General Use Standard Operating Procedure (SOP)

Compressed Gases

Gas cylinder

Globally Harmonized System pictogram Indicating a chemical is a gases under pressure hazard.

*Globally Harmonized System Hazard Class: Gases or chemicals under pressure; Aerosols*

*Examples: Oxygen, carbon monoxide, helium, acetylene, propane, argon, nitric oxide*

**Note**: This SOP is intended to provide general guidance on how to safely work with compressed gases and only addresses safety issues specific to compressed gases. Other hazard classes may also apply. Review Safety Data Sheets (SDS) and refer to other general use SOPs relevant to the chemical you are working with. Contact the Principal Investigator/ Laboratory Supervisor or the WSU Chemical Hygiene Officer for questions concerning the applicability of any item listed in this SOP (OEHS: 313-577-1200).

**If the chemical of interest is a particularly hazardous substance or a high-risk chemical a lab specific SOP is required.**

# Hazard Description

The [OSHA Hazard Communication Standard](https://www.osha.gov/dte/grant_materials/fy07/sh-16625-07/hazcomglossary.pdf) defines a compressed gas as:

* A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C); or
* A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C); or
* A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72.

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

* Liquefied
* Non-liquefied
* Dissolved gases

Note that a compressed gas cylinder with a pressure gauge reading of 0 kPa or 0 psig is not really empty. It still contains gas at atmospheric pressure and therefore must be treated with the same safety precautions as a full cylinder.

Liquefied Gases

Liquefied gases are gases which can become liquids at normal temperatures when they are inside cylinders under pressure. They exist inside the cylinder in a liquid-vapor balance or equilibrium. Initially the cylinder is almost full of liquid, and gas fills the space above the liquid. As gas is removed from the cylinder, enough liquid evaporates to replace it, keeping the pressure in the cylinder constant. Anhydrous ammonia, chlorine, propane, nitrous oxide and carbon dioxide are examples of liquefied gases.

Non-Liquefied Gases

Non-liquefied gases are also known as compressed, pressurized or permanent gases. These gases do not become liquid when they are compressed at normal temperatures, even at very high pressures. Common examples of these are oxygen, nitrogen, helium and argon.

Dissolved Gases

Acetylene is the only common dissolved gas. Acetylene is chemically very unstable. Even at atmospheric pressure, acetylene gas can explode. Nevertheless, acetylene is routinely stored and used safely in cylinders at high pressures (up to 250 psig at 21°C). When acetylene gas is added to the cylinder, the gas dissolves in the acetone. Acetylene in solution is stable.

Compressed gases may also be flammable, pyrophoric, toxic, oxidizing, asphyxiating and/or corrosive. Compressed gases are potentially hazardous since they are under great pressure in a container and can also create health hazardous and/or flammable atmospheres.

## Physical Hazards

* Accidental rupture or valve damage of the cylinder and the rapid release of the pressurized gas can result in injury to persons and damage to objects in the vicinity.
* The rapid release of gas from a ruptured or valve-damaged cylinder may propel the cylinder for a long distance, making them a potential rocket or bomb.
* A gas cylinder falling over can break containers and crush feet.
* Containers may explode when heated.
* Some gases (e.g. silane, diborane, phosphine) are considered pyrophoric and will ignite spontaneously in air.
* Leak of flammable or reactive gases can result in fire and exploding cylinders
* Vapors from liquefied gas are initially heavier than air and spread along the ground.

## **Health Hazards**

* A leak of inert gases (e.g. nitrogen, CO2) can quickly displace air in a large area creating an oxygen-deficient atmosphere (an asphyxiation hazard) if released in an inadequately ventilated room.
* A leak of toxic gases can create poisonous atmospheres.
* Contact with gas or liquefied gas may cause burns, severe injury and/or frostbite.
* Fire may produce irritating, corrosive and/or toxic gas by-products.
* See Safety Data Sheet (SDS) for chemical specific hazard information.

# Control of Hazards - General

* Conduct a hazard assessment to identify proper use and handling techniques, fire safety, storage, and waste disposal issues specific to the chemical being used.
* Never use or move a compressed gas cylinder unless you have been provided with hands on training on how to use and move a cylinder safely.
* Purchase the smallest cylinders at the lowest concentration practical. Limit the number of gas cylinders purchased to what is immediately needed.
  + There are limits on the number of flammable gas cylinders that may be present in a room, depending on factors such as room size and fire resistance rating of the walls. If a lab needs to use multiple cylinders of flammable gases in a room, consult with the WSU Fire Marshal (313-577-3313) to ensure appropriate safety precautions are in place.
* Order gas cylinders with a restrictive flow orifice to limit gas flow rate leaving the cylinder.
* Order with pressure relief device to allow safe venting if excessive pressure develops.
* Inspect the gas cylinder and regulator prior to use. Never use gas cylinders or regulators that are damaged or corroded.
* For flammable gases, use non-sparking, non-ferrous tools for installing regulators and tightening other connections.
* Check connections and hoses regularly for leaks using a gas specific monitoring instrument or soapy water (or equivalent).
* When using highly flammable or toxic gas, check the delivery system for leaks using an inert gas prior to introducing the hazardous gas.
* Open flammable gases a maximum of 1.5 turns (so it’s easier to close valve quickly if needed).
* When using compressed acetylene:
  + Do not exceed a working pressure of 15 psig.
  + Do not use vessels, piping, or other materials that contain a significant amount of copper (usually considered to be more than 50% copper). Acetylene reacts with copper, forming a shock sensitive (explosive) compound.
* Replace valve caps when cylinders are not in use or before moving.
* All compressed gases must be clearly labeled with the correct chemical name.

# Engineering/Ventilation Controls

All components of a system connected to a compressed gas cylinder must be pressure-rated to withstand the maximum pressure capable of being delivered by the cylinder or the maximum output pressure of the regulator that is connected to the cylinder valve. Hazardous gases must be dispensed using systems that are properly cleaned and compatible with the gas in use (including tubing). Use only approved CGA connections compatible with the gas being used. Refer to [Air Liquide Design and Safety Handbook for Specialty Gas Delivery Systems](https://industry.airliquide.us/design-and-safety-handbook-specialty-gases?msclkid=2dbfe3aabb3e11ec81894fcb85349a72) to identify compatible connections and tubing. Or contact the gas vendor for recommendations.

Lab ventilation should have a minimum of 6 air changes per hour.

Depending on the amount, concentration, and other properties of the gas, some of the following controls may be required:

* Consider a ventilated gas cabinet or chemical fume hood for flammable, oxidizing, asphyxiating, corrosive, toxic or other hazardous gases, depending on quantities used, possibly with air flow monitors and alarms.
* Use of a compressed gas that is an irritant, oxidizer, asphyxiant, flammable or has other hazardous properties outside of a fume hood may require special ventilation controls in order to minimize exposure to the material.
* Gas sensors and alarms.
* A mechanical flow control valve (needle valve).
* Restrictive flow orifices that limit the flow of gas.
* A purge assembly for flushing of the regulator and delivery tubing with inert gas.
* Secure storage.
* Gas trapping and scrubbing for exhaust.
* For flammable gases, use a flashback arrestor between regulator and hose. (Prevents flame from entering cylinder.)
* Regulators must be used carefully.
* Never use a regulator for the first time without being trained.
* Not all gases are compatible with all types of regulator materials (e.g., never use stainless steel or Monel regulators with corrosive gases, never use regulators made of copper with hydrogen or acetylene gases) and not all regulators are designed to handle all cylinder pressures. Note, flammable gas cylinders are reverse threaded to help prevent the use of incompatible regulators.
* Never use Teflon tape, grease, or other aids on CGA connections (includes installing regulator). These items can clog the flow of gas, damage the regulator, contaminate the gas for the application, and in some cases, react violently with the gas to produce hazardous situations.
* If a regulator does not fit appropriately on a cylinder for which the regulator is designed, first inspect the threading on the regulator. If the threads on the regulator are not damaged, return the cylinder to the manufacturer and get a replacement.
* Perform a leak check when regulators are first attached to gas cylinders. This can be accomplished by using a soap solution, or other appropriate product like Snoop, that is compatible with the gas. Bubbles indicate a leak. Never use a flame to leak check for flammable or oxidizing gases.
* Always ensure the main cylinder valve is closed and bleed the pressure from the regulator before attempting to remove the regulator.
* Regulators are very fragile, properly store the regulators not in use in a secure location.

# Personal Protective Equipment

In addition to proper street clothing (long pants or equivalent that cover legs and ankles, close-toed non-perforated shoes that completely cover the feet), wear the following Personal Protective Equipment (PPE) when performing lab operations/tasks:

* Safety glasses (If working with cryogenic gases, use safety glasses + face shield).
* Lab coat.
  + Hazard assessment of procedures may indicate the need for a flame resistant lab coat, such as Nomex.
* Appropriate chemical‐resistant gloves.
* Refer to Section 8 “Exposure controls/personal protection” of SDS or a glove selection guide (e.g. [Ansell Chemical Protection Guide](https://www.ansellguardianpartner.com/chemical/home#hp)) to identify appropriate glove type.
* For liquefied compressed gases (liquid nitrogen, oxygen) use PPE (e.g. Cryogenic gloves, face shields) dedicated to handling cryogenic material.

# Special Handling Procedures and Storage Requirements

* **DO NOT** mix gases in compressed gas cylinders purchased from vendors such as Airgas or Praxair. This requires special equipment and precautions to prevent injury or death from ruptured cylinders. There are specific Department of Transportation and OSHA regulations prohibiting such activities except by gas suppliers.
* Store upright and secure with sturdy chains or straps to a wall, or use a cylinder rack, bench mount, or stand.
* Ensure the strap or chain is positioned at approximately 2/3 the height of the cylinder.
* If gas cylinders are not used frequently (not used at least weekly), then the valve must be closed, regulator removed, and the cap secured in place.
* DO NOT store cylinders or lecture bottles with the regulator in place. If the regulator fails, the entire contents of the gas cylinder may be discharged.
* Segregate and clearly mark full and empty cylinders.
* Cylinders shall be grouped by type of gas and the groups segregated as to compatibility.
* For maximum safety, flammable gas cylinders should be stored and used as far away as possible from:
  + ignitable liquids with flash points less than 200 °F (93 °C), oxidizing gases and readily combustible materials such as paper, cardboard, oils, or grease (preferably 20 ft away) or separated by a barrier of noncombustible materials with a ½ hour fire-resistance rating.
  + open flames, ordinary electrical equipment (non-explosion proof), electrical panels/circuit breakers and other sources of ignition (preferably 25 ft away)
  + ventilation intakes, air-conditioning equipment, and air compressors (preferably 50 ft away)
* Acutely toxic compressed gases must be stored in a secure designated area with posted warning signs. See the SOP for acutely toxic gases
* **Post storage areas for flammable gases or oxidizing gases with "Warning! No Smoking or Open Flames" signs (e.g., “Warning! Hydrogen gas. No Smoking or Open Flames”).**
* **DO NOT** store above 125°F or in direct sunlight, or outside of the temperature range specified by the manufacturer.
* **DO NOT** store in cold rooms or other unventilated areas (unless content is compressed air) without OEHS permission.
* Transport with cylinder cap (valve cover) in place and **secured** to a cylinder dolly. Use a helper if possible. Never carry or "walk" cylinders/lecture bottles by hand.

# Waste Disposal

Empty, partially used (no longer needed), or damaged (rusted or structurally compromised) gas cylinders should be returned to the vendor (e.g., Airgas) as soon as possible. Lecture bottles should be disposed of through OEHS by submitting a [Chemical Waste Pickup Request](https://research.wayne.edu/oehs/hazardous/chemical-waste). Do not attempt to empty a partially used gas cylinder, as this may create an explosion and/or suffocation hazard.

# Leak Response

1. **Significant Leak**

For a gas leak which poses a significant hazard to local personnel due to the amount of gas leaked, the hazard class of the gas, or leakage in combination with other serious hazards:

* 1. If this can be done safely without risk to personnel, turn off the gas supply and eliminate ignition sources.
  2. Evacuate the building, pressing the emergency power button while leaving the laboratory (if available), and activating the fire alarm. Go to your Emergency Assembly Point (can be found on building maps located in each building or at the [WSU Emergency Contingency Plan](https://research.wayne.edu/oehs/hazardous/emergency-plan) webpage).
  3. Call WSU Police (313) 577-2222. Available 24 hours a day, 7 days a week.
  4. Remain in the vicinity until emergency personnel arrive and provide them with information on the gases, chemicals, and any other relevant hazards involved.
  5. Once personal safety is established, call OEHS at (313) 577-1200.

1. **Small Leak**

In the event of a relatively small leak that would not result in significant release before shut-off and relief valves can be made operational:

* 1. Alert personnel in the immediate area of the leak and restrict access.
  2. Turn off the gas supply and eliminate all sources of ignition.
  3. Increase ventilation in area (turn on fume hood and open sash, open windows). Vent to outside of building only.
  4. Don appropriate PPE (if not already wearing).
  5. Testing connections and tubing using an acceptable, approved leak detection solution (e.g., soapy water).
  6. If the leak is in the gas supply system, close cylinder valve and tighten leaking connections. Repair or replace connections or tubing if needed.
  7. If the leak is from the cylinder (e.g., valve stem, valve seal, valve threads, pressure safety device, etc.), the cylinder shall be tagged as defective, moved to storage outside of the building, and returned to the supplier ASAP. Do not attempt to correct the leak by tightening the valve stem or pressure safety device while the cylinder is under pressure.

# Emergency Procedures

**\*\*If medical attention required, call WSU police (313-577-2222) immediately\*\***

* **Fire Extinguishers** – Refer to section 5 of the SDS for chemical specific firefighting measures. Both ABC dry powder and carbon dioxide extinguishers are appropriate for most fires.
* **Eyewash/Safety Showers** – Depending on the chemical hazard type, an ANSI approved eyewash station and safety shower may be required, easily accessed, and available within 10 seconds travel time for emergency use. Instruct personnel on the locations of eyewashes and safety showers, and how to activate them, prior to an emergency. Refer to [MIOSHA Fact Sheet: Eyewashes and Safety Showers](https://www.michigan.gov/documents/lara/lara_miosha_cet0199_628109_7.doc) to determine if an eyewash/safety shower is required for your specific chemical.

Please note: Additional hazards present in the laboratory may require that an eyewash or safety shower be present. This emergency equipment is required for treating exposures to workplace hazards such as chemical splashes, biological agents, welding sparks, metal shavings, or fine particulates like dust, dirt and sand.

1. **Health Threatening Emergencies**
   1. **Injuries and Exposures:** 
      1. Remove the injured/exposed individual from the area unless it is unsafe to do so because of the medical condition of the victim or the potential hazard to rescuers. **IF A PERSON IS UNCONSCIOUS DUE TO A SIGNIFICANT GAS LEAK (SIGNIFICANT DISPLACEMENT OF OXYGEN IN THE ROOM), THEN IT IS NOT SAFE FOR ANY PERSONNEL TO ATTEMPT TO RESCUE THE UNCONSCIOUS PERSON WITHOUT AN AIR-SUPPLIED RESPIRATOR.**
      2. Call WSU Police (313) 577-2222.
      3. Administer first aid as appropriate.
         1. Eye contact: Check for and remove any contact lenses. Promptly flush eyes with copious amounts of water for a prolonged period (at least 15 minutes). Seek medical attention. Contact an ophthalmologist.
         2. Ingestion: Ingestion is not considered a potential route of exposure.
         3. Skin contact: Adverse events are not expected from skin exposure to hydrogen gas.
         4. Inhalation: Get to a source of fresh air. Loosen tight clothing such as a collar, tie, belt or waistband. If not breathing, give artificial respiration. If breathing is difficult trained personnel should administer oxygen. Seek medical attention.
      4. Call OEHS (313) 577-1200, to report the exposure.
      5. After seeking medical attention, complete and submit a Report of Injury Form to [Enterprise Risk Management & Insurance Programs](https://risk.wayne.edu/), 313-577-3112.
      6. Bring to the hospital copies of the Safety Data Sheets for all chemicals to which the victim was exposed.
2. **Non-Health Threatening Emergencies**
   1. **Injuries and Exposures**

For injuries and exposures that are not considered serious or a medical emergency, visit:

Henry Ford Occupational Health – Harbortown

3300 East Jefferson, Suite 100

Detroit MI 48207

(313) 656-1618

Monday – Friday 8:00 AM to 6:30 PM

If Henry Ford Occupational Health Center is closed or for serious injuries, visit:

Henry Ford Hospital – Emergency Room

2799 W. Grand Blvd.

Detroit MI 48202

(313) 916-8742

OR

Detroit Receiving Hospital - Emergency Room

4201 St. Antoine St, Detroit, MI 48201

Phone: (313) 745-3000

# Minimum Training Requirements

1. **General Training:**

* Online through the [Collaborative Institutional Training Initiative (CITI)](https://about.citiprogram.org/en/homepage/).
  + Laboratory Safety Training (general lab & chemical safety issues)
  + Hazard Communication
* [Fire Safety](https://risk.wayne.edu/fire-safety).

1. **Laboratory Specific Safety Training:**

* [Laboratory-Specific Safety Training](https://research.wayne.edu/oehs/docs/lab-safety-training-checklist.doc) checklist
* Review of SDS for chemicals involved in process/experiment.
* Review of this SOP.
* Review [WSU Hazardous Waste Management](https://research.wayne.edu/oehs/hazardous/chemical-waste) guidelines.
* Other:

# Laboratory Personnel Review

Prior to initiating work, lab personnel using these types of chemicals must complete the table below confirming that they have read and understood the above SOP and the associated hazards.

| **Name** | **Signature** | **Date** |
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For more information, see [Airgas Compressed Gas Safety eBooks](https://www.airgas.com/solutions/training-process-analysis).

[Air Liquide Gas Encyclopedia](https://encyclopedia.airliquide.com/)