Compressed Gas Cylinder Safety

Office of Risk Management

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Contents

EMERGENCY

Compressed gas cylinders are highly volatile if damaged. If you witness a compressed gas emergency (such as a fire, explosion, leak, rupture, or other cylinder-related emergency etc.):

1. Maintain your distance. Do not approach the cylinder. Warn others within a conservative radius (where possible).
2. Attempt to identify the cylinder or substance from a distance (i.e. from witness accounts, from cylinder users, etc.).
3. Report the situation immediately to Protection Services at ext. 5411 or 613-562-5411. Provide Protection Services with:
    a. Your name.
    b. A number where you can be reached.
    c. The location (building and room number) of the emergency.
    d. Number of cylinders or containers affected (if known).
    e. Hazards and properties associated with the gas (if known).
4. Once you are in a safe location, remain available to assist.

Emergency shower and face wash stations are located near hazard zones throughout campus and are identified by highly visible signage. Users are encouraged to make note of these locations prior to using a compressed gas.

You must report all accidents and incidents, including non-emergencies, to your supervisor/lab manager/principal investigator (PI) and you must complete the uOttawa Accident, Incident or Occupational Illness report form.

INTRODUCTION

Compressed gases are routinely used at the University of Ottawa for a variety of research and operational purposes. The gases within a cylinder vary in chemical properties, ranging from inert and harmless to toxic and/or explosive. The high pressure of the gases inside the cylinder can pose a serious hazard to members of the University community if the cylinder is physically damaged and/or exposed to elevated temperatures. This guide is intended to make users aware of potential, general hazards and proper handling procedures. Additional training and instruction may be required to handle or work with specific gases. Be sure to speak with your supervisor for instructions specific to your workplace.

Additional information and direction are available in the following legislative references and resources:

- Occupational Health and Safety Act – Regulation 851
- Ontario Fire Code (Part 5.6)
- NFPA 55 – Compressed Gases and Cryogenic Fluids Code
- Office of the Ontario Fire Marshall – Illustrated Commentary – Compressed Gas Cylinders
- Faculty Health, Safety and Risk managers (HSRMs)
- Office of Risk Management

SCOPE

This document applies to all personnel who work with or handle compressed gas cylinders. This may include personnel who work in academic labs and workshops, research labs, operational activities, as well as their associated support environments.

This document is intended to address nominal volumes of compressed gases, such as those within laboratories or small cylinder storage location. Large volumes of compressed gases may require special and/or additional fire separations, special ventilation, and other exceptional construction considerations that meet the requirements of the authority having jurisdiction. If you are uncertain about the applicable requirements, please contact the Faculty Health, Safety and Risk Manager, Facility Manager and/or the Office of Risk Management.

DEFINITIONS

Types of compressed gases

Dissolved gas – gases that are dissolved in a liquid solvent – most commonly acetone – when at pressures of 200 KPa (29 psi) or higher. An example of a dissolved gas is acetylene.

Liquefied gas – gases that can become liquids at normal temperatures when held under pressure inside a cylinder. They exist inside the cylinder in a liquid-vapour balance or equilibrium. Initially, the cylinder is almost full of liquid, with gas filling the space above the liquid. As the gas is removed from the cylinder, the liquid evaporates to replace it and keeps the pressure in the cylinder constant. Anhydrous ammonia, chlorine, propane, nitrous oxide, and carbon dioxide are examples of liquefied gases.

Non-liquefied gas – are 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.

Additional definitions

Asphyxiating gas – a substance that may cause asphyxiation by displacing the oxygen in the air necessary to sustain life (simple asphyxiant). Examples of simple asphyxiants include inert gases, such as argon, carbon dioxide, nitrogen, and helium. Other types of gases, referred to as chemical asphyxiants, can also lead to asphyxiation; however, these gases (i.e. carbon monoxide) displace oxygen at the cellular level rather than at an atmospheric level.

Ceiling (C) – concentration of a substance that should not be exceeded at any time during working exposure.

Compressed gas – any contained mixture or material whose absolute pressure exceeds 275.8 kPa at 21°C or whose absolute pressure exceeds 717 kPa at 54°C, or both, or any liquid whose absolute vapour pressure exceeds 275.8 kPa at 37.8°C.

Corrosive gas – a gas that causes visible destruction of, or irreversible alterations to, living tissues by chemical action at the point of contact. Examples of corrosive gases include ammonia and chlorine.

Cylinder – A pressure vessel designed for absolute pressures higher than 276 kPa (40 psi) and having a circular cross-section. This does not include portable tanks, multi-unit tank car tanks, cargo tanks or tank cars.

Fire compartment – an enclosed space within a building surrounded by a form of fire separation. A fire compartment is intended to contain a fire to its area of origin or the smallest area possible.

Flammable gas – a gas which, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less, or a gas which, at ambient temperature and pressure, forms a range of flammable mixtures with air at concentrations equal to or greater than 12 percent by volume, regardless of the lower limit. Examples of flammable gases include acetylene, carbon monoxide, methane, hydrogen, and propane.

Flash point – the lowest temperature at which a liquid produces enough vapour to ignite in the presence of an ignition source.

Health, Safety and Risk Manager (HSRM) – dedicated personnel embedded within all faculties, Facilities, and Housing, who provide full-time support on risk, environmental, and occupational health and safety issues pertinent to their work environment. Contact information for HSRMs may be found on the Office of Risk Management website.

Immediately Dangerous to Life and Health (IDLH) – involves the exposure to contaminant(s) that are likely to cause death or immediate or delayed permanent, adverse health effects or prevent escape from such an environment.

In-Use Cylinder – a compressed cylinder is considered "in-use" when it is connected to an approved gas delivery system (i.e. regulator, manifold, etc.). All other cylinders are considered "stored".

Inert gas – A nonreactive, non-flammable, noncorrosive gas. Examples include argon, helium, krypton, neon, and nitrogen.

Lecture bottle – are small compressed gas cylinders, typically 30-46 cm (12-18 inches) long and 2.5-7.5 cm (1-3 inches) in diameter. Lecture bottles are predominantly used for small volumes of compressed gases or for specialty gases.

Lower Explosive Limit (LEL) – the lowest concentration of a material in air that can burn or explode; expressed as a percentage. When concentrations of the chemical in the air are below the LEL, the chemical mixture is "too lean" to burn.

Oxidizing gas – a non-flammable gas that can sustain and vigorously accelerate combustion in the presence of an ignition source and fuel. Oxygen and chlorine are oxidizers.

Safety data sheet (SDS) – is an information sheet that each manufacturer must prepare for the hazardous products they sell. The information contained in a SDS is intended to communicate hazards, properties, handling, storage and disposal guidelines, and emergency response requirements. The SDS is the successor to a material safety data sheet (MSDS).

Short-term exposure value (STEV) – A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV–TWA. The TLV–STEL is the concentration at which it is believed that workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, 3) dose-rate-dependent toxic effects, or 4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency

Time weighted average (TWA) – the concentration of a substance which nearly any worker may be repeatedly exposed to without adverse effect over a working lifetime involving conventional eight-hour workdays and 40-hour workweeks.

Toxic gas – a gas that has a lethal concentration (LC 50) in air of 2,000 ppm or less by volume of gas (highly toxic has an LC 50 of 200 ppm or less). Examples of toxic gases include carbon monoxide and chlorine.

Upper Explosive Limit (UEL) – the highest concentration of a material in air that can burn or explode; expressed as a percentage. When concentrations of the chemical in air are above the UEL, the chemical mixture is "too rich" to burn.

DUTIES AND RESPONSIBILITIES

In accordance with applicable health and safety legislation and uOttawa policies and procedures, the applicable workplace parties have the following responsibilities and duties.

Workers

Workers are responsible for health and safety issues in the performance of their duties. Workers must:

a. Work in compliance with the provisions of the applicable health and safety legislation and all health and safety procedures and practices that are made known to them
b. Use or wear equipment, protective devices, or clothing as required by the University, and report the absence of, or defect in, any equipment or protective device which may endanger themselves or other workers to their supervisors
c. Report all known health and safety hazards or any violation of the applicable health and safety legislation or University procedures to their supervisor
d. Not use or operate any equipment, machine, device, item or work method in a manner that endangers themselves or other workers. This includes the independent mixing and storage of custom or specialty gases within compressed gas cylinders.
e. Not remove or make ineffective any protective device required by the applicable health and safety legislation or by University procedure, without providing an adequate temporary protective device; once the removal of the protective device is no longer required, the original protective device must be reinstalled immediately
f. Not engage in any prank, contest, feat of strength, unnecessary running, or rough and boisterous conduct, or otherwise endanger their co-workers or themselves
g. Report accidents and incidents to their supervisor, and complete and submit the University Accident, Incident or Occupational Disease form to Human Resources
h. Attend mandatory safety training sessions related to their work environment

Students

Students are not workers and are not subject to the health and safety legislation applicable to workers; however, the University applies the principles of this legislation to students. Students are responsible for conducting themselves in a proper manner to ensure their own safety, as well as that of others, and must adhere to University procedures and directives on health and safety.

Visitors and volunteers

Visitors and volunteers are not workers and are not subject to the health and safety legislation applicable to workers; however, the University applies the principles of this legislation to visitors and volunteers. Visitors and volunteers are responsible for conducting themselves in a proper manner to ensure their own safety, as well as that of others, and must adhere to University procedures and directives on health and safety.

Supervisors

Under the applicable health and safety legislation, a supervisor has several legal obligations, which include: ensuring that workers comply with the Occupational Health and Safety Act; informing workers about hazards; and providing instruction on preventative procedures. The list below summarizes some of the supervisor's legal duties. Supervisors must:

a. Stay informed of the health and safety needs of workers under their authority
b. Initiate the necessary preventive measures to control health and safety hazards associated with activities under their authority
c. Incorporate preventive measures into all functions and activities that presents a risk of an incident or accident with health-related consequences occurring
d. Ensure that workers under their authority work in the required manner, and with the protective devices, measures, and procedures required, under the applicable health and safety legislation
e. Ensure the safety of people or workplace areas under their authority
f. Before starting new work or a new task, ensure that health and safety orientation, instruction, and information are provided by a competent person to people under their authority
g. Ensure that workers under their authority use or wear the equipment, protective devices, or clothing required
h. Ensure that mandatory safety training is provided by a competent person to people under their authority prior to performing the task
i. Provide safety training opportunities for all their staff or people under their responsibility
j. Where health- and safety-related training has been provided, maintain an updated list of all those who have received the training, the name(s) of the person(s) who provided the training, the date on which the training was given, and the type of training provided;
k. Monitor the safety performance of their workers
l. Assist and co-operate with the UJOHSC and the functional occupational health and safety committee members as they carrying out of their functions, as stipulated in the terms of reference under which they must act
m. Report accidents and incidents according to the internal procedure
n. Ensure that fatalities, as well as serious and critical injuries, are immediately reported to Protection Services. Protection Services will immediately inform the Office of Risk Management, which will inform the Ministry of Labour
o. With the assistance of Protection Services, ensure that the scene of an accident where a fatality, serious injury, or critical injury has taken place is preserved such that there is no interference, disturbance, destruction, alteration, or removal of anything at the scene until an investigation is conducted and ORM indicates that the cleaning or moving of evidence from the scene is allowed
p. Ensure that Protection Services and/or a designated first-aid responder are contacted immediately to provide first aid to injured persons
q. Investigate all accidents and incidents to ensure appropriate and necessary action is taken
r. Immediately investigate any work refusal process
s. Ensure that telephones for emergencies are in working order and accessible in University laboratories with increased risk due to the presence or use of hazardous materials in quantities capable of causing injury, or where the type of activity performed is at a level

where there is a risk of injury, or where a room is isolated from public areas and there is limited access to a telephone

t. Where they have hired an external contractor, require that the external contractor adhere to applicable health and safety legislation
u. Where they have engaged visitors, volunteers, or learners, monitor to ensure that such visitors, volunteers, or learners adhere to applicable health and safety legislation
v. All suppliers of compressed gases are responsible for labelling to clearly identify and classify the product, as well as for providing the safety data sheet
w. The University of Ottawa will train workers, ensure that proper labeling is used and understood by workers, and maintain an inventory of hazardous products
x. Ensure that all workers work in accordance with established safe work procedures and participate in required training

IDENTIFICATION OF COMPRESSED GASES

All compressed gases received, used, or stored must be labeled according to applicable legislation. Each cylinder must be marked by a label or tag (or other suitable means) identifying its contents.

Any cylinder that cannot be positively identified shall not be used, shall be marked as "contents unknown", and shall be returned to the uOttawa compressed gas supplier. The colour of a compressed gas cylinder is not to be relied upon to identify a compressed gas.

In addition to the physical compressed gas container, the University highly recommends that users legibly label all gas lines leading from support spaces. These labels should include the:

- Name of the compressed gas (including concentration, if applicable)
- Area served by the compressed gas; and
- Relevant emergency contact information for the lab users.

Lines can be labelled in many ways (colours, abbreviations, chemical formulae etc.); however, full text is preferred because it helps remove doubt or confusion in an emergency.

Cylinder labels

Compressed gas cylinders will feature labelling on the shoulder of the cylinder. The label serves to identify the contents of the cylinder, the distributor of the product, and briefly outlines the hazards of the gas. This label serves as the workplace label for the cylinder. The label must never be removed. Users should not draw or write on the compressed gas cylinder.

Figure 1 – Example of cylinder shoulder identification label.

Safety Data Sheets (SDS)

The compressed gas manufacturer or supplier must supply the SDSs, which are also available through the uOttawa SDS bank. Before initially using the gas, all users must consult and fully understand the relevant SDS. They must know, understand and mitigate to the extent reasonable prior to initial use of the gas all associated hazards. The supervisor/lab manager/principal investigator (PI) is responsible for developing an emergency procedure that must be understood by users of the compressed gas prior to use and for implementing the procedure when necessary.

Workplace signage

Lab doors at uOttawa feature standard signage that denotes the potential hazards within the lab – including compressed gases. Signage is particularly important for compressed gas storage areas. If your lab or workshop door does not display proper signage at the point(s) of entry, or if existing signage requires an update, contact your Facility Manager for assistance.

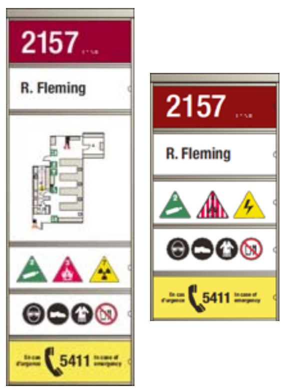

Figure 2 - Examples of uOttawa door signage with, and without, a map denoting hazard zones.

As part of the uOttawa signage package, uOttawa has developed internal hazard signage and posted it in all buildings on campus. Internal hazard pictograms for compressed gases (and other hazards) can be found on the Facilities signage website.

Compressed gas cylinders

Compressed gas cylinders are relatively similar in design. Cylinders will generally feature the following design components.

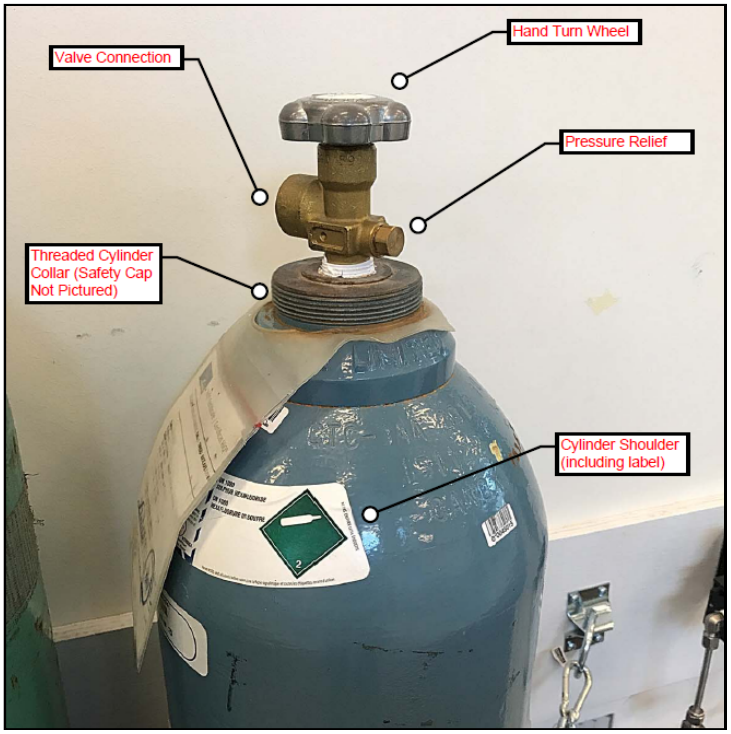

Figure 3 – Compressed gas cylinder design components

All compressed gas cylinders supplied through the uOttawa compressed gas supplier will meet minimum standards. The cylinder will be stamped, normally on its shoulder, with information on the cylinder type, the cylinder serial number, and date of the initial hydrostatic test.

All components of a compressed gas cylinder must be maintained in proper working condition. If the condition of a compressed cylinder is in doubt, remove the cylinder from use and return it to the uOttawa compressed gas supplier in accordance with established Faculty or Service procedures.

Compressed gas cylinder volumes

Compressed gas cylinders are available in many sizes from the uOttawa compressed gas supplier. The most suitable size of compressed gas cylinder will depend on a number of factors, including the type of gas, intended use of the gas, projected consumption, flow rate, etc. Cylinder volume is normally defined as the water capacity (in kilograms) of the cylinder.

Determining mass

The mass of the compressed gas cylinder is available from the uOttawa compressed gas supplier or can be obtained using the volume of the cylinder and the density of the gas to determine the total mass of the cylinder.

Determining expanded volume

The expanded volume of a compressed gas cylinder is available from the uOttawa compressed gas supplier or can be obtained by converting the liquid volume of the cylinder to the expanded gas volume.

The following chart depicts common sizes available from the uOttawa compressed gas supplier.

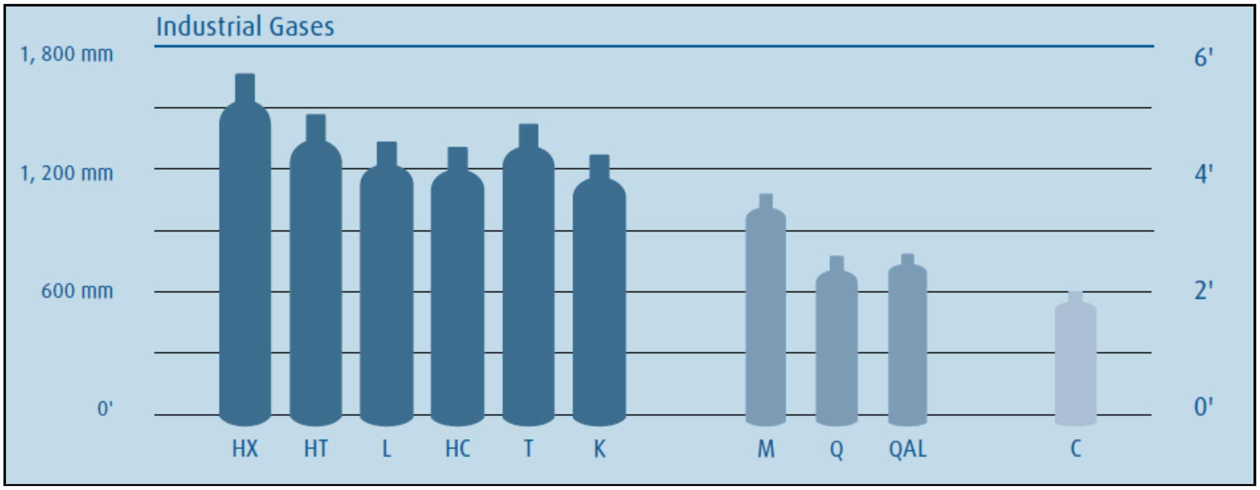

Figure 4 - Common Cylinder Sizes at uOttawa

HAZARDS OF COMPRESSED GASES

A list of hazards inherent to commonly used gases is included in Appendix 1.

Pressure hazards

Regardless of their contents, all compressed gas cylinders present a pressure hazard. Gas is typically released by opening the valve; however, leaks can also release contents and, even at a relatively low pressure, gas can escape rapidly from an open or leaking cylinder.

There are documented cases where damaged cylinders have become uncontrolled projectiles (similar to rockets) and have caused severe injury and property damage. This hazard occurs when the cylinder has experienced substantial physical damage; for example, the valve is sheared off, or the cylinder ruptures and large volumes of gas escape rapidly. Damaged compressed gas cylinders can cause considerable damage; it is vital to maintain the integrity of these cylinders.

All compressed gas cylinders will be labelled with a compressed gas pictogram. Depending on the gas within the compressed gas cylinder, additional pictograms, colours, and numbering may appear on the label.

Figure 5 - Example cylinder labels

Pressure-relief devices

Cylinders are equipped with pressure relief devices where, in situations where excess pressure has built up within the cylinder, the pressure-relief device will activate to relieve the pressure or, in some cases, discharge the contents of the cylinder. The most common form of pressure-relief device is the burst disc. Should the burst disc fail, the cylinder contents will be purged via an opening vacated by the burst disc. A cylinder may also be equipped with fusible plugs, which will melt when they reach temperatures above a given threshold. Finally, the cylinder may have an actual valve, which operates at a particular threshold pressure.

Fire and explosion hazards

Flammable gases

Flammable gases (such as acetylene, ethylene, methane and hydrogen) can burn or explode under certain conditions. These conditions are briefly explained below.

Using hydrogen as an example, the concentration of the gas in air must be between its lower explosive limit (LEL) and the upper explosive limit (UEL). At normal atmospheric pressure and temperature, the LEL of hydrogen gas is 4% and its UEL is 75%. Given this information, hydrogen can be ignited within this range (between 4% and 75%). Hydrogen concentrations lower than 4% are considered too lean to burn, while concentrations above 75% are too rich. It is important to note that not all gases share the same LEL/UEL. A table of common LEL/UEL is provided in Appendix 2.

Once a flammable gas is within its explosive range, it can ignite in the presence of an ignition source. A lab or workshop may house several ignition sources, including sparks, hot surfaces, burners, torches, welding equipment, etc.

The auto-ignition temperature of a gas is the minimum temperature at which the gas self-ignites without an external ignition source. There are some compressed gases that have low auto-ignition temperatures where, in the presence of sufficient heat, they can ignite with little-to-no effort. Some gases are pyrophoric and ignite when exposed to normal atmospheres. These gases have very strict handling requirements and must be carefully handled and stored.

Many flammable compressed gases are heavier than air – the most notable example being propane. If a cylinder leaks in a poorly ventilated area, these gases can settle and collect in low-lying areas, such as sewers, pits, trenches, crawlspaces, basements or other low-lying areas.

Under some conditions, a gas can spread far from its source, leaving a flammable trail behind it. If the gas trail comes into contact with an ignition source, the fire produced can flash back to the cylinder or source, creating an explosion.

Flammable gases will feature the flame pictogram. Examples include hydrogen, methane, acetylene and propane.

Figure 6 – Example flammable pictograms

Oxidizing gases

Oxidizing gases are any gases that will support and accelerate a fire. These gases can cause extremely rapid and violent reactions that often result in fires and explosions. A normal atmospheric oxygen condition is approximately 20.9 percent; however even at slightly higher oxygen concentrations, combustible materials will ignite more easily and burn faster. Fires in atmospheres enriched with oxidizing gases are difficult to extinguish and have the potential to rapidly spread to adjacent areas.

Oxidizing gases will feature the flaming "O" pictogram. Examples include chlorine, fluorine and oxygen.

Figure 7 – Example oxidizing material pictograms

Dangerously reactive gases

Some pure gases are chemically unstable on their own. These gases, if exposed to the proper conditions (such as increases in temperatures or physical damage to the container) can produce significant, and in some cases violent, reactions. Many of these dangerously reactive gases have inhibitors added to help prevent adverse reactions. Nonetheless, care is required in handling these materials. Acetylene (in its pure form) is considered a dangerously reactive gas.

Health hazards

Some compressed gases (such as carbon monoxide and hydrogen sulfide) are toxic, meaning they can cause adverse acute and/or chronic health effects. The toxicity is dependent on several factors, including the type of gas, duration of exposure, route of exposure, body part affected, concentration of substance, existing control measures, etc.

Inert compressed gases (such as argon and helium) produce a unique hazard. While an inert gas will not burn or explode, elevated concentrations can displace sufficient oxygen to cause asphyxiation and/or death. Low oxygen levels can particularly be a problem in poorly ventilated, confined areas. Inert compressed gases are ubiquitous across campus.

Additionally, some compressed gases are corrosive. These gases will burn and destroy body tissues and metals on contact. These gases are generally toxic; they include ammonia, hydrogen chloride, and chlorine. Any cylinder that appears to be rusted or corroded should not be used; it should be removed from service and returned to the compressed gas supplier.

Gases that fall under any of the above categories should be stored in compressed gas cylinders that may also include pictograms for:

- Corrosive hazards
- Explosive hazards
- Acute / chronic toxic effects

Figure 8 - Example cylinder labels

GENERAL CYLINDER REQUIREMENTS

Mechanical damage

Cylinders containing compressed gas must be protected against mechanical damage. Damage can occur many ways, most notably due to fire, heat, or physical impact (dents) caused by mishandling a cylinder or its use in an unsuitable environment. Do not allow cylinders to strike each other or other objects.

Valve caps and chains are typical examples of protection against mechanical damage. The valve cap protects the sensitive connection component of the cylinder, while the chain is intended to protect the cylinder from tipping or falling over. Any stored cylinder containing compressed gas shall have its valve cap securely installed and be securely in place, either on racks or by other physically secured means. Physical security may include:

- Attaching a cylinder to a laboratory bench top, permanent wall, or cylinder storage cage using a suitable chain or strap;
- Resting the cylinder in a non-tip/clamshell base designed for the cylinder.

A chain or nylon strap placed too high or low will not suitably secure a cylinder from falling. We recommend that the chain be made of steel and at least 0.65 cm (¼ inch) in diameter. Do not use damaged chains, wire, rope, or other material to secure a compressed gas cylinder. Here are some examples of properly secured cylinders.

Figure 9 – Securing compressed gas cylinders.

CYLINDER CONNECTIONS

Fittings

All gas regulators, valves, and other fittings must be inspected before each use. Do not use regulators that show gauge pressure discrepancies, bubbles upon leak testing, old regulators (i.e. greater than 10 years' old) or other abnormal characteristics: mark them as damaged and removed them from service. It is important to note that the accuracy of a regulator gauge can decrease over time, so we recommend that regulators be dated, re-tested, and replaced every ten (10) years.

The Compressed Gas Association (CGA) has established standard cylinder valve connections to prevent the mixing of incompatible gases; therefore, regulators are not interchangeable. Check which type of regulator is required for the cylinder prior to ordering: do not use an improper regulator. Cylinder connections have different requirements (diameter and size), locations (internal and external) and threads (right/left-threaded). In general, right-handed threads are used for non-fuel cylinders and water pumps, while left-handed threads are used for fuel and oil-pump gases. We highly recommended that you use only CGA standard combinations. The connector model is normally identified on the side of the connection. A list of common CGA connections is provided in Appendix 3.

The cylinder valve should always be readily accessible. Once work is complete, the main cylinder valve should be closed. Valves should remain closed when the equipment is unattended or not operating. Cylinders will be equipped with either a hand wheel or a stem valve. For stem valves, the spindle key should remain on the stem while the cylinder is in service.

All distribution lines from compressed gas cylinders must be run from compatible materials.

Connecting a regulator to a compressed gas cylinder

1. Before attempting to connect a regulator to a compressed gas cylinder, ensure that you've selected the proper regulator: use Compressed Gas Association (CGA) regulator fittings. If necessary, check with your supervisor, Health, Safety and Risk Manager, Risk Management,

and/or the uOttawa compressed gas supplier for additional information. Never use a compressed gas cylinder without a regulator.

2. Where hoses and tubing are required, maintain the shortest, most direct route from the cylinder to the apparatus/equipment. Periodically check the hoses and tubing for integrity.
3. Check regulator fittings and cylinder valves for damage, most notably to the threads and seat. Remove any debris observed with a dry, lint-free cloth. If damage is observed or integrity is in question, remove the cylinder/regulator from service and notify your supervisor.
4. Set pressure regulator to zero. Ensure that two full threads remain engaged within the regulator body.
5. Fully close the regulator outlet valve.
6. Seat the regulator and hand tighten the connection. Do not force the connection: if you cannot easily connect the regulator by hand, you may be using an incorrect regulator or the regulator may be damaged.
7. Hand-tighten the regulator. Tighten until snug using a regulator wrench or adjustable wrench (if necessary). Do not over tighten connection. Connections should be made with ease.
8. Teflon tape, oil or grease should not be required to make the connection and shall not be used. Do not create or use cylinder adaptors.

Opening compressed gas cylinders

Once the regulator has been successfully connected, you are ready to open the cylinder valve.

1. Position the regulator outlet in the opposite direction (i.e. away from you). Slowly open the cylinder 1/8 of a turn. The pressure gauge on the regulator should read full. Do not “crack open” the cylinder.
2. Using a dilute soap solution in a spray bottle, check for leaks at all connections and periodically on tubing. If leaks are present, the soap solution will bubble. If bubbles are observed, close the cylinder valve and repeat the connection steps. Re-test the connection(s) using the soap solution.
3. If no leaks are noted, the regulator has been properly connected. Adjust cylinder and regulator to the desired working pressure. Ensure that the regulator’s maximum delivery pressure is not exceeded. Ensure that you leave at least two threads in the cylinder valve.
4. Open regulator outlet valve.

Shutdowns

For purposes of this document, and in practice for users, there are two types of shutdowns:

Temporary shutdown

A temporary shutdown is a brief pause in work, after which work quickly resumes. A temporary shutdown may be achieved by closing the main cylinder valve completely. Normally, the regulator and cylinder set-up remain in place.

Extended shutdown

An extended shutdown is a prolonged period during which compressed gases will not be used. An extended shutdown may be initiated by closing the main cylinder valve completely, then setting the pressure valve on the regulator to zero (0). If the system has a pressure release valve downstream from the regulator, open the valve to purge the remaining gas in the delivery line. However, certain gases, such as toxic gases, require special, dedicated purge procedures to ensure the health and safety of users. The lab supervisor must establish the purge procedure. Limited volumes of inert gases (such as argon, nitrogen, carbon dioxide, etc.) can be safely purged without additional hazard controls.

Once the regulator and supply lines have been purged, disconnect the regulator from the cylinder and reinstall the valve cap. Store the cylinder in its intended storage location and secure the cylinder to prevent mechanical damage (i.e. falling).

Do not leave regulators connected to cylinders to bypass cylinder storage requirements.

STORAGE OF COMPRESSED GASES

Storage of compressed gas cylinders applies to those cylinders which are deemed to be "stored", that is, not "in-use".

Before determining where and how compressed gas cylinders will be stored, the following questions must be asked.

- Where will cylinders be stored – indoors or outdoors?
- What kind of gas is being stored?
    - If flammable compressed gas, is the mass over 25 kg?
    - If non-flammable compressed gas, is the mass over 150 kg?

If the mass is less than those corresponding to the respective gas types, the provisions of section 5.6.2.1 through 5.6.2.4 (*Ontario Fire Code*, Division B, Part 5) do not apply. That said, additional storage requirements and hazard controls may be necessary for lesser volumes – especially for non-flammable toxic compressed gases – or for different compressed gases. Consultation may still be required for volumes less than those noted.

Cylinders meeting or exceeding the above noted volumes require special considerations.

The following table is intended to help quickly define the storage requirements of compressed gas cylinders. The work area is assumed to be 10 m^2 (i.e. a 10-by-10-foot room).

Type of Gas	Requirements	Action
Toxic	Any size	Contact the Facility Manager, Health, Safety and Risk Manager and/or Risk Management
Corrosive	Any size	Contact the Facility Manager, Health, Safety and Risk Manager and/or Risk Management
Oxidizing	Not to be stored with incompatible materials	Follow compressed gas guidelines
Non-Flammable.	- Aggregate capacity is more than 150 kg	Contact the Facility Manager, Health, Safety and Risk Manager and/or Risk Management
	- Aggregate capacity is less than 150 kg	Follow compressed gas guidelines

Type of Gas	Requirements	Action
Flammable – heavier than air	- Aggregate capacity is less than 100 kg - Number of cylinders is less than three (3) - Cylinders not located below grade and - Fire compartment has ventilation in accordance with *Ontario Fire Code*	Follow compressed gas guidelines
	- Aggregate capacity exceeds 100 kg - Number of cylinders is more than three (3) - Cylinders intended to be located below grade; or - Fire compartment does not have ventilation in accordance with *Ontario Fire Code* - Is propane	Contact the Facility Manager, Health, Safety and Risk Manager and/or Risk Management
Flammable – lighter than air	- Aggregate capacity is less than 60 m^3 in a building not equipped with sprinklers - Aggregate capacity is less than 170 m^3 in a building equipped with sprinklers	Follow compressed gas guidelines
	- Aggregate capacity is more than 60 m^3 in a building not equipped with sprinklers. - Aggregate capacity is more than 170 m^3 in a building equipped with sprinklers.	Contact the Facility Manager, Health, Safety and Risk Manager and/or Risk Management

Table 1 - Overview of Compressed Gas Storage Requirements

Just-in-time delivery

The University of Ottawa recognizes that certain types of work require auxiliary (i.e. spare) compressed gas cylinders to be available on site. Auxiliary cylinders allow work to continue unimpeded, with limited interruptions to research and normal operations. Nonetheless, compressed gas cylinders are available, in most cases, the next business day from the uOttawa compressed gas supplier. To order a cylinder, follow the ordering protocol established within your faculty or service.

NFPA 55 (*Compressed Gases and Cryogenic Fluids Code*) does not specify limits for the laboratory storage of non-flammable (or inert) gases. Nonetheless, the *National Fire Code of Canada* states that dangerous goods kept within a laboratory should be restricted to the amount required for normal operation. **We highly recommend that you keep as few cylinders as possible within a laboratory workplace.** This practice not only reduces the overall risk of storing auxiliary cylinders, it also frees up additional space in the lab or workshop. In some cases, the user may not require additional control measures if total compressed gas volumes are minimized.

Temperature limitations

Cylinders containing any compressed gas shall be stored in areas where the ambient air temperature does not exceed 52°C (125°F). Compressed gas cylinders, especially those containing flammable gases, must be stored away from sources of ignition, such as open flames, electrical sparks, welding operations, or other heat sources, etc.

Ventilation

When storing cylinders inside a building, the storage location must be dry and suitably ventilated. The ventilation must vent to the exterior and must ensure a minimum of one (1) air change per hour, or have natural ventilation to the outside with non-closable, louvered openings that meet the conditions outlined in section 5.6.2.4(4) of the *Ontario Fire Code*.

Compressed gas compatibility

Compressed gas compatibility must also be taken into consideration. For example, oxidizers cannot be stored in the same area as flammables without specific design requirements. Such requirements may include physical distances or separations (i.e. fire walls). Refer to the compressed gas compatibility chart in Appendix 4.

Physical storage locations

It is possible to safely store compressed gases either inside or outside a building. The following criteria have been summarized from the *Ontario Fire Code* for convenience; please check the *Ontario Fire Code* for information related to your particular application.

Outdoor storage

Cylinders stored outdoors must:

- Be properly segregated, including empty cylinders
- Be supported on a raised concrete (or other non-combustible) platform
- Be locked in an enclosure used exclusively for compressed gas storage
- Be surrounded by a locked fence not less than 1.8 m (6 feet) high. The gate must be able to open fully. The enclosure shall be firmly anchored and built such that climbing it is not feasible. A solid roof structure is required.
- Be stored upright
- Be secured with chains or straps
- Have emergency contact names and numbers prominently displayed or easily available.
- Not be stored in direct sunlight and must be kept below maximum ambient temperature requirements (52̊C / 125°F).
- Not be stored near smoking areas.

Any outdoor compressed gas cylinder storage location must be sufficiently far away from a building opening based to account for its expanded gas capacity. Contact your Facility Manager, local Health, Safety and Risk Manager, and/or the Office of Risk Management for assistance in determining requirements for outdoor storage locations at uOttawa.

Prior to considering an outdoor storage location, be mindful of the climate in Ottawa. The outdoor storage of compressed gas cylinders may also present additional hazards (i.e. snow, freezing rain, and ice) for workers; suitable control measures must be implemented for additional hazards created.

BBQ propane tanks are the most common type of cylinders stored in outdoor enclosures. These enclosures can be found at ARC, DRO and UCU. BBQ tanks and propane cylinders may not be stored indoors. Please refer to Ontario Regulation 211/01 and CSA 149.2-10 for additional information.

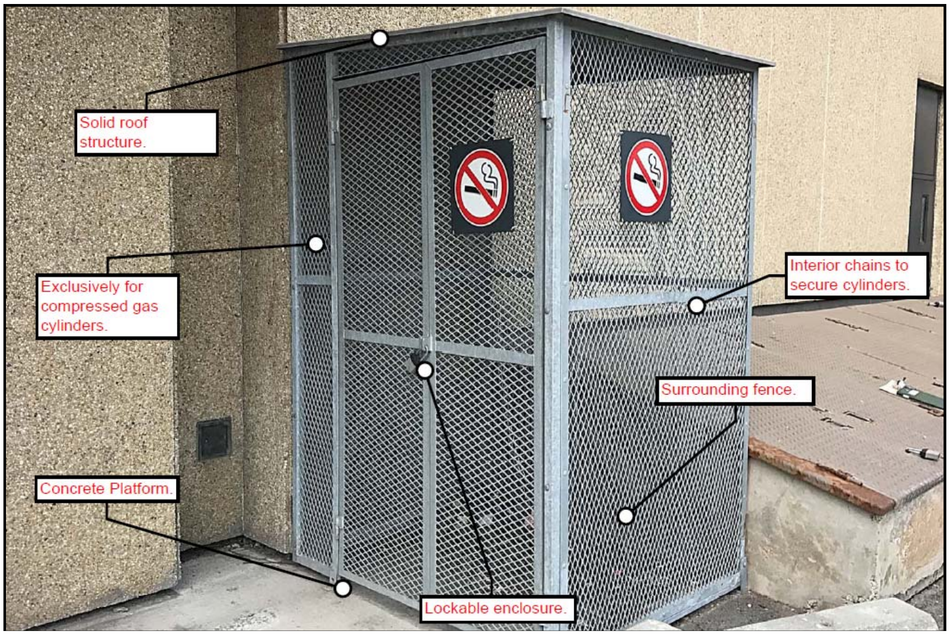

Figure 10 – Example of outdoor compressed gas cylinder storage requirements

Indoor storage

The predominant indoor storage locations of compressed gas cylinders at uOttawa are approved, ground level areas. Cylinders stored indoors must:

- Be properly segregated, including empty cylinders
- Be accessible at all times
- Be stored in a well-ventilated area
- Be located away from ignition sources
- Be located at ground level; storage shall not be permitted below grade
- Be labelled or stored where the emergency contact names and numbers are prominently displayed
- Be stored upright
- Be secured with restraining devices, or inside protective barriers (or railings)

Figure 11 – Example storage at D'Iorio

Indoor storage of flammable gases

There are additional requirements for the indoor storage of compressed, flammable gases. The intention of these requirements is to reduce the likelihood of a fire or explosion, and to limit the extent of damage in the event of an incident. The indoor storage location must:

- Be separated from the rest of the building by a two-hour fire separation.
- Be located on the exterior wall of the building and be provided with explosion venting in accordance with NFPA 68 *Guide for Venting Deflagrations*
- Be equipped with self-closing door latches with a 1.5-hour fire separation
- Be equipped with ventilation in accordance with section 5.6.2.4(4) of the *Ontario Fire Code*.
- Not be equipped with fuel-fired equipment or high-temperature heating elements
- Be used for the sole and exclusive purpose of storing compressed gas cylinders.

Lighter-than-air flammable gases – alternate storage

Compressed gases that are lighter than air may be stored in alternate rooms, provided that they are stored:

- In a building of combustible construction that is not equipped with sprinklers so long as the aggregate capacity of expanded gas is not more than 60 m^3
- In a building of combustible construction that is equipped with sprinklers, so long as the aggregate capacity of expanded gas is not more than 170 m^3
- In a building of non-combustible construction so long as the aggregate capacity of expanded gas is not more than 170 m^3.

Heavier-than-air flammable gases – alternate storage

Flammable heavier-than-air gases may be stored in alternate rooms, provided that they are stored in a fire compartment whose fire-resistance rating is at least 45 minutes and

a. The aggregate capacity does not exceed 100 kg
b. The number of cylinders does not exceed three
c. The cylinders are not located in a basement or below grade; and
d. The fire compartment is equipped with ventilation in accordance with section 5.6.2.4(4) of the *Ontario Fire Code*.

Reactive gases

Gases that react with one another must be stored in separate fire compartments separated by a fire separation whose fire resistance rating is at least one hour. This separation is illustrated in the figure below. Exceptions are also detailed below.

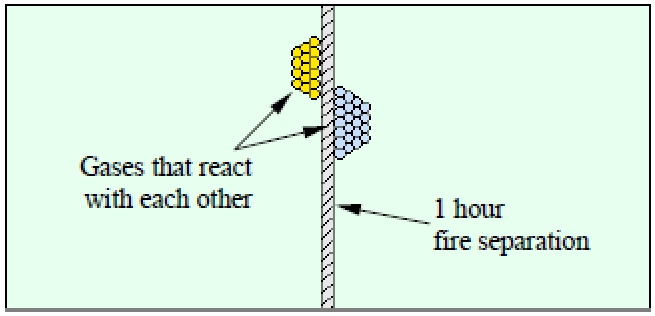

Figure 12 – Physical separation of gases that may react with one another

Lighter-than-air reactive gases

Gases that are lighter than air that may react with one another may be stored in the same fire compartment provided that they are separated by a distance of 7.5 m (25 feet), or by a concrete wall that is at least 2 m (6 feet) high, projecting at least 1 m beyond the cylinders stored in the area. This situation is illustrated in the figure below.

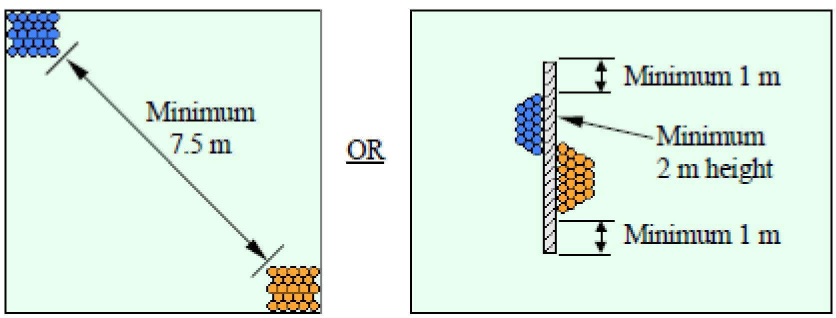

Figure 13 – Physical separation for reactive, lighter-than-air gases.

Heavier-than-air reactive gases

Gases that are heavier than air and which may react with one another may be stored in the same fire compartment, provided that they are separated by a distance of 15 m (50 feet), or by a concrete wall at least 1.5 m (5 feet) high, projecting such that the minimum vapour travel distance of gases is not less than 15 m.

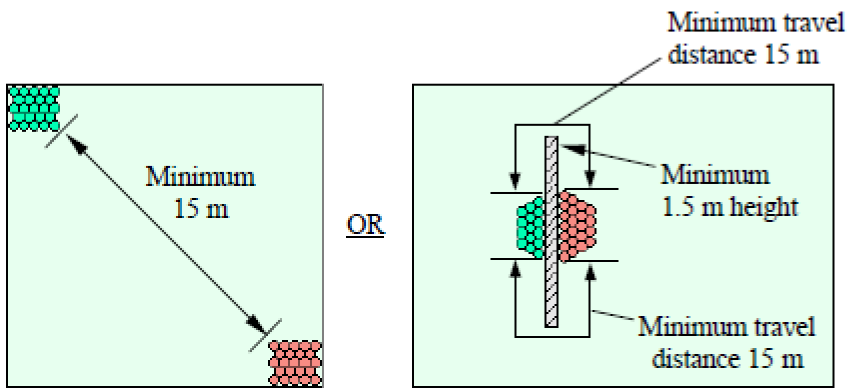

Figure 14 – Physical separation for reactive, heavier than air gases.

TRANSPORTING CYLINDERS

Most compressed gas cylinder transportation will be conducted by the uOttawa compressed gas supplier. Once a compressed gas cylinder arrives at a designated location, such as Science Store, Engineering Shipping/Receiving, or Medicine, the uOttawa employee accepting delivery will check the cylinder (contents, condition, etc.) and will notify the end-user, who will be asked to pick up the cylinder from the loading area as soon as possible. Loading areas at uOttawa are intended to be used for shipping, receiving, and loading; these areas are not intended or equipped to serve as auxiliary, long-term storage locations for compressed gases.

Lab users will take a dedicated cylinder trolley or transport cart to pick up the compressed gas cylinder. It must be loaded on the trolley or cart with the valve cap securely in place and must be secured to the trolley. Under no circumstances are cylinders to be moved any other way (i.e. rolling, carrying, dragging, etc.). We recommend that lab users survey the intended path of travel before moving the cylinder to ensure that the path is free of stationary obstructions and that the cylinder can be moved between classes.

Lecture bottles may be carried by hand.

Figure 15 - Examples of compressed gas cylinder transport carts.

It is safest to use an elevator to transport compressed gas cylinders between floors is the safest practice. However, you must proceed cautiously: a sudden release of compressed gas (i.e. leak or pressure release) could potentially displace enough within the confined space of the elevator to cause harm, albeit in extreme cases. When transporting a cylinder in an elevator, we recommend that users use the buddy system to send the cylinder unescorted to the desired floor and meet the cylinder at its intended location. Persons who see an unaccompanied compressed gas cylinder on the elevator must not enter the elevator until the person transporting the cylinder has removed it.

Special transportation procedures must be followed to transport a compressed gas cylinder between campuses. The easiest and recommended method is to consume the contents of the cylinder at the originating location, have the gas supplier pick up the old cylinder, and then have the gas supplier deliver a new cylinder to the new location. With sufficient notice, the uOttawa compressed gas supplier may be able to transport a cylinder to the new location. **The transportation of compressed gas cylinders in personal vehicles is strictly prohibited.**

Satellite locations

In the case of deliveries to satellite locations that do not have an established shipping/receiving location, contact the Facility Manager(s) and/or Health, Safety and Risk Manager to discuss delivery options

RETURNING COMPRESSED GAS CYLINDERS

Compressed gas cylinders at uOttawa are primarily by each faculty's shipping and receiving services. Re-usable cylinders (i.e. those provided by the uOttawa compressed gas supplier; normally greater than 10 cm diameter) are returned to the supplier as part of the compressed gas service agreement. The prompt return of compressed gas cylinders (either empty or otherwise) not only reduces risk within your lab, it also frees up valuable lab space.

Empty cylinders should be marked as such and returned to the uOttawa compressed gas supplier as soon as possible, or when new cylinders are delivered. Ensure that when ordering compressed gas cylinders that the uOttawa compressed gas supplier can take back the empty cylinder(s) to reduce their storage on campus.

To return a compressed gas cylinder, follow the procedure established within your faculty or service.

Hazardous waste

Smaller cylinders (i.e. lecture bottles) are managed by the uOttawa Hazardous Waste Program. To arrange for special disposal service of lecture bottles, please complete the Hazardous Materials Technical Services Regular Collection Request form. If you have any questions about the hazardous waste program, please contact enviro@uottawa.ca. Under no circumstances are cylinders (or lecture bottles) to be cut, opened, or otherwise willfully compromised.

Smaller, refillable cylinders are available from the uOttawa compressed gas supplier. The refillable cylinders reduce costs associated with disposal and are available in the same volumes as lecture bottles. We encourage users to purchase the refillable cylinders.

EXHAUSTED ENCLOSURES

Depending on the compressed gas in question, an exhausted enclosure (or gas cabinet) may be necessary to ensure the protection of the user(s) and members of the University community. A gas cabinet is a fully enclosed, non-combustible enclosure that provides an isolated environment for compressed gas cylinders in storage or in use. Gas cabinets provide a physical separation for compressed gases and are generally installed to contain toxic, highly flammable, or pyrophoric compressed gases. In these cases, the gas cabinet is vented to allow potential contaminants escaping the compressed gas cylinder to be exhausted from the building. We strongly recommend that systems that store such compressed gases be equipped with an additional alarm system.

Where a gas cabinet is required or is used to provide further separation of hazards, the gas cabinet and associated ducting must be installed and maintained in accordance with established standards. Contact the Health, Safety and Risk Manager and/or the Office of Risk Management for assistance in determining the requirements specific to your workplace.

ATMOSPHERIC SENSORS

Certain substances are acutely toxic and/or may be undetectable. These substances will require additional engineered safeguards to ensure the health and safety of all personnel. Atmospheric sensors can be installed to supplement engineered controls. These sensors are installed near anticipated hazard zone(s) and continuously monitor the surrounding atmosphere.

Atmospheric sensors may be used to warn laboratory users when their environment is:

- Oxygen deficient or oxygen enriched
- Explosive
- Toxic

Figure 16 - Example of an oxygen sensor

Multiple sensors may be tied to a relay point and displayed visually as part of an annunciator panel located outside the hazard zone. As an example, the atmospheric sensors at ARC located throughout the building are relayed to a general panel on the ground level, away from the hazard zones. This type of installation allows first responders to safely investigate the alarm in question prior to entering the hazard zone.

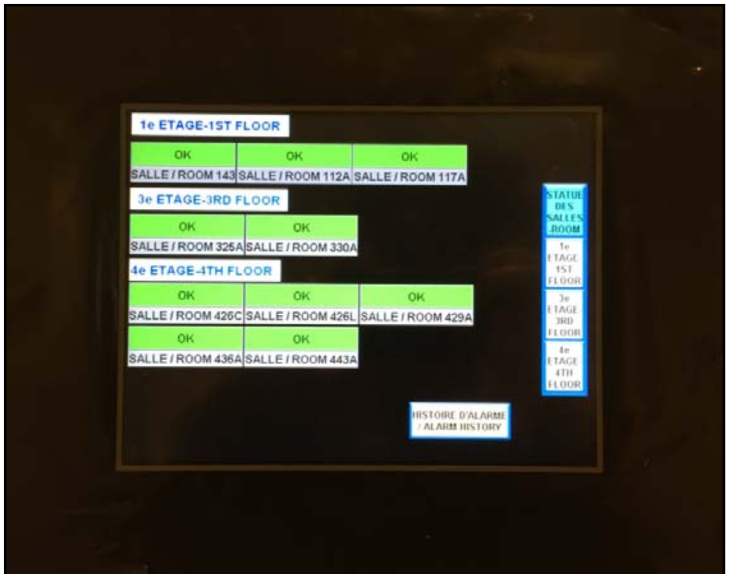

Figure 17 – Annunciator panel as installed at ARC.

In the event of leak of a hazardous compressed gas, the sensor activates locally and at Protection Services (optional service). This action audibly and visually warns personnel nearby of the hazard and then initiates an emergency response from Protection Services. We also recommend that the activation of these sensors also trigger auxiliary action; for example, an increase in room ventilation rates for simple asphyxiants (i.e. nitrogen), or a deactivation of gas flow for toxic materials (i.e. chlorine).

In laboratories with support closets feeding the lab – depending on the compressed gas – multiple atmospheric sensors may be required to monitor both the compressed gas distribution source and the laboratory hazard zone itself.

Sensor recommendations

Each location should be independently assessed to meet atmospheric sensor requirements; however, it is ***generally recommended*** to have atmospheric sensors in locations where there are:

- Explosive hazards
  - Alarms detect flammable gases that are explosive hazards to provide early warning of potentially explosive atmospheres. Many flammable gases cannot be detected by their physical properties; therefore, early warning of hazardous conditions is required. Depending on the sensor, it may be able to detect a reasonably wide spectrum of flammable gases, provided that the alarm is located in keeping with the products' physical properties (i.e. vapour density).
- Toxic atmospheres
  - Toxic gases may have low exposure limits; therefore, it is vital that sensors warn of a potential low-level exposure. Alarms for toxic gases are unique to the substance being monitored.
- Oxygen deficient / oxygen enriched atmospheres
  - An oxygen deficient atmosphere can be determined by calculating the volume of the intended usage location, determining the expanded volume of the cylinder gas, determining air exchanges within the intended usage location, and calculating the total potential displacement of oxygen. If the resulting oxygen concentration is less

than 19.5%, we recommend the installation of an atmospheric sensor. An oxygen-enriched atmosphere can be similarly determined, but with the upper oxygen concentration as 23.0%. Alarms are sole-purpose oxygen (O_2) sensors.

Alarm activation thresholds

Alarm activation thresholds are determined in advance of alarm commissioning and are set conservatively depending on the substance being monitored. Be careful to set the alarm at a level where action is required, but not at a level that would generate false (or nuisance) alarms. Alarms may be dual stage, meaning they can be configured to provide both a low and high activation alarm. The low alarm warns of a potentially hazardous condition and provides time to address the situation, while the high alarm warns of an imminently hazardous condition that requires immediate action. The following table provides general recommendations for alarm activation thresholds.

Alarm	Low Alarm	High Alarm	Details
Flammable	10% LEL	20% LEL	If a single stage alarm is selected, the default activation limit is 20% LEL.
Oxygen Deficient	N/A	$< 19.5\%\ O_2$	N/A
Oxygen Enriched	N/A	$> 23.0\%\ O_2$	N/A
Toxic	One-half (½) the TWA of the substance being monitored.	TWA of the substance being monitored or one-half (½) IDLH in unoccupied environment (i.e. gas cabinet).	If a single stage alarm is selected, the default activation limit is one-half (½) the TWA of substance being monitored. If high alarm activates, compressed gas cylinder must be automatically shut down.

Table 2 - General Recommendations for Alarm Activation Thresholds

None of the above conditions preclude a more conservative alarm activation threshold.

Calibration

Alarms are calibrated at pre-established times; generally, calibrations are conducted quarterly. Facilities (University) manages the sensor calibration activities provided that the PI or lab manager agrees. The calibration technician requires access to the sensor for a few moments at the required frequency (i.e. every three months). Where necessary, such as when access to clean rooms is required, the lab users will need to coordinate with Facilities and/or the calibration technician to arrange for this servicing.

The calibration organization will also provide a sequence of operations for each sensor. The document will detail:

- The location of the alarm
- The type of gas monitored
- The specifications of the alarm (i.e. model, serial number, etc.)

- Alarm activation set points (low/high; where applicable)
- The operational sequence of the specific alarm, including the automated actions initiated by the monitoring system (i.e. contact Protection, duration of alarm, activation / deactivation procedures, etc.).

We recommend that users incorporate the sequence of operations into the sensor emergency plan.

Sensor emergency plans

All sensors require a written emergency plan prior to their commissioning and regardless of whether they are monitored. The plan must be developed by the supervisor / lab manager / principal investigator and must be approved by the faculty's or service's Health, Safety and Risk Manager. The plan must also be provided to the Office of Risk Management and Protection Services. The plan must include the following criteria:

- Substance being monitored (including full name(s) of substance).
- Concentration of substance.
- Exposure limits for the substance (ppm, mg/m^3, etc.), including the time-weighted average (TWA), the short-term exposure limit (STEL) and the ceiling (C), where established.
- Emergency contact information for personnel responsible for the lab. This includes home / cell phone numbers for the following personnel:
    - The principal investigator
    - The lab manager (if applicable)
    - Post-doctoral personnel (if applicable)
    - Senior graduate student(s) (if applicable)

If the alarm is being monitored, Protection Services will notify a designated, competent person of all alarm activations. The designated person will be required to:

- Provide information on the substance being monitored, including implications of the specific situation (human health, infrastructure, environment, etc.).
- Initiate immediate corrective action.
- Advise of any additional hazardous conditions that may be produced as a result of the sensor activation.

Protection Services maintain the privacy of all contact information, which will be used exclusively for emergency situations pertaining to the work areas. Protection Services will not conduct activities on behalf of the lab users. Lab users are responsible for notifying Protection Services when their contact information changes.

Additional items to consider in a sensor emergency plan include:

- Communication plan for lab users.
- Emergency response equipment and training appropriate for the substance(s) in question.
- Conducting regular emergency training exercises with lab personnel / University officials.

An emergency template is provided in the Fixed Atmospheric Sensor guidelines. If you need assistance to write an atmospheric sensor emergency plan, please contact the Health, Safety and Risk Manager and/or the Office of Risk Management.

PERSONAL PROTECTIVE EQUIPMENT

All users of compressed gases are required to wear the personal protective equipment appropriate to the circumstances, which may include but is not limited to:

- Appropriate laboratory clothing
    - Pants and closed footwear
- Lab coat
- Protective eyewear (glasses, goggles, face shield, etc.)
- Gloves
- Respiratory equipment

Additional personal protective equipment may be required, based on a hazard assessment.

Users of personal protective equipment require training and, in the case of some PPE, fit testing, to ensure that the user will be adequately protected. Remember that personal protective equipment does not remove the hazard, and it will only protect the user if worn correctly.

TRAINING

Training on the safe use of compressed gas cylinders is available from the Office of Risk Management via the uOttawa compressed gas supplier. Information on upcoming workshops and registration is available online.

Recommended training topics include:

- Correctly identifying common gas cylinders;
- Identifying hazards (including flammability, asphyxiation, toxic, etc.);
- Understanding the proper conditions under which gases should be stored;
- Introducing safe handling practices;
- Understanding safety features of cylinders and how they operate;
- Safely transporting cylinders inside a building.

APPENDIX 1 – HAZARDS OF COMMONLY USED COMPRESSED GASES

Nitrogen (N_2), Argon (Ar) and Helium (He)
These inert gases are predominantly simple asphyxiants: in sufficient volumes, they will displace oxygen from an area. Typically, these gases do not have any warning properties and are undetectable. Prolonged exposure to low oxygen conditions can lead to unconsciousness and/or death. Initial symptoms of oxygen deprivation include increased respiration, elevated cardiac output and fatigue; additional symptoms may also be present. It is also possible that there are no apparent symptoms prior to unconsciousness. In low concentrations, these gases do not have physiological effects. These gases are non-flammable.

Carbon Dioxide (CO_2)
Much like inert gases, carbon dioxide is a simple asphyxiant and is heavier than air; therefore, it will accumulate in low or confined areas. Unlike the simple asphyxiants above, carbon dioxide has prescribed threshold limit value of 5,000 ppm (TWA) and 30,000 ppm (STEL). CO_2 is a non-flammable gas.

Carbon Monoxide (CO)
Carbon monoxide is a chemical asphyxiant. CO combines more easily with haemoglobin in red blood cells, forming carboxyhaemoglobin, which significantly inhibits the body's ability to transfer oxygen. Carbon monoxide is referred to as "the silent killer" due to its properties; it is not detectable in the atmosphere and has a reasonably low exposure limit of 25 ppm (TWA). CO is a flammable gas.

Oxygen (O_2)
Although not a fuel per se, oxygen is a hazard. Oxygen is an essential part of human respiration; however, as an oxidizer, compressed oxygen encourages combustion – even small increases in atmospheric oxygen content may promote fire or explosion. For this reason, oxidizers must be stored separately from incompatible gases (i.e. flammable gases).

Hydrogen (H_2)
Being a highly flammable gas, hydrogen is readily ignitable. Hydrogen is lighter than air and does not have physical warning properties.

Acetylene (C_2H_2)
The principle hazards of acetylene are fire and explosion. Acetylene is a highly flammable gas and when in a cylinder, it must be stored and used upright because the acetylene is dissolved in an acetone solution. Once the cylinder is opened, gaseous acetylene is dispensed. We strongly discourage the use of acetylene at pressures above 15 psi due to potential for decomposition, which increases the risk of fire and/or explosion.

APPENDIX 2 – COMMON COMPRESSED GAS LEL/UEL

Gas	LEL (%)	UEL (%)	Gas	LEL (%)	UEL (%)
Acetone	2.6%	13.0%	Heptane	1.1%	6.7%
Acetylene	2.5%	100.0%	Hexane	1.2%	7.4%
Acrylonitrile	3.0%	17.0%	Hydrogen	4.0%	75.0%
Allene	1.5%	11.5%	Hydrogen Cyanide	5.6%	40.0%
Ammonia	15.0%	28.0%	Hydrogen Sulfide	4.0%	44.0%
Benzene	1.3%	7.9%	Isobutane	1.8%	8.4%
1,3-Butadiene	2.0%	12.0%	Isobutylene	1.8%	9.6%
Butane	1.8%	8.4%	Isopropanol	2.2%	--
n-Butanol	1.7%	12.0%	Methane	5.0%	15.0%
1-Butene	1.6%	10.0%	Methanol	6.7%	36.0%
Cis-2-Butene	1.7%	9.7%	Methylacetylene	1.7%	11.7%
Trans-2-Butene	1.7%	9.7%	Methyl Bromide	10.0%	15.0%
Butyl Acetate	1.4%	8.0%	3-Methyl-1-Butene	1.5%	9.1%
Carbon Monoxide	12.5%	74.0%	Methyl Cellosolve	2.5%	20.0%
Carbonyl Sulfide	12.0%	29.0%	Methyl Chloride	7.0%	17.4%
Chlorotrifluoroethylene	8.4%	38.7%	Methyl Ethyl Ketone	1.9%	10.0%
Cumene	0.9%	6.5%	Methyl Mercaptan	3.9%	21.8%
Cyanogen	6.6%	32.0%	Methyl Vinyl Ether	2.6%	39.0%
Cyclohexane	1.3%	7.8%	Monoethylamine	3.5%	14.0%
Cyclopropane	2.4%	10.4%	Monomethylamine	4.9%	20.7%
Deuterium	4.9%	75.0%	Nickel Carbonyl	2.0%	--
Diborane	0.8%	88.0%	Pentane	1.4%	7.8%
Dicholorosilane	4.1%	98.8%	Picoline	1.4%	--
Diethylbenzene	0.8%	--	Propane	2.1%	9.5%
1,1-Difluoro-1-Chloroethane	9.0%	14.8%	Propylene	2.4%	11.0%
1,1-Difluoroethane	5.1%	17.1%	Propylene Oxide	2.8%	37.0%
1,1-Difluoroethylene	5.5%	21.3%	Styrene	1.1%	--
Dimethylamine	2.8%	14.4%	Tetrafluoroethylene	4.0%	43.0%
Dimethyl Ether	3.4%	27.0%	Tetrahydrofuran	2.0%	--
2,2-Dimethylpropane	1.4%	7.5%	Toluene	1.2%	7.1%
Ethane	3.0%	12.4%	Trichloroethylene	12.0%	40.0%
Ethanol	3.3%	19.0%	Trimethylamine	2.0%	12.0%
Ethyl Acetate	2.2%	11.0%	Turpentine	0.7%	--
Ethyl Benzene	1.0%	6.7%	Vinyl Acetate	2.6%	--
Ethyl Chloride	3.8%	15.4%	Vinyl Bromide	9.0%	14.0%
Ethylene	2.7%	36.0%	Vinyl Chloride	4.0%	22.0%
Eythelen Oxide	3.6%	100.0%	Vinyl Fluoride	2.6%	21.7%
Gasoline	1.2%	7.1%	Xylene	1.1%	6.6%

Adapted from Matheson Trigas (www.mathersontrigas.com)

APPENDIX 3 – COMMON CGA CONNECTIONS

Gas	CGA Valve Connection
Acetylene	510 - Female thread - Male regulator 300 - Male thread - Female regulator
Air	590 / 346
Ammonia	240 / 660 / 705
Argon	580 / 677 / 680
Boron trichloride	660
Boron trifluoride	330
Butane	510
Carbon dioxide	320
Carbon monoxide	350
Chlorine	660
Ethane	350
Ethylene	350
Ethylene oxide	510
Helium	580 / 677 / 680
Hydrogen	350
Hydrogen chloride	330
Hydrogen sulfide	330
Isobutane	510
Isobutylene	510
Methane	350
Methyl chloride	510
Neon	580
Nitric oxide	660
Nitrogen	580 / 677 / 680
Nitrous oxide	326
Oxygen	540
Sulphur dioxide	660
Sulphur hexafluoride	590
Xenon	580

Adapted from Linde Canada (http://www.lindecanada.com/internet.lg.lg.can/en/images/Linde_Scientific_Catalogue_0315135_94035

APPENDIX 4 – COMPRESSED GAS CYLINDER COMPATIBILITY CHART

Class of Dangerous Good		Explosives	Flammable gases	Non-toxic, non-flammable gases	Toxic gases	Flammable liquids	Flammable solids	Spontaneously combustible	Water sensitive	Oxidizing agent	Organic peroxide	Toxic gases	Radioactive material	Corrosive	Miscellaneous dangerous goods
1	Explosives	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
2.1	Flammable gases	Red	Green	White	Yellow	Yellow	Red	Red	Red	Red	Red	Yellow	Red	Yellow	White
2.2	Non-toxic, non-flammable gases	Red	White	Green	White	Yellow	Yellow	Red	Yellow	Yellow	Red	Yellow	Yellow	Yellow	White
2.3	Toxic gases	Red	Yellow	White	Green	White	Yellow	Red	Yellow	Red	Red	Yellow	Yellow	Yellow	White
3	Flammable liquids	Red	Yellow	Yellow	White	Green	White	Red	Yellow	Red	Red	Yellow	Red	Yellow	White
4.1	Flammable solids	Red	Red	Yellow	Yellow	White	Green	Red	White	Red	Red	White	Red	Yellow	White
4.2	Spontaneously combustible	Red	Red	Red	Red	Red	Red	Green	White	Red	Red	White	Red	Yellow	White
4.3	Water sensitive	Red	Red	Yellow	Yellow	Yellow	White	White	Green	Red	Red	Yellow	Red	Red	White
5.1	Oxidizing agent	Red	Red	Yellow	Red	Red	Red	Red	Red	Green	Red	Yellow	Red	Red	Yellow
5.2	Organic peroxide	Red	Red	Red	Red	Red	Red	Red	Red	Red	Green	Yellow	Red	Red	Yellow
6	Toxic gases	Red	Yellow	Yellow	Yellow	Yellow	White	White	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow
7	Radioactive material	Red	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Yellow	Green	Red	Yellow
8	Corrosive	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Yellow	Red	Green	White
9	Miscellaneous dangerous goods	Red	White	White	White	White	White	White	White	Yellow	Yellow	Yellow	Yellow	White	Green

Red	Incompatible - Do not store together
Yellow	Caution and conditions apply. Avoid storing together
Green	Compatible when stored correctly
White	Can be stored together

*Based on *Storage Compatibility of Dangerous Goods* (Australian National University)

APPENDIX 5 – REFERENCES

- *Regulation 213/07 – Fire Code* made under *Fire Prevention and Protection Act; 1997*; Part 5, section 5.6.
- *Guide to the Ontario Fire Code – 2015*; Service Ontario (available from the Office of Risk Management).
- *Office of the Ontario Fire Marshall – Section 5.6 Compressed Gas Cylinders – Illustrated Commentary* (available from the Office of Risk Management).
- *NFPA 55-13 – Compressed Gases and Cryogenic Fluids Code* (available from the Office of Risk Management).
- *Ontario Occupational Health and Safety Act*
- CSA 149.2-10 – Propane Storage and Handling Code (available from the Office of Risk Management).
- Canadian Centre for Occupational Health and Safety