COMPRESSED OR LIQUEFIED GASES IN LABORATORIES AND LABORATORY SUPPORT FACILITIES

Program Statement
All laboratories and laboratory support facility employees engaged in the use of compressed or liquefied gases shall adhere to the requirements stated in the Compressed Or Liquefied Gases in Laboratories and Laboratory Support Facilities and all related safety programs of the Office for Research.

Reason for Program/Purpose
The use of hazardous chemicals in the laboratory is regulated by the Occupational Safety and Health Administration (OSHA) Occupational exposure to hazardous chemicals in laboratories 29 CFR 1910.1450. Areas outside laboratories where hazardous materials are handled are regulated by the OSHA Hazard Communication Standard 29 CFR 1910.1200 and Compressed Gases 29 CFR 1910 Subpart H, M and Q. The storage of gases is regulated by the International Building Code (2003), the International Fire Code (IFC 2003), applicable standards of the Compressed Gas Association (CGA) and the National Fire Protection Association (NFPA). The University requires each research group to maintain concentrations and/or quantities below the thresholds of consequence as promulgated by the Department of Homeland Security (DHS) Chemical Facilities Anti-Terrorism Standards (CFATS).

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Who Approved This Program
Laboratory and Chemical Safety Committee
Jay Walsh, Vice President for Research
Michael Blayney, Office for Research Safety
Chris Johnson, Risk Management
Bruce Lewis, University Police
Ron Naylor, Facilities Management

Who Needs to Know This Program
This program applies to Northwestern University faculty, staff, students, and visitors working in laboratories or laboratory support facilities. They are thereon referred to as “laboratory workers”. Others shall follow the guidelines of their administrative units or employers.

Website Address for this Program

Contacts
If you have any questions on the program or procedure for COMPRESSED OR LIQUEFIED GASES IN LABORATORIES AND LABORATORY SUPPORT FACILITIES program, you may:

1. Call the Office for Research Safety at 847-491-5581, or

2. Send an e-mail to Researchsafety@northwestern.edu

Definitions
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Bulk systems</td>
<td>Assembly of storage containers, pressure regulators, PRDs, vaporizers manifolds, and interconnecting piping that has a storage capacity of more than 20,000 scf (566m³) of compressed gas or cryogenic fluid including unconnected reserves regardless of storage pressure. A bulk system terminates at the point where gas at service pressure enters the supply line. (Reference: CGA P-18 2006)</td>
</tr>
<tr>
<td>Emergency alarm system</td>
<td>A system to provide indication and warning of emergency situations involving hazardous materials</td>
</tr>
<tr>
<td>Excess flow control</td>
<td>A fail-safe system or other approved means designed to shut off flow caused by a rupture in pressurized piping systems.</td>
</tr>
<tr>
<td>Oxygen deficient atmosphere</td>
<td>An atmosphere in which the oxygen concentration is less than 19.5% by volume.</td>
</tr>
<tr>
<td>Permissible exposure limit (PEL)</td>
<td>The allowable OSHA limit for an air contaminant in which workers may be exposed day after day without adverse health effects.</td>
</tr>
<tr>
<td>Standard cubic foot (scf)</td>
<td>Cubic foot of gas measured at 70°F (21.1 °C) and 14.7 psia (101.3 kPa abs).</td>
</tr>
<tr>
<td>Restricted Commodity</td>
<td>The following hazardous gases above their threshold concentration are classified as Restricted Commodity.</td>
</tr>
<tr>
<td>Arsine &gt;0.67%</td>
<td>15lb</td>
</tr>
<tr>
<td>Diborane &gt;2.67%</td>
<td>15lb</td>
</tr>
<tr>
<td>Dichlorosilane &gt;10.47%</td>
<td>45lb</td>
</tr>
<tr>
<td>Fluorine &gt;6.17%</td>
<td>15lb</td>
</tr>
<tr>
<td>Hydrogen sulfide &gt;23.73%</td>
<td>45lb</td>
</tr>
<tr>
<td>Phosphine &gt;0.67%</td>
<td>15lb</td>
</tr>
</tbody>
</table>

The right column shows the quantity Threshold of Consequence per DHS.
Toxic gas and highly toxic gas

A toxic gas is one with a median lethal concentration (LC50) of more than 200 and less than 2,000 parts per million by volume of gas or vapor when administered by inhalation for an hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each. A highly toxic gas is characterized by a median LC50 of 200 ppm or less under the same conditions. (Reference: CGA P-1.1991)

Program/Procedures

1.1 PI/Laboratory Supervisor Responsibility

- Ensure that workers know and follow the guidelines for compressed and liquefied gases.
- Determine the required levels of protective apparel and equipment, and availability.
- Assure that the quantity of compressed and liquefied gases does not exceed maximum allowable quantities at or above the threshold concentration.
- Maintain an up-to-date inventory record.
- Ensure that facilities and training for use of any material being ordered are adequate.
- Develop a written response protocol for activation of any emergency alarm system that is mutually agreed upon by University Police, Risk Management, Research Safety and Facilities Management and disseminate the protocol to the designated responders.

1.2 Laboratory Worker Responsibility

- Conduct all work with compressed or liquefied gases in accordance with standard operating procedures.
- Notify the PI/Supervisor and ORS of any accidents, incidents involving material releases, and adverse health, safety and environmental conditions.

1.3 ORS Responsibility

The Assistant Director for Safety shall function as the University's Chemical Hygiene Officer (CHO). The CHO or designated ORS personnel shall:

- monitor the maintenance of the chemical inventory program,
- review and approve purchase requests for Restricted Commodity
- develop and conduct Laboratory Safety training,
- assess the use of personal protective equipment,
- provide guidance in environmental detection,
- provide guidance and act as a resource to departmental safety committees and
personnel,
- assist in the development of specific standard operating and emergency response procedures, and
- review laboratory designs according to the Program on Safety Review of New and Renovated Facilities and Equipment

1.4 Facilities Management Responsibility
The designated Facilities Management project manager shall follow the Program on Safety Review of New and Renovated Facilities and Equipment and assist in developing a mutually agreed upon emergency response plan. The periodic maintenance of required gas detection and emergency alarm systems that are designed and installed through Facilities Management shall be completed through Facilities Management Operations.

1.5 University Police Responsibility
University Police shall staff a central station 24/7 and follow the mutually agreed upon response protocol in case of an alarm activation of a required emergency alarm system.

1.6 Risk Management
Risk Management staff review laboratory designs in accordance with the Program on Safety Review of New and Renovated Facilities and Equipment, and assist in the development of emergency response procedures.

2.0 Restricted Commodity
Investigators must order Restricted Commodity using NUFinancials. The selected COMMODITY CATEGORY in NUFinancials must be LAB-HAZARDOUS GASES. Investigators must ensure that each person placing orders, whether department office staff or laboratory staff, understands these requirements. ORS must review and approve all requisitions for Restricted Commodity. ORS will not approve purchase orders for LAB-HAZARDOUS GASES intended for use outside of authorized University facilities.

3 Compressed Gases.

3.1 Securing Cylinders.
An added hazard is the potential for accidental pressure release; a cylinder with the valve broken off can turn into a rocket. It is important to keep cylinders secured to the bench or wall and to keep the caps on when they are not in use. Chicago code requires that cylinders be chained to the wall. In Evanston, cylinders may be secured by bench straps, floor stands, or chains. See the Tables in Sections 6.1 and 6.2 for maximum size and quantity limitations for compressed-gas or liquefied-gas cylinders in laboratories.

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

- Lecture bottles shall be stored where the temperature does not exceed 50° C, because unlike larger cylinders, they do not have pressure-relief devices to prevent rupturing.
- 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 or contact ORS. 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.

3.3 Storage.
Maximum allowable storage quantities vary depending on campus, building, floor, control area, fire rated design and type of gas. Only cylinders that are in use shall be kept in the laboratory. When the 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.

3.4 Transport.
When transporting a cylinder, use a wheeled cylinder cart with the capped cylinder strapped to the cart.

3.5 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. 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.

3.6 Environmental.
Do not expose cylinders to temperatures higher than 50° C. Some rupture devices on cylinders release at about 65° C.

4 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. 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. 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 2003 – Section 3704.2.2.7 Treatment Systems)

If the physiological warning properties for the toxic or highly toxic gas(es) are above the PEL an emergency alarm system may be required (NFPA 2005 - 55-7.9.6.1); consult with the Office for Research Safety regarding this determination. Consult the emergency plan for the given lab area to determine the action expected during a leak situation. ORS shall be contacted for information on selection, fit testing, and training if respirators or SCBA have been provided. No one may use respirators on the job without prior medical approval, fit testing, and training. The visual alarm of a continuous leak detection system shall be blue at malfunction, yellow at the warning level and red at the danger level. A required leak detection system shall send all alarm signals to University Police.

For the use of highly toxic gases with a NFPA 704 Health rating of 4 see the Process Hazard Review in Research.

5 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 2003 - 2703.2.2.1).

The visual alarm of a continuous flammable gas detection system shall be yellow at the warning level and red at the danger level. A 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 1910.153. This requires the use of Grade T welding hose color coded red/green for all oxy-gas welding applications and the installation of flash arresters on hydrogen and acetylene cylinders.

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-1-1966. Acetylene cylinders are partially filled with acetone and should always be kept upright. 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 acetylide.
Never exceed the pressure limit indicated by the warning red line of an acetylene pressure
gauge.

5.2 Hydrogen
Individual hydrogen gas cylinders should contain less than 400scf. Hydrogen gas vessels as
larger quantities may require a laboratory designed with explosion control and other safety
measures.

6 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. 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 nonflammmable 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 which then become prone to shatter like a fragile piece of glass.

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. A blue
indicator light shall indicate a detection system malfunction. A required atmosphere
monitoring system shall send all alarm signals to University Police.
6.2.1 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 cubic foot per minute per square foot of floor area determined by the area enclosed. (Reference: CGA P-18 2006)

7 Quantity Limits
See the definition of Restricted Commodity for threshold concentration and quantity limit of specially regulated gases.
Flammable gas cylinders must be stored 20ft away from oxidizers and oxygen gas cylinders or separated by a fire rated wall. Refillable gas cylinders supplied by gas vendors at a pressure of 2,200 – 2,400psi, contain an average of 250 cubic feet of gas at normal temperature and atmospheric pressure.

7.1 Quantity Limits on the Evanston 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 Office for Research Safety.
The regulations for the Evanston Campus differ from the regulations on the Chicago Campus.
The building users on the Evanston 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 Facilities Management.
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. Typical research laboratories are not constructed to High Hazard Group specifications.

7.2 Quantity Limits on the Chicago Campus
Note that the McGaw/Olson building is classified as institutional occupancy NOT business occupancy, which limits the storage quantities in accordance with NFPA 99. Contact ORS for further information.

Maximum Size and Quantity Limitations for Compressed or Liquefied Gas Cylinders in Laboratories located in Buildings classified Business Occupancy

<table>
<thead>
<tr>
<th></th>
<th>Flammable Gases and Oxygen</th>
<th>Liquefied Flammable Gases</th>
<th>Gases with High Health Hazard Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum cylinder size (approximate dimensions)</td>
<td>10 × 50inches</td>
<td>9 × 30inches</td>
<td>4 × 15inches</td>
</tr>
<tr>
<td>In sprinklered areas</td>
<td>6\textsuperscript{b}</td>
<td>3</td>
<td>3\textsuperscript{a}</td>
</tr>
</tbody>
</table>
a) Cylinders of all toxic gases shall be kept in a continuously mechanically ventilated hood or other continuously mechanically vented enclosure, with no more than 3 cylinders per enclosure.

b) In instructional laboratory work areas, the total number of cylinders shall be reduced to 3 maximum-sized cylinders. Ten approximately 2" × 12" cylinders (lecture bottles) are allowed. In other than instructional laboratories, 25 lecture bottles are permitted.


8 Information and Training
The PI or laboratory supervisor shall ensure that the laboratory workers are informed of the hazards of chemicals present in their work area.

The PI or laboratory supervisor shall develop a written response protocol for activation of the emergency alarm system. ORS shall work with the PI or laboratory supervisor to provide hazard awareness training to designated NU first responders. Emergency response protocol becomes active once there is mutual agreement among the designated responders including University Police.

All laboratory workers shall attend mandatory Laboratory Safety training in accordance with ORS Training Program. Training shall be conducted at the time of the laboratory worker's initial assignment to a work area where compressed or liquefied gases are present and prior to assignments involving new exposure situations.

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Forms/Instructions

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<th>Hazardous Material</th>
<th>Below grade/Basement</th>
<th>1st floor/grade</th>
<th>2nd floor</th>
<th>3rd floor</th>
<th>4th to 6th floor level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenic flammable</td>
<td>33gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>33gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5gal</td>
</tr>
<tr>
<td>Cryogenic Oxidizing</td>
<td>33gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>33gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22gal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5gal</td>
</tr>
<tr>
<td>Flammable gas (gaseous)</td>
<td>750 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1,000 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>750 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>500 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>125 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Flammable gas (liquefied)</td>
<td>22.5gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>30gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>22.5gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>15gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>3.7gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oxidizing gas (gaseous)</td>
<td>1,125 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1,500 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1,125 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>750 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>187 cubic feet&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Oxidizing gas (liquefied)</td>
<td>11gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>15gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>11gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>7gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.8gal&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Corrosive</td>
<td>607 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>810 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>607 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>405 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>101 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Highly toxic (needs ORS approval)</td>
<td>20 cubic feet&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20 cubic feet&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20 cubic feet&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20 cubic feet&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20 cubic feet&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Toxic</td>
<td>607 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>810 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>607 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>405 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
<td>101 cubic feet&lt;sup&gt;b&lt;/sup&gt;</td>
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**Related Information**

**History/Revision Dates**

**Origination Date:** 07/12/2010
Last Amended Date: 09/27/2013

Next Review Date: Month, Day, Year