

Use and storage of compressed, liquified, or cryogenic gases

Background

TTU laboratory operations may require the use of compressed, liquified, or cryogenic gases. While all gases contain substantial potential energy in their containers, depending on the particular gas, there is also a potential for exposure to toxic, corrosive, flammable, reactive, or oxygen depleting materials. Anyone using a gas must be familiar with its hazards; reading the Safety Data Sheet (SDS) is an excellent introduction to the safe handling, use, and storage of a compressed, liquified, or cryogenic gas. Additionally, all laboratories and research projects employing gases must comply with the provisions of this Appendix.

The language in this Appendix is intended to set out current minimum standards for the safe use of compressed gases and provide additional provisions to implement in the future. Basic compliance is the bare minimum required for laboratory operations and is indicated by terms such as will, shall, must. *Better* compliance represents a step up in safety procedures, policies, and practices. *Best* compliance is the highest standard and ensures that lab operations fully align with requirements set out by National Fire Protection Association (NFPA) and Occupational Safety and Health Association (OSHA). Both *better* > d *best* compliance elements will identified with arrow bullet points (➤).

All laboratories will be required to meet the standards of *better* compliance within two years of the implementation of this Appendix.

Building and experimental design proposing the use of compressed, liquified, or cryogenic gases shall involve representatives from EHS and the Fire Marshals to ensure that (1) building and floor limitations on compressed gas quantities are followed and (2) the laboratory space is appropriately sized and equipped to accommodate these materials.

Prohibited activities

The following activities are prohibited:

- Dispensing of any type of gas into another container (apart from cryogenic materials).
- Leaving experiments using toxic, extremely toxic, flammable, oxidizing, corrosive, or reactive/ pyrophoric, gases unattended. This does not apply to gas systems that supply analytical devices, gas systems used in exhausted cabinets and hoods, or gas systems used in laboratories with gas monitoring sensors that can alert an individual outside the lab of a release.

Ordering

- All compressed, liquified, or cryogenic gases are considered hazardous materials and must be identified as such when ordered through TechBuy.
- Labs wishing to order flammable, oxidizing, toxic, extremely toxic, reactive/pyrophoric, unstable, or corrosive gases must consult with EHS prior to placing an initial order.

Gas Inventory

Laboratories will maintain an inventory of the following gas types stored or in use in the lab space. The inventory will include the gas type, number of containers, date of expiry for container certification, and container size. This information will be provided to EHS on January 1 and July 1 of each year.

- Flammable
- Toxic and extremely toxic
- Reactive/ pyrophoric
- Oxidizing
- Corrosive
- Unstable
- Cryogenic gases in quantities greater than 5 liters¹

Training

All individuals using gases in the laboratory will complete the following training prior to working with or moving a gas container:

- Laboratory safety
- Compressed gas safety
- Liquid nitrogen safety (if using or transferring liquid nitrogen)

Individuals using any type of gas container or manifold system must be able to demonstrate that they can turn on and off gases that they intend to use. All individuals using hazardous gas types (flammable, corrosive, oxidizing, reactive/ pyrophoric, unstable, and toxic/ highly toxic) must be specifically trained on the hazards of these gases, means to detect releases, methods employed to mitigate the hazards, and emergency procedures in the event of a release.

Transport

Moving cylinders and gas containers presents several risks; containers can be heavy, bulky, and difficult to move by hand and the valve assembly can become damaged if the cylinder is dropped or struck. The following provisions address transportation of gas containers.

3rd Party transport

Compressed, liquified, and cryogenic gases are considered hazardous materials for purposes of transportation by freight carriers (by air, rail, marine, or over the road). All freight transportation of these materials must be cleared through [EHS Materials Shipping](#).

Vehicle transport

- Texas Tech University vehicles, not personal vehicles, will be used to transport gas containers.
- Gas containers may not be transported in the same compartment of the vehicle as the driver or passengers.

¹ This refers to total quantity of cryogenic gases in the work area, not just the amount in one container.

- Gas containers will be secured to prevent movement during transport.
- Containers must be transported with valves closed and protected.
- Gas containers shall not be allowed to be exposed to high temperatures during transport.
- Incompatible gases shall be segregated during transportation (see segregation information below).

Hand transport

- Large gas containers must be transported using dollies or carts that allow the container to be secured during movement.
- Containers must be transported with valves closed and protected.
- Gas containers shall not be allowed to be exposed to high temperatures during transport.
- Incompatible gases shall be segregated during transportation (see segregation information below).
- Freight elevators are preferred for moving gases between floors; gas containers shall not be transported with the non-laboratory personnel in elevators.
 - *Better:* Flammable, corrosive, toxic, and cryogenic gases shall be transported in an empty elevator.²
 - *Better:* a portable oxygen meter may be used when gases are being transported in confined spaces such as elevators as a means of detecting potential leaks.
 - *Best:* a portable multi-gas meter that can measure O₂ and flammability and specific gases may be used when gases are being transported in confined spaces such as elevators as a means of detecting potential leaks.

Storage of gases

As gases represent a larger hazard in smaller spaces, the amount of gas containers in a laboratory space shall be kept to a minimum. As long as the quantity limitations set out below are not exceeded, labs should keep no more than two spare containers of each gas type in the lab space.

- *Better:* One spare cylinder for each gas type may be kept in the lab space.³

Gas containers that are not regularly used must not be stored in occupied laboratory spaces.

General

- Store gases in cool, dry, well ventilated, and secure area.
- Gases must not be stored where they would impede exit from the space or building (i.e., away from emergency exits, not under stairs, etc.).
- Hazard warnings indicating gas use shall be posted at entrances to laboratory or storage space.

² NFPA 45 A 8.3.3.1

³ NFPA 45 10.1.6.3 & 10.1.6.4

Quantities

The National Fire Protection Association (NFPA) sets limits on quantities of gases that can be stored or used inside a building.⁴ These limits are difficult to translate to individual lab spaces since they are based on the construction features of the building like firewalls, fire doors, and fire suppression systems. To simplify the application of gas storage guidelines to laboratories, TTU has adopted the following storage limitations for laboratory spaces of 750 square feet or greater.

The table below, and accompanying adjustments, represent the maximum allowable quantity (MAQ) of a particular gas type that may be stored and used in a laboratory space. For example, the maximum quantity of an oxidizing gas for storage or use in a third floor, 700 sf lab that was stored in vented cabinets would be 1,500 scf x 0.5 [for third floor location] x 0.5 [for <750 sf of lab space] x 2 [for vented cabinets] = 750 scf.

<i>Gas Type</i>	<i>Class (DOT codes)</i>	<i>MAQ for storage room or lab space >750 sf</i>	<i>Notes</i>
Cryogenic	Inert (2.2)	5 liters ⁵	
Flammable	Gas (2.1)	1,000 scf	
	Liquified (2.1)	150 lb	
	LP (2.1)	300 lb	
Inert	Gas (2.2)	NL	
	Liquified (2.2)	NL	
Oxidizing	Gas (2.2, 5.1)	1,500 scf	
	Liquified (2.2 5.1)	150 lb	
Corrosive	Gas (2.2, 8)	810 scf	
	Liquified (2.2 8)	150 lb	
Pyrophoric	Gas	50 scf	
	Liquified	4 lb	
Toxic	Gas (2.3)	810 scf	
	Liquified (2.3)	150 lb	
Highly Toxic	Gas (2.3)	20 scf	
	Liquified (2.3)	4 lb	
Unstable	Gas, 3 or 4 detonable	10 scf	
	Gas, 3 non-detonable	50 scf	
	Gas, 2	750 scf	
	Liquified, 3 or 4 detonable	1 lb	
	Liquified, 3 non-detonable	2 lb	
	Liquified, 2	150 lb	

Table notes and adjustments to MAQ.

- NL- no limits on quantities to be used or stored
- MAQ- maximum allowable quantity

⁴ NFPA 55, Table 6.3.1.1.

⁵ This is not a maximum limit of cryogenic gas that can be used or stored in this space. It is the threshold that triggers the need for an oxygen sensor.

<i>Adjustment to MAQ</i>	<i>Multiplier</i>
Storage: materials are stored in a dedicated gas storage room or approved gas cabinet.	2.0
Lab use: lab space is in basement or second floor	0.75
Lab use: lab space is in sub-basement or third floor	0.50
Lab use: lab space is on fourth floor or above	0.125
Lab use/ storage: lab space or non-dedicated gas storage room <750 square feet	0.50
Lab use: gas being used is in an approved cabinet, gas cabinet, or exhausted enclosure	2.0
Lab use: lab is an instructional (teaching) lab ⁶	0.10

Rooms devoted to gas storage should not exceed the quantity limitations outlined above.

- *Best:* Gas storage rooms shall meet all requirements set out by NFPA.

Security

- The contents and hazards of a gas container shall be readily apparent to lab personnel through labeling or signage. Cylinders must be labeled as to contents and DOT hazard class.⁷
- Gas containers must be secured upright for storage or use. Straps, chains attached to a solid object, or a cylinder stand are appropriate for securing cylinders. Multiple cylinders of compatible gases may be tightly nested and secured with a single chain or strap.
 - *Best:* Gas cylinders are individually secured and not nested.
 - *Best:* Where multiple gas types are aggregated, the location for each gas type is identified with signage.
- Cylinders in storage must be closed and capped.

Segregation

Flammable, corrosive, oxidizing, reactive/ pyrophoric, unstable, and toxic/ highly toxic gas types are considered hazardous gas types. Each cylinder or container of a hazardous gas type must be separated from any other cylinder or container of a hazardous gas type by at least 20 feet or by a container-height fire barrier with ½ hour fire resistance.⁸ For gases with separation restrictions, that restriction may be reduced to 5 feet if one gas is in a gas cabinet and reduced to zero if both gases are in a gas cabinet.⁹

Use of gases

Note that all provisions for safe storage of gases apply, as appropriate, to the use of gases as well.

Setup

- Researchers should set up experiments to minimize the amount of gas needed.

⁶ NFPA 55, 10.1.6.7

⁷ NFPA 55 7.1.7

⁸ NFPA 55 Table 7.1.10.2 & 7.1.10.2.2

⁹ NFPA 55 7.1.10.2.3

- Regulators for cylinders will be selected in accordance with the type of gas being used. An experienced individual or the gas vendor must be consulted to provide information on the appropriate regulators for each gas type employed and how to set up and attach the regulator.
- Grease, Teflon tape, oil, soapy water, or other materials shall not be used on regulator threads.
- Pressure regulators must have two gauges (inlet and outlet side).¹⁰
- Gas cylinders shall be located so they may not obstruct egress from the lab space. If a gas cylinder or cryogenic container is located adjacent to an egress point, the lab space must have a second egress point.¹¹
- Gas systems will be checked for leaks prior to use. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
- Manifolds and piping used to distribute gases will be selected with the gas type and pressure in mind and be assembled and installed by a competent person in accordance with NFPA 54 and 55 and manufacturer's specifications.
- Piping used to distribute gases shall be labeled as to the gas type at the supply and discharge point.¹²
- Manual shut valves for gases will be within 6 feet of the point of use.¹³
- Flow control or excess flow valves should be incorporated in gas delivery design in a way that minimizes the potential volume of releases from the experimental apparatus.
- Exhaust from gas-fed experimental apparatus must be considered as having the same hazard of the supply gas and be appropriately monitored and/or vented.
 - *Better:* Exhaust gas composition is monitored and categorized to determine actual hazard.



Use

- Cylinder valves, not regulator valves, will be used to turn gas on and off. Cylinder valves shall be operated by hand- do not use wrenches or other tools.
- Users will wear safety glasses when pressurizing regulators and lines. Turn gas on slowly and ensure gauge faces are facing away from individuals.
- Gas container valves will be off, unless in use.
- Gas containers and associated equipment shall be regularly inspected for damage or loose connections.

Emergency procedures

- Laboratories will develop emergency procedures to address releases of gases used in the laboratory. These procedures will contain information on the hazards of the gases

¹⁰ NFPA 45 10.1.5.2

¹¹ NFPA 45 5.3.1 (5) & 5.3.1 (6)

¹² NFPA 45 10.2.5

¹³ NFPA 45 10.2.3

used, means of detecting releases, procedures to shut down experimental apparatus, and notification requirements.

- TTU Fire Marshal will be provided an inventory of hazardous gas types found in each building.
- In the event of a release of a hazardous gas type, lab personnel must call 9-911 from a campus phone or 911 from a cell phone. Shut off sources of energy and ignition and evacuate the lab promptly. If it is safe to do so, attempt to close the cylinder valve. Notify the DSO and building manager of the issue and do not re-enter the lab space until it has been cleared by emergency responders or EHS personnel.
- All incidents and near-misses associated with gas use will be reported to EHS within 24 hours.

Security

Storage areas and laboratories using hazardous gas types must take measures to secure gas containers, prevent unauthorized use, and ensure that all containers are accounted for.

Gas specific requirements

General

Gas containers must be regularly recertified to be refilled or used for transportation. Cylinders have the date of their last testing embossed in the steel or aluminum, generally around the neck of the bottle. Some cylinders have multiple dates displayed as they have been recertified multiple times.



The following example explains how to read the testing dates. Cylinder test dates are stamped in a month_INSPECTOR CODE_year format. The photo to the left shows several date stamps- the initial stamp at the top is dated 12/91 with a B842 inspector code between the month and the year. The next date stamp is 03/05 and final stamp is 08/14. Some dates will have stars or + signs stamped behind them. Hydrostatic tests are

valid for 5 years; if the test date has a star behind it, the test is valid for 10 years.

- Laboratories may not accept cylinder deliveries of cylinders with invalid test dates.
- Laboratories may not store cylinders with test dates that have expired more than 7 years ago.
 - *Better:* Laboratories may not store cylinders with test dates that have expired more than 3 years ago.

Flammable gases

- Flammable gases will have a flashback arrestor as part of the regulator to ensure that flame cannot propagate back into the tank. For piping longer than 50 feet, a second flashback arrestor must be installed at the point of use.
- Labs employing flammable gases will regularly inspect piping and manifolds and perform leak testing annually. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
 - *Better:* Labs employing flammable gases will regularly inspect piping and manifolds and perform leak testing quarterly. The method of leak detection employed, the date conducted, and the individual conducting it will be documented.
 - *Better:* Laboratories employing flammable gases will install a % LEL monitor that will provide a local alarm of gas releases.
 - *Better:* Laboratories employing flammable gases will employ local ventilation at locations in the gas delivery system where leaks are more likely (regulator, manifolds, etc).
 - *Best:* Laboratories employing flammable gases will install a flammable gas monitor that will provide a local alarm of gas releases and notify outside personnel.
- Flammable gas cylinder valves should only be opened ½ to ¾ turn.
- Acetylene gas will be used at less than 15 pounds of pressure.

Corrosive gases

- *Better:* Corrosive gases should be used in fume hoods where possible.
- *Best:* Corrosive gases are stored and used in vented cabinets.
- *Better:* Where possible, gas-specific monitors will be employed to provide a local alarm of gas releases.
 - *Best:* Laboratories employing corrosive gases will install a gas monitor that will provide a local alarm of gas releases and notify outside personnel.
- *Better:* Laboratories employing corrosive gases will employ local ventilation at locations in the gas delivery system where leaks are more likely (regulator, manifolds, etc).
- Non-empty corrosive gas containers will be returned to the supplier no later than the expiration of their hydrostatic test date. Labs using these gases will implement tracking to ensure this occurs.
 - *Best:* Non-empty corrosive gas containers will be returned to the supplier within 3 years of shipping date.¹⁴
- Labs employing corrosive gases will regularly inspect piping and manifolds and perform leak testing twice per year. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
 - *Better:* Labs employing corrosive gases will regularly inspect piping and manifolds and perform leak testing quarterly. The method of leak detection

¹⁴ NFPA 45 A10.1.2

employed, the date conducted, and the individual conducting it will be documented.

- Hydrofluoric acid and hydrogen bromide gases must be returned to the supplier within 2 years of shipping date.¹⁵ Labs using these gases will implement tracking to ensure this occurs.

Toxic and extremely toxic gases

These gases present an extreme hazard to laboratory personnel, particularly for gases like carbon monoxide or hydrogen sulfide that have poor warning properties. Toxic and extremely toxic gases should be used in lab spaces equipped with appropriate safety features to limit the hazards.

- Laboratories employing toxic and extremely toxic gases will employ local ventilation at locations in the gas delivery system where leaks are more likely (regulator, manifolds, etc).
 - *Better:* Toxic and extremely toxic gases should be used in fume hoods where possible.
 - *Best:* Toxic and extremely toxic gases are stored in an NFPA 55 compliant gas room or used from approved gas cabinets, or exhausted enclosures.¹⁶
- For gases with poor warning properties, gas-specific monitors will be employed to provide a local alarm of gas releases.
 - *Best:* Laboratories employing toxic and extremely toxic gases will install a gas monitor that will provide a local alarm of gas releases and notify outside personnel.
- Non-empty toxic and extremely toxic gas containers will be returned to the supplier no later than the expiration of their hydrostatic test date. Labs using these gases will implement tracking to ensure this occurs.
 - *Best:* Non-empty toxic and extremely toxic gas containers will be returned to the supplier within 3 years of shipping date.¹⁷
- Labs employing toxic and extremely toxic gases will regularly inspect piping and manifolds and perform leak testing twice per year. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
 - *Better:* Labs employing toxic and extremely toxic gases will regularly inspect piping and manifolds and perform leak testing quarterly. The method of leak detection employed, the date conducted, and the individual conducting it will be documented.

Oxidizing gases

- No oils or greases will be used on oxidizing gas fittings.
- *Better:* Laboratories employing oxidizing gases will employ local ventilation at locations in the gas delivery system where leaks are more likely (regulator, manifolds, etc).

¹⁵ NFPA 45 A10.1.2

¹⁶ NFPA 45 10.1.4.1

¹⁷ NFPA 45 A10.1.2

- Labs employing oxidizing gases will regularly inspect piping and manifolds and perform leak testing annually. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
- *Better:* Labs employing oxidizing gases will regularly inspect piping and manifolds and perform leak testing quarterly. The method of leak detection employed, the date conducted, and the individual conducting it will be documented.
- *Better:* Labs using oxygen will install an oxygen sensor that will provide a local alarm of gas releases.
- *Best:* Laboratories using oxygen will install a gas monitor that will provide a local alarm of gas releases and notify outside personnel.

Reactive and pyrophoric gases

These gases present an extreme hazard to laboratory personnel; they should be used in lab spaces equipped with appropriate safety features to limit personnel exposure to the hazards.

- Pyrophoric and reactive gases should be used in fume hoods and away from combustible materials.
- *Best:* Pyrophoric and reactive gases larger than lecture size must be used from sprinklered safety cabinets.¹⁸
- *Best:* These gases must be stored in an NFPA 55 compliant gas room or used from approved gas cabinets, or exhausted enclosures.¹⁹
- Where possible, gas-specific monitors will be employed to provide a local alarm of gas releases.
- *Best:* Laboratories employing pyrophoric and reactive gases will install a flammable gas monitor that will provide a local alarm of gas releases and notify outside personnel.
- Non-empty pyrophoric and reactive gas containers will be returned to the supplier no later than the expiration of their hydrostatic test date. Labs using these gases will implement tracking to ensure this occurs.
 - *Best:* Non-empty pyrophoric gas containers will be returned to the supplier within 3 years of shipping date.²⁰
- Labs employing pyrophoric and reactive gases will regularly inspect piping and manifolds and perform leak testing twice per year. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
 - *Better:* Labs employing pyrophoric and reactive gases will regularly inspect piping and manifolds and perform leak testing quarterly. The method of leak detection employed, the date conducted, and the individual conducting it will be documented.

Unstable gases

The laboratory use of these gases will be evaluated by EHS on a case-by-case basis.

¹⁸ NFPA 45 10.1.4.3

¹⁹ NFPA 45 10.1.4.1

²⁰ NFPA 45 A10.1.2

Inert gases (both compressed and cryogenic)

Inert gases do not present the hazards of the gases listed above, but they often have poor warning properties and can displace available oxygen in laboratory spaces if they are released. This is particularly true of cryogenic gases which expand to fill a volume 600 to 800 times that of the container if released.

- Individuals working with cryogenic gases must have insulated gloves and face shields as part of their PPE ensemble.
- Laboratories with more than 10 full-sized inert gas cylinders in use or storage will install an oxygen sensor that will provide a local alarm of gas releases.
- Areas where cryogenic gases are dispensed will have an oxygen sensor installed.
- Laboratories using or storing cryogenic gases will install an oxygen sensor that will provide a local alarm of gas release based on the size of the cryogenic gas container and the square footage of the room. For each 150 square feet of laboratory space, 1 liter of cryogenic gas may be stored or used without the installation of an oxygen sensor.
 - *Better:* Laboratories employing oxygen sensors as noted above will install a gas monitor that will provide a local alarm of gas releases and notify outside personnel.
- Labs employing inert gases will regularly inspect piping and manifolds and perform leak testing annually. The method of leak detection employed, the date conducted, and the individual conducting it will be documented. Flames may not be used for leak detection.
 - *Better:* Labs employing inert gases will regularly inspect piping and manifolds and perform leak testing quarterly. The method of leak detection employed, the date conducted, and the individual conducting it will be documented.
 - *Better:* Laboratories employing inert gases will employ local ventilation at locations in the gas delivery system where leaks are more likely (regulator, manifolds, etc).

Cylinder disposal

Gas cylinders are likely to be regulated as both hazardous waste and hazardous materials for transportation. Coordinate with the gas vendor to remove surplus or unneeded gas containers.

- Damaged cylinders must be removed from the laboratory promptly. Contact EHS to coordinate removal and appropriate disposal.
- Empty gas containers will be marked as such and removed from the lab as soon as possible.
- Handle and store empty gas cylinders as if they are full.

Appendix and lab practices review

A Chemical Hygiene Plan and associated laboratory SOPs are not static documents; they should gradually improve over time as regulations change, new best practices come online, and labs gain familiarity with experimental tools.²¹ The contents of this appendix will be reviewed annually by the ILSC and updated to (1) reflect changes in regulation or best practices and (2) lab practices in place across TTU. As *better* and *best* practices become the norm across

²¹ 29 CFR 1910.1450(e)(4)

campus, those standards will become the new baseline safety standard for use of compressed, liquified, and cryogenic gases.

Laboratories will annually review experimental practices associated with gas use, review lessons learned from incidents and near misses, and identify areas where lab practices could change to meet the *better* or *best* practices in this Appendix.