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SUMMARY: More than 200 different substances are commonly shipped in compressed gas containers. Compressed gases can be classified or categorized a variety of ways and are often based on a common source, similar use, related chemical structure or similar physical properties and many gases can fall into multiple categories. Generally, the term “compressed gas” also refers to liquefied and dissolved gases meeting these criteria and also includes cryogenic gases, e.g., Nitrogen (N₂), Hydrogen (H₂), Helium (He). Refer to the Occupational Safety and Environmental Health (OSEH) Department’s guideline for Cryogenic Liquid Use (Research) for additional information on cryogenic liquids.
Multiple hazards may be associated with compressed gases:

- Fire and explosion hazards of flammable, pyrophoric, or reactive gases;
- Health hazards of toxic, corrosive or asphyxiating gases, and;
- Pressure hazards due to the high pressures within most cylinders that can result in a rapid release and subsequent violent pinwheeling or (propulsion) rocketing of the cylinder.

This document describes administrative controls to protect personnel during the handling, storage and use of compressed gases.

**SCOPE:**

This Guideline applies to all University of Michigan (U-M) personnel that use or store compressed gases. It contains information regarding proper storage, handling and use as well as restrictions on quantities of compressed gas cylinders allowed in laboratories and additional requirements associated with use of higher hazard materials.

**REFERENCE REGULATIONS:**

MIOSHA Part 69, Compressed Gases: Acetylene, Hydrogen, Oxygen, Nitrous Oxide.  

MIOSHA Part 12 Gas Welding and Cutting standard:  

**DEFINITIONS:**

**Absolute Pressure** – A pressure value in relation to total vacuum. Equal to the sum of a pressure gauge reading and atmospheric pressure (14.69 psia or 1.01 bar at sea level).

**Air** – The mixture of gases that surrounds the earth. The composition of air is 78.08% nitrogen, 20.95% oxygen, 0.03% carbon dioxide, and 0.93% argon. Standard air has a density of 0.075 lb/ft³ (1.2 kg/m³) measured dry at 70°F (21°C) and 760 mm Hg pressure, M.W. 28.3.

**Anhydrous** – A descriptive term meaning without water.

**Asphyxiating gas** – A gas, including inert (noble) gases that may cause suffocation by displacing the oxygen in the air necessary to sustain life, or is labeled by the DOT as Division 2.2. Examples include: argon (Ar), carbon dioxide (CO₂), helium (He), and nitrogen (N₂).
CGA – Compressed Gas Association. An association that specifies cylinder valve outlet connections for specific gas services based on safety considerations.

Chemical Hygiene Plan (CHP) – a written policy, developed and implemented by lab management, which sets forth procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards associated with the use of hazardous chemicals. In essence, it is a lab safety manual.

Compressed Gas – Any gas or mixture of gases exerting in a container, a pressure exceeding 40.6 psia (280 kPa, abs) at 68°F (20°C). Also, any flammable liquid having an absolute vapor pressure exceeding 40.6 psia (280 kPa, absolute) at 100°F (37.8°C) as determined by ANSI/ASTM D323, American Standard Test Method for Vapor Pressure of Petroleum Products (Ried Method).

Corrosive Gas – Gases that can cause visible destruction of, or irreversible alterations in, living tissue (e.g., skin, eyes, or respiratory system) by chemical action when they come in contact, or do so in the presence of water, are classified as corrosive. It is essential that equipment used for handling corrosive gases be constructed of proper materials. Proper protective clothing and equipment must be used to minimize exposure to corrosive materials. Examples include: (acid gases), chlorine (Cl₂), hydrogen bromide (HBr), hydrogen chloride (HCl), hydrogen fluoride (HF), and sulfur dioxide (SO₂) and (alkaline gases) ammonia (NH₃), monomethylamine (CH₃N), dimethylamine (C₂H₇N) and trimethylamine (C₃H₉N).

D.O.T. – (United States) Department of Transportation (oversees federal highway, air, railroad, and maritime and other transportation functions).

Flammable Gas - a gas is considered flammable when either a mixture of 13% or less (by volume) with air is ignitable at 14.7 psia (101.3 kPa) or has a flammable range with air of at least 12% regardless of the lower limit. (These limits shall be determined at 14.7 psia (101.3 kPa) of pressure and a temperature of 68°F (20°C).) Examples include: acetylene (C₂H₂), carbon monoxide (CO), ethane (C₂H₆), hydrogen (H₂), methane (CH₄), hydrogen sulfide (H₂S), phosphine (PH₃), diborane (B₂H₆) and arsine (AsH₃).

Gas Pressure Units – Gas pressure is commonly given in units of pounds per square inch (psi). The metric unit is kilopascal (kPa). One psi equals 6.895 kPa.
Inert Gas – A term used to describe a variety of gases which are chemically inactive. For instance molecular nitrogen is often used as an inert gas in food packaging to ensure that food does not spoil in transit. Helium and neon are the only true elemental inert gases, because they do not form any true chemical compounds like the heavier noble gases do.

Laboratory Work Area – a room or space for testing, analysis, research, instruction, or similar work activities that involve the use of chemicals.

LC50 – LC stands for lethal concentration. LC50 is the concentration of a material in air which causes the death of 50% (one half) of a group of test animals. The material is inhaled over a set period of time, usually 1 or 4 hours. The LC50 helps determine the short-term poisoning potential of a material. The value is expressed in g/kg or mg/kg of body weight.

Lecture Bottles - High pressure gas cylinders which are generally sold outright by the gas supplier and are not returnable to gas supplier. Lecture bottles may be purchased with flammable, corrosive and other hazardous material as defined in 49 CFR, Department of Transportation (DOT), and 29 CFR, Occupational Safety and Health Administration (OSHA). Lecture bottles have the designation "LB".

Safety Data Sheets (SDS) – chemical information sheets produced by the manufacturer accordance with the OSHA provisions of 29 CFR 1910.1200 containing the following information: identification and synonyms, hazardous components, physical data, fire and explosion data, toxicity data, health effects and first aid, reactivity, storage and disposal procedures, spill and leak procedures, and protective equipment. It also contains a contact number in case of emergency.

Nesting – A method of securing flat-bottom cylinders upright in a tight mass using a contiguous three-point contact system whereby all cylinders within a group have a minimum of three points of contact with other cylinders, walls or bracing. This method of securing cylinders is prohibited at the University of Michigan. (All) Nested cylinders must be held together using a chain or other device to prevent falling or tipping.

Noble Gas - The noble gases are the chemical elements in group 18 (old-style Group 0) of the periodic table. This chemical series contains helium, neon, argon, krypton, xenon and radon. The noble gases were previously referred to as inert gases, but this term is not strictly accurate because several of them do take part in chemical reactions. Another older term was rare gases, although in fact they form a considerable part (0.93% by volume, 1.29% by mass) of the Earth's atmosphere.
Oxidizing Gas - include oxygen (O₂) and gas mixtures containing a high percentage (> 23.5%) of oxygen. These gases can accelerate combustion and upon contact with combustible materials, may cause a fire or explosion. Therefore, this type of gas should be stored away from all combustible materials, potential sources of ignition and flammable gases.

Oxygen deficiency - A condition that occurs when a breathable atmosphere contains less than 19.5% oxygen. Note: normal air contains 20.8% oxygen.

Personal Protective Equipment (PPE) - devices worn by workers to protect against hazards in the environment. Examples include safety glasses, goggles, face shields, respirators, gloves, hard hats, steel-toed shoes, and hearing protection.

Poison (Toxic) Gas - a gas that poses serious health hazards to people and typically have LC₅₀ (lethal concentration that kills 50% of a population of test animals) values of 5,000 ppm or less. Examples include: arsine (AsH₃), diborane (B₂H₆), nitric oxide (NO), nitrogen dioxide (NO₂), phosgene (CCl₂O), and phosphine (PH₃).

Pressure regulator - A pressure and/or temperature activated device used to prevent the pressure from rising above a predetermined maximum, thereby preventing rupture of a normally charged cylinder when subjected to a standard fire test.

psia – Pounds per square inch, absolute.

psig – Pounds per square inch, gauge.

Pyrophoric gas – Materials that spontaneously ignite on contact with air at normal conditions. Examples include: silane (SiH₄), disilane (Si₂H₆), dichlorosilane (SiCl₂H₂), diborane (B₂H₆) and phosphine (PH₃)

Standard Operating Procedure (SOP) - a concise document that gives safety instructions specific to the process and associated equipment.

Valve protection cap - A rigid removable cover provided for container valve protection during handling, transportation and storage.

RESPONSIBILITY: Deans, Directors, and Department Heads

Ensure that adequate facilities, ventilation, and equipment are provided for the safe use of compressed gases.
Coordinate the implementation of recommended remedial action.

Ensure an environment where principal investigators and other personnel are encouraged to follow this Guideline.

Actively support this Guideline within individual units.

Principal Investigators

Implement procedures in accordance with this Guideline.

Ensure that staff is aware of this Guideline, instructed on the details of implementation, and provided with equipment and controls. Maintain documentation as required.

Assign resources to support the implementation of this Guideline.

Follow Work Connection procedures is there is an accident or injury. [http://www.umich.edu/~connect/forms.htm](http://www.umich.edu/~connect/forms.htm)

Laboratory Managers or Senior Research Personnel

Ensure employees are instructed on and follow proper procedures and utilize protective equipment provided during their work as detailed in written SOPs.

Include all compressed gases in the lab chemical inventory

OSEH

Provide technical assistance and conduct safety audits.

Employees

Comply with this Guideline and any further safety recommendations initiated by the Principal Investigator as detailed in written SOPs.

Conduct assigned tasks in a safe manner, wear appropriate personal protective equipment, and only use equipment for which they have been formally trained.

Report to the Principal Investigator any job related injuries or illnesses, health and safety concerns, and unsafe or unhealthy working conditions.
Review chemical hazard information detailed on SDSs before beginning work with compressed gases.

PROCEDURES:

A. Standard Operating Procedures (SOP)

Read the SDS, and safety precautions for all compressed gases used, and incorporate these precautions into the Chemical Hygiene Plan (CHP) with written Standard Operating Procedures. Refer to Hazards of Common Compressed Gases for additional information. A SOP Template can be used as a starting point. All employees should be trained on SOP’s for the materials they will be using. And documentation of this training should be kept in the lab’s Chemical Hygiene Plan.

B. General Compressed Gas Safety Information

In addition to training individuals on the SOP for the specific gas and its associated hazards, users of compressed gas cylinders should also be trained on basic safety associated with their use. Refer to General Compressed Gas Safety Information for training material on labeling, handling, use, and storage for compressed gas cylinders and information on regulators and valves.

C. Purchasing

The U-M has strategic supplier contracts with vendors for compressed gases. A policy for the purchase of restricted gases requires the pre-approval of the Occupational Safety and Environmental Health Department. The Restricted Hazardous Gas Policy and Restricted Hazardous Gases Authorization Form are available on the U-M Procurement website.

The following laboratories/departments are exempt from this policy: Lurie Nanofabrication Facility; Plant Department; U-M Medical Center Departments; Dental School Clinical Operations; U-M – Dearborn Natural Science Department.

D. Laboratory Limits

The amount of hazardous compressed gas should be limited to that which is deemed necessary for the research. Efforts to substitute materials for lesser hazardous gas should also be taken, whenever feasible. Materials should be maintained in the smallest quantities possible and only one backup cylinder of any gas should be ordered. If
possible, a just in time delivery system should be utilized to minimize quantities on hand.

There are code requirements that establish maximum allowable quantities (MAQ) of hazardous gas that can be used and stored within a building. These are dependent on many variables such as occupancy class, construction materials, sprinkler protection, floors above grade, fire control zones, etc. OSEH will work with you and your facilities management to determine the MAQ for the laboratory work area. **Cylinders not “in use” shall not be stored in the laboratory unit.** One backup cylinder for each gas in use is generally allowed given that the maximum allowable quantities are not exceeded.

E. Ventilation and Safety Features

Based on the hazards of the gas involved, there may be additional requirements associated with the use of the gas in the laboratory. Continuously exhausted gas cabinets or enclosures, gas detection systems, alarms, etc. may be required. Consultation with an OSEH representative will help determine the specific requirements needed. A code analysis may also be required. Refer to Additional Requirements for Toxic, Pyrophoric and Flammable Gases.

F. Inspection

Cylinders should be inspected regularly for corrosion, pitting, cuts, gouges, etc. Valves and regulators should be inspected before each use to check for damage. Cylinder regulators and connections should also be tested for leaks. A soapy water solution can be used for argon, nitrogen, hydrogen or air. For other gases, consult the gas supplier.

Refer to gas suppliers recommendations for long-term storage of cylinders. In lieu of this guidance, 3 years should be the maximum a cylinder is use. A one year cadence on cylinder change-out is the ideal.

G. Emergency Procedures

An emergency plan should be prepared and updated wherever compressed gases are handled, stored, or used. The plan should contain the following information:

i. The type of emergency equipment available and its location

ii. A brief description of any testing or maintenance programs for the available emergency equipment
iii. An indication that hazard identification labeling is provided for each storage area
iv. The location of posted emergency procedures
v. A safety data sheet (SDS) that is available for each compressed gas stored or used on site
vi. A list of personnel who are designated and trained to be liaison personnel for the fire department and who are responsible for the following:
   1. Aiding emergency responders in planning
   2. Identifying the location of the compressed gases stored and used
   3. Accessing the SDS
   4. Knowing the site emergency procedures
vii. A list of the types and quantities of compressed gases within the laboratory.

H. Disposal of Cylinders

Cylinders should be returned to the supplier for disposal. To dispose of empty lecture bottles that cannot be returned to the vendor, write “empty” on the outside of each cylinder and place in a cardboard box. Complete a hazardous waste manifest, listing the contents of the box, and contact OSEH Hazardous Materials Management at 3-4568 to schedule a pickup.

RELATED DOCUMENTS:

* Handbook of Compressed Gases, Compressed Gas Association, Inc.*

* CGA P-1 – 2000, Safe Handling of Compressed Gases in Containers, Compressed Gas Association, Inc.*

* CGA C-6: Standards for Visual Inspection of Compressed Gas Cylinders, Compressed Gas Association, Inc.*

* CGA S-1.1, Pressure Relief Device Standards- Part 1-Cylinders for Compressed Gases, Compressed Gas Association, Inc.*

* CGA S-1.2, Pressure Relief Device Standards- Part 2- Portable Containers for Compressed Gases, Compressed Gas Association, Inc.*

* CGA S-1.3, Pressure Relief Device Standards- Part 3-Stationary Storage Containers for Compressed Gas, Compressed Gas Association, Inc.*

* CGA V-1, Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connection, Compressed Gas Association, Inc.*
NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*


OSEH [Personal Protective Equipment](#) Guideline

**TECHNICAL SUPPORT:** All referenced Guidelines, regulations, and other documents are available through OSEH (3-6973). OSEH can also provide technical support for the proper use and storage of compressed gases.