
Gases Under Pressure (Excluding toxic and highly toxic gases) Standard Operating Procedure Template

Type of SOP: Process Hazardous Chemical X Hazardous Class

To customize this SOP, add lab-specific information to the sections below marked in RED, as applicable. Completion of the last section (“Lab-Specific Information”) is required. Also, any of the content below may be amended with lab-specific information to enhance worker safety as desired.

Purpose

The purpose of this standard operating procedure is to acquaint you with the proper and safe handling, use, storage and disposal of compressed gases. However, the following gases are **excluded** from this SOP:

- *those that considered toxic, or highly toxic*

The common toxic and highly toxic gases are listed in APPENDIX A. Given their high hazard and special regulations that apply to their use, these materials should have their OWN GAS-SPECIFIC SOP, rather than this generic gas SOP. Contact EH&S for assistance. In some cases, the volume or concentration of toxic/highly toxic gas may allow less rigorous control measures.

So, this SOP would typically apply to inert gases like nitrogen, argon and helium, flammable gases like hydrogen, methane, propane, plus oxygen (oxidizer; fluorine and chlorine are also strong oxidizers, but because of their high toxicity should have their own SOP).

Properties & Hazards

Chemicals in this category present hazards based on one, or more of these characteristics:

- the pressurized nature of their storage and use
- flammability
- oxidizing ability
- high toxicity (as stated above these do not fall under this SOP, but should be addressed separately given their extreme hazard)

All chemicals in this band are considered generally hazardous and the band is general

- gases which are contained in a receptacle at a pressure of 29 p.s.i. (200 kPa) or more at 20 °C
- gases which are liquefied or liquefied and refrigerated

The [Globally Harmonized System of Chemical Classification](#) symbol and hazard codes for compressed gases are:



H280: compressed, liquefied, or dissolved gas

Controls

Basic pressurized gas control measures are noted here. For further information, see Sec. 7D of [Prudent Practices in the Laboratory](#) by the National Research Council. Gas vendors are another good source of information on gas equipment and handling.

A. Administrative Controls

General practices:

1. Be sure to review the Safety Data Sheet (SDS) for all chemicals to be used in the experiment.
2. Avoid working alone. At least one other person must be present in the same laboratory when any work involving hazardous chemicals is being done.
3. Eliminate or substitute for a less hazardous material when possible.

4. Design your experiment to use the least amount of material possible to achieve the desired result.
5. Verify your experimental set-up and procedure prior to use. Be familiar with the Safety Data Sheets for all chemicals in use. Assess the hazards to ensure that appropriate controls are in place to minimize risk and address emergency shut-down procedures as appropriate.
6. Consult with the PI if the work involves procedure scale-up or other large quantities or there are any questions regarding appropriate safety procedures.

B. Engineering Controls

1. In general, it is preferable to perform all work with hazardous chemicals in a fume hood. Sash height should be kept as low as possible to avoid the escape of vapors, gases and particulates.
2. Supplemental equipment such as blast shields should be used when working with chemicals or processes that may result in explosions or pressure releases.
3. Consider the use of a glove box, toxic gas cabinet or other local exhaust in order to further contain hazards as appropriate. Gas cabinets may be required for some toxic gas applications.

For further information on engineering controls see the following pages in Sec. II of the Chemical Hygiene Plan:

- Fume Hood Usage Guide
- Criteria for Implementing Engineering Controls

C. Personal Protective Equipment (PPE)

See the PPE information under Sec. II of the *UCSB chemical Hygiene Plan* regarding:

- the UC PPE Policy and policy summary (what PPE is needed and when/where to use)
- obtaining your free PPE via use of the *Laboratory Hazard Assessment Tool*
- glove selection criteria
- respirator use, etc.

Special Handling & Storage Requirements

Hazard-specific practices:

Storage Areas

1. Store full and empty cylinders separately to avoid confusion. Serious back flow can occur when an empty cylinder is attached to a pressurized system.
2. Select a cool, dry, and well-ventilated area.
 - a. Cool areas minimize pressure increases that can result from heat or direct sunlight.
 - b. Dryness deters rust and corrosion.
 - c. Ventilation is essential in case of leaks.
 - d. Never store compressed gas cylinders (with the exception of compressed air) in environmental rooms (i.e., refrigerated cold rooms or warm rooms). These rooms are not well ventilated and could pose a serious safety concern should a cylinder fail.
3. Arrange storage facilities to permit inventory rotation, using cylinders in order as received from the supplier.
4. Do not store cylinders next to doors or in corridors where they could possibly obstruct emergency exit from the building.
5. Designate an area to store empty cylinders for return to the supplier. An area on or adjacent to your building's loading dock is suitable.
6. Separate oxidizers or other incompatibles (e.g., oxygen) from flammables by at least 20 feet, or by a non-combustible wall.

Storage Guidelines

1. Implement these ideal storage practices:
 - a. Restrain cylinders - During the 1994 Northridge earthquake, gas cylinders that had been double-chained and bolted to a secure surface stayed in place. Single-chain restraints were not as successful. C-clamps did not work at all. Restrain cylinders as follows:
 - i. Store cylinders upright and secure them to a substantial, fixed surface with upper and lower restraints made of non-combustible material, preferably chain and Unistrut®.
 - ii. Position the upper restraint no less than 1 foot from the shoulder of the cylinder. Position the lower restraint no less than 1 foot from the floor.
 - iii. C-clamps or bench mounting brackets are not allowed!
 - iv. Multiple cylinder restraint - Limit 3 cylinders to each double-chain

- restraint system.
- b. Properly label the cylinders and storage area.
 - c. Cap cylinders when not in use.
 - d. Store cylinders away from non-compatibles.
 - e. Store empty cylinders separately from full cylinders.
2. Do not keep non-corrosive gases longer than 5 years from the last hydrostatic test date (usually stamped just below the neck of the cylinder) unless otherwise regulated.
 3. Return all cylinders that appear unsafe or show signs of corrosion, dents, dings, pitting, bulging, etc.
 4. Review your cylinder inventory regularly.
 - a. Return cylinders to the vendor if they're no longer being used. This removes potential hazards and saves on cylinder rental fees (cylinders are typically rented or leased, rather than purchased) and possible reconditioning fees.
 - b. Note: Some vendors charge a reconditioning fee on each cylinder that is not returned within 2 years. This fee may be significant in relation to the actual cost of the gas.
 5. In addition to standard storage requirements listed above, employ special precautions for cylinders containing flammable, oxidizing, or corrosive gases (empty or full) as described below
 - a. Flammable gases
 - i. Separate from cylinders containing oxidizing gases by a minimum distance of 20 feet or by a noncombustible partition
 - ii. When approved gas storage cabinets are used, the cabinets must be equipped with fire sprinklers. (Note: Fire code piping and connection requirements may apply for your facility. Consult the EH&S Chemical Hygiene Officer.
 - iii. Never store flammable gas near ignition or heat sources, or unprotected electrical connections.
 - iv. Keep quantities to a minimum. There may be circumstances where using a pure flammable gas may pose unacceptable risks. It may be necessary to purchase a reduced concentration mixture (e.g., 1% hydrogen and 99% argon).
 - v. If you need large volumes (more than 1 large cylinder), contact the EH&S Chemical Hygiene Officer,
 - b. Oxidizing gases
 - i. Do not permit oil or grease to come in contact with compressed oxidizing gases — explosions may occur!
 - ii. Separate oxidizers from cylinders containing flammable gases by a minimum distance of 20 feet or by a noncombustible partition extending not less than 18 inches above and to the sides of the stored material.
 - iii. Never store oxidizers near flammable solvents, combustible

materials, unprotected electrical connections, or ignition or heat sources. (Note: Fire code piping requirements may apply in your facility. Consult the EH&S Chemical Hygiene Officer.)

- c. Corrosive gases
 - i. Never store lecture bottles of corrosives longer than 6 months and cylinders more than 2 years. (e.g., ammonia, hydrogen chloride, chlorine, and methylamine). Cylinders containing corrosives degrade over time.

Operational Guidelines

1. Know the hazard classification of particular gases you are working with and specific safety requirements as discussed above.
2. Label both the cylinder and gas line with the name of the gas. Do not depend on color codes.
3. Work in a well-ventilated area when using compressed gases.
4. Use the correct regulator. Ensure that each gas in use has its own dedicated regulator. Never use adapters.
5. Never permit a flame or spark to come in contact with any part of a compressed gas cylinder. Have flashback protectors installed on cylinders of flammable gases, such as oxy-acetylene torch units.
6. Use a trap or suitable check valve when discharging gas into a liquid to prevent liquid from getting back into the cylinder or regulator.
7. Lecture bottles use universal threads and valves, and some of them are interchangeable. This increases the risk of accidentally mixing incompatible materials.
8. In addition to standard operational requirements listed above, employ special precautions for cylinders containing flammable, oxidizing, or corrosive gases (empty or full) as described below.
 - a. Flammable gases
 - i. Use flow restrictors to prevent a sudden large unexpected release.
 - ii. Detection systems may be required.
 - b. Oxidizing gases
 - i. Diligently clean regulators and tubing used with oxidizing gases to remove oil and other reducing agents.
 - c. Corrosive gases
 - i. Inspect cylinder valves periodically for corrosion.
 1. If a cylinder or valve is noticeably corroded, contact the gas vendor and follow their instructions.
 2. Alert the vendor to any damage that might impair the integrity of the cylinder before the cylinder is returned.

- ii. Use caution if flow does not immediately start when a valve is opened slightly — there could be a plug in the valve.

Transporting Gas Cylinders

1. Leave the valve protection cap in place until the cylinder has been secured against a wall or bench or placed in a cylinder stand, and is ready for use.
2. Use a hand truck or other suitable device to transport cylinders, even for short distances. Secure the cylinder to the hand truck with a chain or strap.
 - a. Do not roll, drag, or slide containers.
 - b. Do not lift cylinders by cylinder caps.
3. Before returning empty cylinders to the supplier:
 - a. Close the valve. Leave some positive pressure in the cylinder.
 - b. Replace any valve outlet and protective caps originally shipped with the cylinder.
 - c. Mark or label the cylinder "empty" and store it in a designated area for the supplier.
4. Move any cylinders that have been left unattended into a secure location as soon as possible.

Spill and Incident Procedures

See directions under the “*Chemical Incident*” and “*Medical Emergency*” tabs of the *UCSB Emergency Information Flipchart* – should already be posted in all labs.



Hazard-specific Incident Practices:

1. In case of cylinder leaks that can't be stopped by tightening the valve gland or packing nut, do the following:
 - a. For hazardous gases:
 - i. Leave the room, closing the door behind you.
 - ii. Secure the room to prevent entry.
 - iii. Sound the fire alarm, unless the gas leak is relatively slow and

- contained within a gas cabinet, or fume hood.
- iv. Call for emergency assistance. Dial 9-1-1, preferably from a cell phone. Tell the dispatcher the name of the gas.
- b. For non-hazardous gases:
- i. Close the leaking valve. If it is still leaking, replace the cylinder cap and notify EHS.

Waste Disposal Procedure

See “Chemical Waste Disposal” in Sec. II of the UCSB Chemical Hygiene Plan.

Safety Data Sheet (SDS) Location

Online SDSs can be accessed at <http://ehs.ucsb.edu/labsafety/msds>

PRIOR APPROVAL/REVIEW REQUIRED

Prior approval and training is required to change cylinders.

DESIGNATED AREA

The lab only uses one high-pressure gas: Argon, and two tools are connected to the bottle:

1. Laser-welder
2. Custom 3-D printer

LAB-SPECIFIC INFORMATION (required) (*Examples of appropriate content*)

- Argon is used as an inert shielding gas.
- The rack holds two cylinders – one full and one in-use.
- Notify lab staff when a cylinder is empty and they will replace it with a full one.

APPENDIX A:

Hazardous Gas Classification Table

(Because of their acute toxicity and high level of regulatory oversight, the gases listed here should not use this generic SOP, but rather a gas-specific version – contact EH&S)

Gas and Formula	CAS and UN or NA No.	UBC / CFC Class ¹	IDLH ²	LC50 ³	PEL ⁴
Ammonia – NH ₃	7664–41–7, UN1005	Corrosive ^{5,6} , flammable	300 ppm	4000 ppm	50 ppm
Arsine – AsH ₃	7784–42–1, UN2188	Highly toxic, flammable	3 ppm	20 ppm	0.05 ppm
Boron Tribromide – BBr ₃	10294–33–4, UN2692	Toxic	50 ppm	380 ppm	1 ppm ^{4(C)}
Boron Trichloride – BCl ₃	10294–34–5, UN1741	Corrosive ⁵	25 ppm ^Z	2541 ppm	5 ppm
Boron Trifluoride – BF ₃	7637–07–2, UN1008	Toxic	25 ppm	806 ppm	1 ppm ^{4(C)}
Bromine – Br ₂	7726–95–6, UN1744	Highly toxic, corrosive, oxidizer	3 ppm	113 ppm	0.1 ppm
Carbon Monoxide – CO	630–08–0, UN1016	Flammable ⁵	1200 ppm	3760 ppm	50 ppm
Chlorine – Cl ₂	7782–50–5, UN1017	Toxic, corrosive, oxidizer	10 ppm	293 ppm	1 ppm ^{4(C)}
Chlorine Dioxide – ClO ₂	10049–04–4, NA9191	Toxic, oxidizer	5 ppm	250 ppm	0.1 ppm
Chlorine Trifluoride – ClF ₃	7790–91–2, UN1749	Toxic, oxidizer	20 ppm	299 ppm	0.1 ppm ^{4(C)}
Diborane – B ₂ H ₆	19278–45–7, UN1911	Highly toxic, flammable	15 ppm	80 ppm	0.1 ppm
Dichlorosilane – SiH ₂ Cl ₂ (HCl)	4109–96–0, UN2189	Toxic, corrosive, flammable	50 ppm	314 ppm	5 ppm ^{4(C)}
Ethylene Oxide – C ₂ H ₄ O	75–21–8, UN1040	Flammable ⁵	800 ppm	4350 ppm	1 ppm
Fluorine – F ₂	7782–41–4, UN1045	Highly toxic, oxidizer	25 ppm	185 ppm	0.1 ppm
Germane – GeH ₄	7782–65–2, UN2192	Toxic, flammable	6 ppm ^Z	622 ppm	0.2 ppm ⁸
Hydrogen Bromide – HBr	10035–10–6, UN1048	Corrosive ⁵	30 ppm	2860 ppm	3 ppm
Hydrogen Chloride – HCl	7647–01–0, UN1050	Corrosive ⁵	50 ppm	2810 ppm	5 ppm ^{4(C)}

Gas and Formula	CAS and UN or NA No.	UBC / CFC Class ¹	IDLH ²	LC50 ³	PEL ⁴
Hydrogen Cyanide – HCN	74–90–8, UN1051	Highly toxic, flammable	50 ppm	40 ppm	10 ppm
Hydrogen Fluoride – HF	7664–39–3, UN1052	Toxic	30 ppm	1300 ppm	3 ppm
Hydrogen Selenide – H ₂ Se	7783–07–5, UN2202	Highly toxic, flammable	1 ppm	2 ppm	0.05 ppm
Hydrogen Sulfide – H ₂ S	7783–06–4, UN1053	Toxic, flammable	100 ppm	712 ppm	20 ppm
Methyl Bromide – CH ₃ Br	74–83–9, UN1062	Toxic, flammable	250 ppm	1007 ppm	20 ppm ^{4(C)}
Methylisocyanate – CH ₃ NCO	624–83–9, UN2480	Highly toxic, flammable	3 ppm	22 ppm	0.02 ppm
Methyl Mercaptan – CH ₃ SH	74–93–1, UN1064	Toxic, flammable	150 ppm	1350 ppm	10 ppm ^{4(C)}
Nickel Carbonyl – Ni(CO) ₄	13463–39–3, UN1259	Highly toxic, flammable	2 ppm	18 ppm	0.001 ppm
Nitric Oxide – NO	10102–43–9, UN1660	Highly toxic, oxidizer	100 ppm	115 ppm	25 ppm
Nitrogen Dioxide – NO ₂	10102–44–0, UN1067	Highly toxic, oxidizer	20 ppm	115 ppm	5 ppm ^{4(C)}
Phosgene – COCl ₂	75–44–5, UN1076	Highly toxic	2 ppm	5 ppm	0.1 ppm
Phosphine – PH ₃	7803–51–2, UN2199	Highly toxic, pyrophoric	50 ppm	20 ppm	0.3 ppm
Phosphorus Oxychloride – POCl ₃	10025–87–3, UN1810	Highly toxic	0.96 ppm ^Z	96 ppm	0.1 ppm ⁸
Phosphorus Pentafluoride – PF ₅	7647–19–0, UN2198	Toxic, oxidizer	2.6 ppm ^Z	260 ppm	3 ppm
Phosphorus Trichloride – PCl ₃	7719–12–2, UN1809	Toxic, oxidizer	25 ppm	208 ppm	0.5 ppm
Selenium Hexafluoride – SeF ₆	7783–79–1, UN2194	Highly toxic	2 ppm	50 ppm	0.05 ppm (as Se)
Silicon Tetrachloride – SiCl ₄ (HCl)	10026–04–7, UN1818	Toxic, corrosive	50 ppm	750 ppm	5 ppm ^{4(C)}
Silicon Tetrafluoride – SiF ₄ (HF)	7783–61–1, UN1859	Toxic	30 ppm	450 ppm	0.1 ppm
Stibine – SbH ₃	7803–52–3, UN2676	Highly toxic, flammable	5 ppm	20 ppm	0.1 ppm
Sulfur Dioxide – SO ₂	7446–09–5, UN1079	Corrosive ⁵	100 ppm	2520 ppm	5 ppm
Sulfuryl Fluoride – SO ₂ F ₂	2699–79–8, UN2191	Corrosive ⁵	200 ppm	3020 ppm	5 ppm
Tellurium Hexafluoride – TeF ₆	7783–80–4, UN2195	Highly toxic	1 ppm	25 ppm	0.02 ppm (as Te)

Gas and Formula	CAS and UN or NA No.	UBC / CFC Class ¹	IDLH ²	LC50 ³	PEL ⁴
Titanium Tetrachloride – TiCl ₄	7550–45–0, UN1838	Highly toxic, corrosive	1.3 ppm	119 ppm	—
Tungsten Hexafluoride – WF ₆ (HF)	7783–82–6, UN2196	Toxic, corrosive	30 ppm	217 ppm	0.1 ppm

(Table adapted from Santa Clara County's Hazardous Gas Table.)

Footnotes:

1. UBC/ CFC Class. **Gases listed as either toxic or highly toxic should not use this SOP, but develop a gas-specific SOP**
 - a. UBC (Uniform Building Code)
 - b. CFC (California Fire Code)
 - c. Class as defined in CFC:
 - i. Health hazards per Article 2
 - ii. Highly toxic = < 200 LC50
 - iii. Toxic = 201–2000 LC50
 - d. Physical hazards per CFC Standard 7903.
2. **IDLH (Immediately Dangerous to Life and Health)** values published in 1994 by the National Institute for Occupational Safety and Health (NIOSH).
3. **LC50 data (Lethal concentration 50%):** Lowest reported value, 1 hour adjusted, taken from Dept. of Transportation, Compressed Gas Association, Registry of Toxic Effects of Chemical Substances.
4. **PEL (Permissible Exposure Limit)** values published by Occupational Safety & Health Administration (OSHA). OSHA values used if available; otherwise, Threshold Limit Values (TLV) from ACGIH. (C) = TLV-ceiling limit, an exposure limit not to be exceeded under any circumstances.
5. Moderately toxic per cities of San Jose, Santa Clara, and Milpitas: LC50 = 2,000–5000.
6. When used as a refrigerant, Uniform Building Code Class does not apply.
7. IDLH determined by 0.01 of LC50.
8. Cal/OSHA PEL, Title 8, Section 5155, 9/1/95