Gas. A nonreactive, nonflammable, noncorrosive gas such as argon, helium, krypton, neon, nitrogen, and xenon.

Irritant Gas. A chemical that is not corrosive, but that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500.41, for an exposure of 4 or more hours or by other appropriate techniques, it results in an empirical score of 5 or more. A chemical is classified as an eye irritant if so determined under the procedure listed in 16 CFR 1500.42, or other appropriate techniques.

Nonflammable Gas. A gas that does not meet the definition of a flammable gas.

Oxidizing Gas. A gas that can support and accelerate combustion of other materials.

Pyrophoric Gas. A gas with an autoignition temperature in air at or below 54.4°C (130°F).

Toxic Gas. A gas with a median lethal concentration (LC50) in air of more than 200 ppm, but not more than 2000 ppm by volume of gas or vapor, or more than 2 mg/L, but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 g and 300 g (0.44 lb and 0.66 lb) each.

Unstable Reactive Gas. A gas that, in the pure state or as commercially produced, will vigorously polymerize, decompose, or condense, become self-reactive, or otherwise undergo a violent chemical change under conditions of shock, pressure, or temperature.

- **Class 2 Unstable Reactive Gas**. Materials that readily undergo violent chemical change at elevated temperatures and pressures.
- **Class 3 Unstable Reactive Gas**. Materials that in themselves are capable of detonation or explosive decomposition or explosive reaction, but that require a strong initiating source or that must be heated under confinement before initiation.
- **Class 4 Unstable Reactive Gas**. Materials that in themselves are readily capable of detonation or explosive decomposition or explosive reaction at normal temperatures and pressures.