ENVIRONMENTAL HEALTH AND SAFETY

COMPRESSED GAS SAFETY MANUAL

August 2017

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SECTION A: GENERAL

1. Purpose and Scope

Compressed, liquefied and cryogenic gases are routinely used in laboratories and various other operations at Concordia University. These guidelines are applicable to all faculty, staff, students, and visitors at the University who will be using and handling cylinders of compressed gases.

Compressed and liquefied gases have the potential for creating hazardous working environments. Environmental Health and Safety (EHS) promotes the safe use of gases by offering information on the proper storage, handling, use and disposal of compressed gas cylinders.

2. Compressed Gas Safety

According to WHMIS, compressed gas is a substance that is a gas at normal room temperature and pressure and is contained under pressure, usually in a cylinder. Some compressed gases (e.g. acetylene) are stabilized in the cylinder by dissolving the gas in a liquid or solid matrix. The handling of compressed gases must be considered more hazardous than the handling of liquid and solid materials because of the following properties unique to compressed gases: pressure, low flash points for flammable gases, low boiling points, and no visual and/or odor detection of many hazardous gases.

Compressed and liquefied gases are routinely used in laboratories and various other operations at Concordia University. They have the potential for creating hazardous working environments. Guidelines concerning the use and storage of compressed gas can be found within the following regulations or codes/standards:

- Regulation Respecting Occupational Health and Safety (art. 77-80)
- Regulation Respecting Gas and Public Safety (art. 26)
- Propane Storage and Handling Code, CSA B149.2
- NFPA 45 Standards on Fire Protection for Laboratories Using Chemicals
- NFPA 55 Compressed Gases and Cryogenic Fluids Code
- NFPA 58 Liquefied Petroleum Gas Code
- National Fire Code of Canada (including Quebec modifications)
- Québec - Code de la sécurité routière : Règlement sur le transport des matières dangereuses
- Transport Canada – Transportation of Dangerous Goods Regulations (TGDR)
- Selection and Use of Cylinders, Spheres, Tubes and other Containers for the Transportation of Dangerous Goods Class 2, CSA B340

Contact EHS for a hazard assessment PRIOR to moving or setting up any compressed gas cylinder.

3. Responsibilities

3.1. PI/Laboratory Supervisor Responsibility

Supervisors are responsible for:

- Ensuring staff, students and visitors that fall under their direct line of supervision receive appropriate training specific to the compressed gases they are handling and using;
- Contact EHS office for a hazard assessment PRIOR to moving or setting up any compressed gas cylinder;
- Ensuring that staff, students and visitors that fall under their direct line of supervision are made aware of, understand and adhere to the guidelines for compressed gases;
- Ensuring that compressed gases are used only for their intended purpose and in accordance with the defined procedures and rules;
- Ensuring that applicable Safety Data Sheets (SDS), or other relevant literature is made readily available;
- Providing staff, students and visitors that fall under their direct line of supervision with appropriate personal protective equipment (PPE);
- Assuring that the quantity of compressed and liquefied gases does not exceed maximum allowable quantities;
- Reporting any injury or near-miss incident involving the use of compressed gases, including accidental releases and exposure, to EHS as per the VPS-42 policy on injury reporting and investigation.

3.2. Students, Staff and Visitors

Staff, students and visitors are responsible for:

- Conducting all work with compressed gases in accordance with these guidelines, applicable laboratory standard operating procedures (SOPs), and/or other defined safety rules and regulations;
- Wearing appropriate PPE when handling compressed gases;
- Notifying their Supervisor and EHS of any injuries or near-miss incidents involving the use of compressed gases, including accidental releases and exposure.

3.3. Environmental Health and Safety (EHS)

EHS is responsible for:

- Preparing guidelines for the safe use of compressed gases;
- Review compressed gases installations prior starting of experiment
- Providing hazardous waste disposal services;
- Responding and investigating injuries or near-miss incidents involving the use of compressed gases, including accidental releases and exposure;

- Overseeing regulatory compliance concerning the use, storage and handling of compressed gases.

4. Types of Compressed Gas

Liquefied gases: any gases that fill the space above the liquid at the vapor pressure of the substance at that temperature. As gas is removed from the cylinder, liquid evaporates to replace it, keeping the pressure in the cylinder constant, so long as liquid is present.

Common examples include: ammonia, chlorine, propane, nitrous oxide and carbon dioxide.

Non-liquefied gases: also known as compressed, pressurized or permanent gases. These gases do not become liquid when they are compressed at room temperature, even at very high pressures.

Common examples include: oxygen, nitrogen, helium and argon.

Dissolved gases: gases which are dissolved in a liquid solvent at pressures of 29 psi gauge or higher. Acetylene is the only commonly dissolved gas. Acetylene is chemically very unstable. Even at atmospheric pressure, acetylene gas can explode. Acetylene cylinders are fully packed with inert, porous filler. The filler is saturated with acetone or other suitable solvent and the acetylene, when added to the tank, dissolves into the acetone.

Cryogenic gases: gases that have been cooled to a liquid state below 150 Kelvin (-123°C). They are extremely cold and can produce intense burns. They can be non-flammable, flammable or oxidizing.

Common examples include: liquid nitrogen, liquid helium and liquid argon.

5. Hazards Associated with Compressed Gases

Since gases are invisible their presence is not readily identifiable and they have the potential to asphyxiate, burn or harm users. These hazards can be avoided if users follow information contained in the Safety Data Sheet (SDS), reference document or other similar technical information available from compressed gas manufacturers or distributors.

5.1. Pressure

All compressed gases are hazardous due to the high pressure inside the cylinder. Internal cylinder pressures may go as high as 6,000 lbs per square inch (psi) but are typically between 2,000 to 3,000 psi. To better understand how high the pressure of compressed gases actually is, a car tire pressure is usually between 35-45 psi. Damage to the cylinder valve can result in a rapid release of the high pressure gas propelling the cylinder as a rocket, causing permanent personal injury and damage to property.

5.2. Fire and Explosion

Flammable gases such as acetylene, propane and hydrogen can burn or explode under certain conditions. If flammable gases are allowed to accumulate until their concentration is between their defined Lower Explosion Limit (LEL) and Upper Explosion Limit (UEL), an explosion may occur if there is an ignition source present. Figure 5.2.1 shows the flammability range of some typical gases.

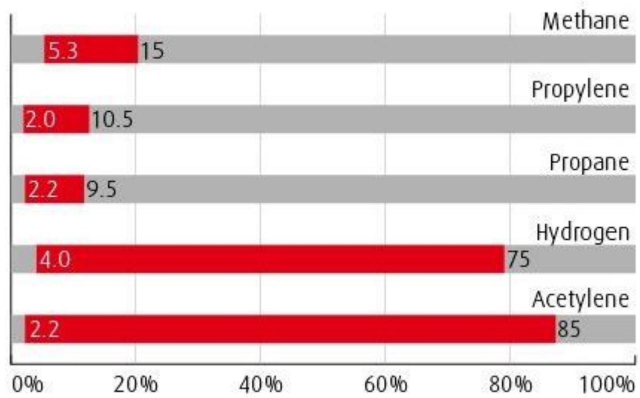


Figure 5.2.1: Flammability ranges of common gases.
The concentration range where fire risk exists is shown in red. (ref: www.aga.se)

Every flammable compressed cylinders, lines and equipment set-ups must be bonded and grounded. Refer to **Appendix I** for the list of Common Flammable Gases.

5.3. Health Hazards

Many gases are toxic and can cause serious health problems dependent upon the specific gas and its concentration, length of exposure, and route of entry. Health symptoms of exposure to gases can be immediate or delayed. Refer to **Appendix I** for a list of Common or Highly Toxic Gases.

Proper ventilation is always required when working with toxic gases (e.g. fume hood, ventilated gas cabinet). Permanent gas detectors may also be required, or the need to carry personal gas detectors for leak detection. Gas detectors and monitors must be calibrated and maintained as per the manufacturer's operating instructions. Records of this maintenance must be maintained. Contact EHS for assistance in conducting a risk assessment to determine if a gas detection system is required and what type of gas detection system must be used.

5.4. Chemical Burns

Some compressed gases are corrosive. They can burn or damage skin on contact, burn the eyes or lungs if inhaled, as well as attack and corrode metals.

Corrosive gas manipulations may pose an inhalation hazard and should therefore be done in a chemical fume hood in order to control exposure. In the absence of a local exhaust system, users **must** wear appropriate respiratory protection. Anyone required to wear respiratory protection must be trained and fit-tested **before starting to use protection respirator**. Contact EHS for information regarding our Respiratory Protection Program.

Other precautions include:

- protecting all exposed skin surfaces from contact with corrosive gases;
- ensuring that regulators and valves of gases are closed when the cylinder(s) are not in use and properly purged and cleaned with dry air or inert gas such as nitrogen;
- using a neutralization trap to catch any excess corrosive gas.

5.5. Asphyxiation

Asphyxiation is the main hazard associated with inert gases such as helium, argon, and nitrogen. If these gases escape undetected into the air of the work environment, they can quickly reduce the oxygen levels below concentrations necessary to support consciousness (Table 5.5.1).

Table 5.5.1: Oxygen deficiency symptoms

Oxygen content (vol%)	Effects and symptoms (at atmospheric pressure)
11-14	Diminution of physical and intellectual performance without person's knowledge
8-11	Possibility of fainting after a short period without prior warning
6-8	Fainting within a few minutes, resuscitation possible if carried out immediately
0-6	Fainting almost immediate, death ensues, brain damage if rescued

Indoor areas where large amounts of inert gas cylinders are installed need to be continuously monitored with an atmosphere monitoring system (Figure 5.5.1). The system monitors oxygen levels and provides an audible and/or visual alarm (red light) when the oxygen level drops below 19.5%. The atmosphere monitoring system must be located inside the area **and** immediately outside of all entrances to the area (preventing entrance in room if oxygen concentration is too low). If you have large amounts of inert gas cylinders in your area, contact EHS for a risk assessment and determination of what type of atmosphere monitoring system is required, if any.

Figure 5.5.1: Fixed or portable oxygen monitoring alarm devices.
(ref: www.directindustry.com; www.pureairemonitoring.com; www.pce-instruments.com)

5.6. Physical Hazards

Compressed gas cylinders are large, heavy and awkward to handle. They are usually made of steel, aluminum or a type of composite. Improper handling, or not properly securing cylinders while in use, can cause cylinders to fall causing injury to workers. A common industrial size high pressure cylinder of 5 ft. in height weighs an average of 65 kg (140 lbs).

Gas cylinders are available in a variety of sizes to suit a particular need or application. Common cylinder sizes are presented in Figure 5.6.1 with their respective internal amounts of gas (cubic feet).

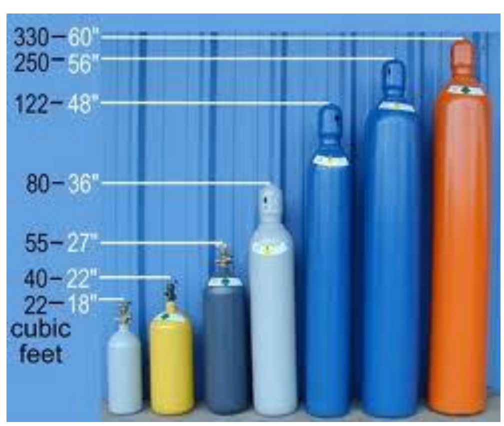


Figure 5.6.1: Internal amount of gas (cubic feet) in cylinders.
(ref: ls1tech.com)

The vast majority of gases are heavier than air and will therefore accumulate and concentrate in lower areas, for example: basement, sewers or pits. Only a handful of gases are lighter than air, refer to Table 5.6.1. for examples.

Table 5.6.1: Density (vs air) of lighter than air gases

Gas	Density (vs air)
Hydrogen (H_2)	0.07
Helium (He)	0.14
Methane (CH_4)	0.55
Ammonia (NH_3)	0.59
Water Vapor	0.62
Natural Gas (typical)	0.60 – 0.70
Neon (Ne)	0.70
Acetylene	0.91
Carbon Monoxide (CO)	0.97
Nitrogen (N_2)	0.97
Ethylene	0.97

5.7. Cylinder Damage

Cylinders can be damaged in several ways:

Fire and heat: cause the cylinder to expand and contract with pressure changes. Cylinders are designed, to some degree, to handle such pressure changes, however, cylinders made of aluminum are affected by heat more than cylinders made of steel and can rupture.

Arc damage: from welding operations can result in a heat rise sufficient enough to cause arc damage to the cylinder causing a pressure explosion or the pressure relief device to activate. Arc burns are easily recognized by a spot, or series of spots, of freshly burned paint, exposing bare metal

Dents: occur from impact or mishandling, which can weaken the walls of the cylinder making it more susceptible to rupture.

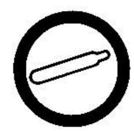
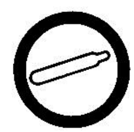
Figure 5.7.1: Cylinders showing arc and corrosion damage (ref: www.engineeredinspection.com;www.nautinst.org)

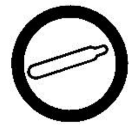
Corrosion: from moisture, salt, corrosives, and other materials can corrode cylinders, especially the bottom of the cylinder where stored on the ground. Cylinders should be stored in a dry location, and on a concrete surface.

5.8. Classes of Compressed Gases

The different classes of compressed gases are described in Table 5.8.1. All compressed gas classes will be represented by the cylinder WHMIS pictogram (1988 or 2015), along with the pictogram corresponding to their specific danger(s).

Table 5.8.1: Classes of compressed gases with respective WHMIS classification

Classes	Description	WHMIS 2015	WHMIS 1988	Examples
Gases under pressure	Include compressed gases, liquefied gases, dissolved gases and refrigerated liquefied gases.			Any gas compressed in a cylinder
Inert Gases	Gases that do not react with other materials at ordinary temperature and pressure. They are non-flammable and non-toxic.			Nitrogen Helium Argon
Flammable Gases	Gases that have the ability to ignite (catch fire) easily and the main hazards are fire or explosion.			Hydrogen Propane Acetylene
Oxidizing Gases	Gases which may cause or intensify a fire or cause a fire or explosion.			Oxygen Nitrous oxide Chlorine
Corrosive Gases	Gases that may be corrosive (chemically damage or destroy) to metals, cause severe skin burns and serious eye damage/eye irritation.			Ammonia Hydrogen chloride Hydrogen fluoride
Pyrophoric Gases	Gases that can catch fire very quickly (spontaneously) if exposed to temperatures at or below 54°C.			Silane Phosphine Arsine
Simple Asphyxiants	Gases that are non- or minimally toxic, but may displace oxygen in air and cause rapid suffocation.	**No pictogram**	**No pictogram**	Nitrogen Argon Helium

Toxic Gases	Gases that are fatal, toxic or harmful if inhaled.			Carbon monoxide Chlorine Hydrogen sulfide
Cryogenic Gases	Gases with a boiling point of -90°C at atmospheric pressure and are extremely cold and can produce intense burns.			Liquid nitrogen Liquid helium Liquid argon

6. Hazards of Commonly Used Gases

6.1. Nitrogen (N_2), Argon (Ar) and Helium (He)

These gases can cause rapid asphyxiation and death if released in a confined area. Nitrogen and helium are lighter than air (refer to Table 5.6.1), but argon is heavier (density of 1.38).

Their main characteristics are:

- odourless;
- no warning signs before unconsciousness occurs;
- causes instant unconsciousness may occur followed by death at high concentrations;
- does not burn;
- inert.

Oxygen deficiency monitors (Figure 5.5.1) should be used whenever large amounts of these gases are present in a specific work area.

6.2. Carbon Dioxide (CO_2)

Carbon dioxide is primarily an asphyxiant, but also has mild toxic properties. The occupational exposure limits (OELs) for carbon dioxide are:

- 5,000 ppm (0.5%) by volume - calculated as an 8h time-weighted average concentration in air.
- 15,000 ppm (1.5%) for a 15 minute period.

Its main characteristics are:

- can cause the nose to sting;
- much heavier than air;
- will collect in ducts, drains and low lying areas
- causes instant unconsciousness may occur followed by death at high concentrations.

For these reasons, **a carbon dioxide monitor should be used when there is a risk of CO_2 exposure**, rather than an oxygen deficiency monitor.

Table 6.2.1: Carbon dioxide exposure symptoms

Carbon dioxide content (%vol)	Effects and symptoms
2-4	Slight feeling of suffocation and an increased breathing rate
5	Headaches, dizziness and sweating can occur after 30 minutes of exposure
5-9	Breathing becomes laboured, judgement impaired
5-9	Breathing becomes laboured, judgement impaired
9	Fatal after approximately four hours of exposure
12	Immediate unconsciousness; fatality may occur after a few minutes

6.3. Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, tasteless gas and is highly toxic to humans and animals. Carbon monoxide combines with hemoglobin to produce carboxy-hemoglobin. This prevents hemoglobin from carrying oxygen to the tissues, effectively reducing the oxygen-carrying capacity of the blood, leading to hypoxia.

Common symptoms of carbon monoxide poisoning include: headaches, nausea, vomiting, dizziness, lethargy, and the feeling of weakness.

This odourless gas is also produced as a by-product of combustion when common fuel-burning appliances and equipment that use natural gas, oil, wood, propane and kerosene, don’t get enough air to burn up completely.

The acute effects produced by carbon monoxide in relation to ambient concentration in parts per million are listed below (Table 6.3.1).

The installation of permanent CO gas detectors or carrying personal sensing devices for leak detection is required wherever compressed CO gas is being used or may be generated.

Table 6.3.1: Carbon monoxide exposure symptoms

Concentration	Symptoms
35 ppm (0.0035%)	Headache and dizziness within six to eight hours of constant exposure
100 ppm (0.01%)	Slight headache within two to three hours of exposure
200 ppm (0.02%)	Slight headache within two to three hours; loss of judgment
400 ppm (0.04%)	Frontal lobe headache within one to two hours
800 ppm (0.08%)	Dizziness, nausea, and convulsions within 45 minutes; numbness within 2 hours
1,600 ppm (0.16%)	Headache, increased heart rate, dizziness, and nausea within 20 minutes; death in less than 2 hours
3,200 ppm (0.32%)	Headache, dizziness and nausea within five to ten minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache and dizziness within one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes.
12,800 ppm (1.28%)	Unconsciousness after 2–3 breaths. Death in less than three minutes.

6.4. Hydrogen (H_2)

Hydrogen is a flammable gas. A mixture of hydrogen and oxygen or air will explode in a confined area in the presence of a spark. A hydrogen flame is virtually invisible in a well-lighted area.

Its main characteristics are:

- odourless;
- much lighter than air;
- will collect at the highest point in any enclosed space unless there is a high level of ventilation;
- fire and explosion hazard;
- very low ignition energy.

6.5. Oxygen (O_2) and Other Oxidizing Gases

Oxidizing gases are non-flammable, but in the presence of an ignition source and fuel can support and vigorously accelerate combustion. Oxygen enrichment of the air, even by a few percentages, considerably increases the intensity of fire. Sparks which would normally be regarded as harmless can cause fire and materials which do not normally burn in air such as fireproofing materials, burn vigorously in oxygen-enriched air.

Examples of common oxidizing gases include:

- Oxygen;
- Nitrous oxide (N_2O);
- Chlorine;
- Fluorine.

Cylinders that contain oxidizers whether full or empty must be stored away from fuel gas cylinders (e.g. propane, hydrogen, etc.) at a minimum of 20 feet. In the event they are stored together, they must be separated by a wall that is 5 feet high with a fire resistance barrier of at least 30 minutes. If the cylinders are stored indoors, the area must be fully equipped with sprinklers.

Oxygen is an oxidizer gas; it strongly supports and accelerates a flame or fire. Its main characteristics are:

- odourless;
- generally considered non-toxic at climatic pressure;
- will not burn, but supports and accelerates combustion;
- materials not normally considered combustible, but may be ignited by sparks in oxygen rich atmospheres;
- no oil, grease or lubricants should come into contact with oxygen.

6.6. Acetylene

Acetylene is an extremely flammable gas. It is different from other flammable gases because it is unstable. Under certain conditions, it can decompose explosively into its individual elements, carbon and hydrogen.

Its main characteristics are:

- distinctive garlic smell, even at very small concentrations;
- fire and explosion hazards are greater than LPG, but it is slightly lighter than air and less likely to collect in ducts and drains;
- requires minimal energy to ignite in air or oxygen.

A flashback can occur if there is a flammable mixture of fuel gas, and oxygen in the hoses when the torch is lit. A flashback is the reversing of the flame such that it travels through the line back into the pressure regulator or cylinder. If it is not stopped, the flame will ignite the mixture and will travel backwards from the torch, along the hoses, through the regulator and into the cylinder. A flashback can trigger decomposition of the acetylene in the fuel hose, in the regulator, and in the cylinder itself. Flashback arresters must be installed on the pressure regulators on both the acetylene cylinder and the oxygen cylinder with check valves for every 4.5 m (15 ft.) of hose used. In the event a fire propagates through the hose, the arrester will stop the fire from reaching the tank. Typical oxy-acetylene gas welding equipment is shown in Figure 6.6.1.

Under certain conditions, acetylene forms explosive compounds with copper, silver and mercury. Therefore, do not use copper fittings or tubing on acetylene tanks. Contact between acetylene and these metals, and their salts, must be avoided. It also reacts violently with fluorine and other halogens.

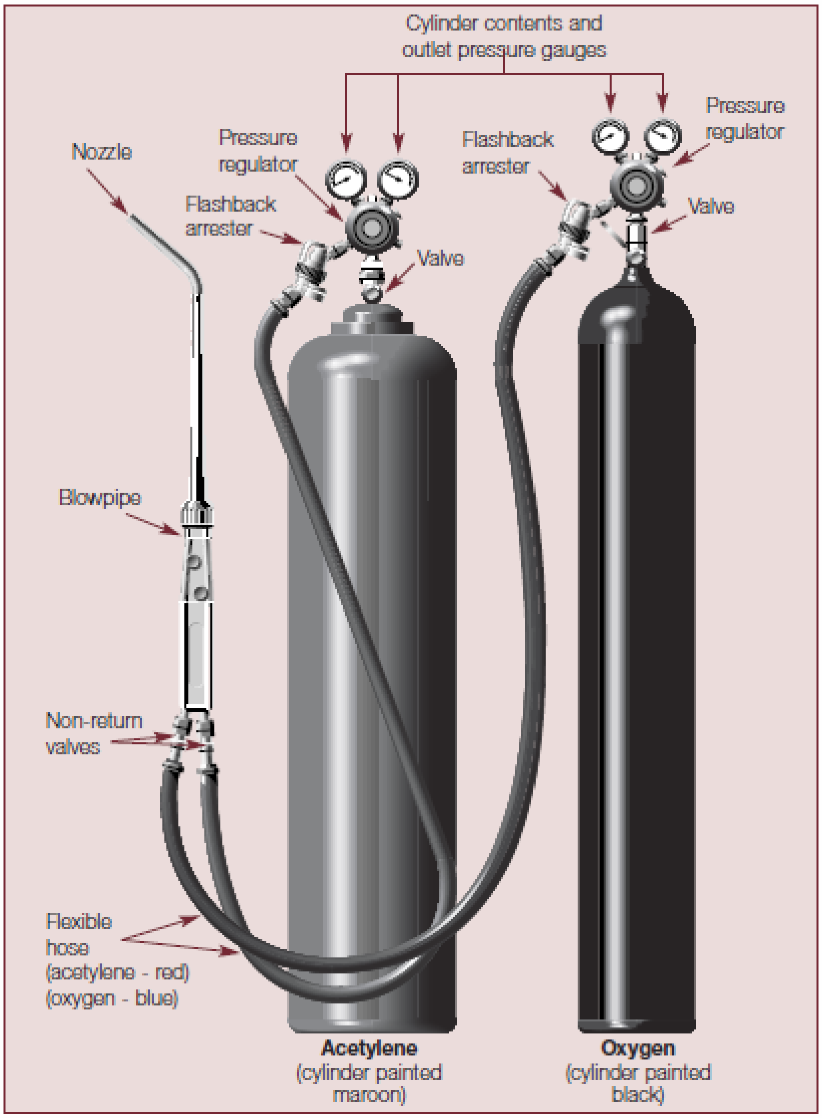


Figure 6.6.1: Typical equipment used in oxy-acetylene gas welding.
(ref: HSE: Take care with acetylene)

6.7. Refrigerant Gases

Refrigerant gases are commercial gases used as a heat exchange material. Some examples of early refrigerant gases/liquids are sulfur dioxide (SO_2) and ammonia (NH_3). Both are very noxious, irritating substances. They are no longer used in domestic refrigerators, though ammonia continues to be popular in large industrial applications.

Most of the early refrigerant gases that were toxic, corrosive, or flammable, have been replaced by halocarbons, which are halogenated substances that contain bromine, chlorine and fluorine. In practice, they are chlorofluorocarbons (CFCs), bromofluorocarbons (halons), hydrochlorofluorocarbons (HCFCs), methyl bromide (CH_3Br), carbon tetrachloride (CCl_4) and methyl chloroform (1, 1, 1-trichloroethane).

Refrigerant gases have ideal thermodynamic properties for use as refrigerants. Often referred as Freon (trade name), these refrigerant gases are typically non-flammable, chemically stable and low in toxicity. The refrigeration industry has adopted a system of identifying refrigerant chemicals by assigning them "R" numbers. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) created the system to help identify these gases without having to deal with their proper chemical names. Refer to **Appendix II** for a list of typical refrigerant gas names**.**

Although halocarbon refrigerant gases have low toxicity, at very high concentrations they can displace oxygen. As more oxygen is displaced, continued exposure can lead to asphyxiation (suffocation), coma, central nervous system depression, and—eventually—death.

Figure 6.7.1: Typical refrigerant gas cylinders (ref: www.everwellparts.com;www.md-technical.com)

Furthermore, the stability of most of these refrigerant gases and their chlorine content have linked them to the depletion of the stratospheric ozone layer and to an increase in the earth's temperature.

An international agreement was reached in September 1987 to phase out all fully halogenated CFCs by the year 2000, and to regularly review the use of transitional ozone-safe alternative refrigerants, which are scheduled to be replaced no later than 2040. Under the Montreal Protocol on Substances that Deplete the Ozone Layer, Canada, the United States and some 55 other nations agreed to restrict the future availability of fully halogenated CFCs. The controlled substances affected by this agreement include CFCs 11, 12, 113, 114 and 115, and Halons 1211, 1301 and 2402.

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are considered the replacements for CFCs in refrigeration and air conditioning systems. HFCs do not contain chlorine, and their potential for depleting the ozone layer is significantly less than that of CFCs.

Regulations concerning halogenated refrigeration gases can be found at:

[Quebec – Regulation respecting halocarbons]

[Canada – Federal halocarbon regulations]

6.8. Gas Duster Aerosols

Gas duster, also known as canned air or compressed air, is a product used for cleaning electronic equipment, and other sensitive devices that cannot be cleaned using water. Despite the name "canned air", the cans actually contain gases that are much easier to compress into liquids, such as 1,1-difluoroethane, 1,1,1-trifluoroethane, or 1,1,1,2-tetrafluoroethane (Figure 6.8.1).

1,1-Difluoroethane (DFE) (HFC-152a) is the alternative fluorocarbons most widely used as a component of gas dusters and similar aerosol products. Although it is recognized that the toxicity of DFE is extremely low, some cases of fatal poisoning by DFE inhalation have been reported. Intentional abuse of DFE has been noted to cause transient symptoms such as light-headedness, euphoria, irregular heartbeat with a strange sensation in the chest, heart thumping, apprehension, feelings of fainting and dizziness, tremors, pulmonary irritation, and coma.

Figure 6.8.1: Typical gas duster aerosols.
(ref: www.instructables.com; www.staples.ca; www.amazon.com)

Due to DFE being a refrigerant gas when the liquid is released from the can it boils at a very low temperature, rapidly cooling any surface it touches. The refrigerant gas can cause frostbite when coming into direct contact with the skin. Furthermore, DFE is classified as a flammable gas. The fire decomposition by-products include hydrofluoric acid and possibly carbonyl fluoride.

6.9. Cryogenic Gases

Cryogenic gases are usually shipped by manufacturers in liquid cylinders (Figure 6.9.1). They are pressurized containers specifically designed for cryogenic liquids. This type of container has valves for filling and dispensing the cryogenic liquid, and a pressure-control valve with a frangible (bursting) disk as backup protection.

Figure 6.9.1: Liquid cylinder (Dewar) with pressure-control relief valve exhausting excess gas (ref: Concordia University)

There are particular hazards and risks associated with working with cryogenic gases. Users should assess the risks and take suitable precautions for their personal safety and the safety of those around them. Cryogens Guidelines can be found on the EHS website.

Cryogenic liquids and their boil-off gases rapidly freeze human tissue and cause embrittlement of many common materials. Below are a few of the cryogens found at the university:

- Liquid Helium: -269°C
- Liquid Nitrogen: -196°C
- Liquid Argon: -186°C
- Liquid Oxygen: -183°C
- Dry Ice (CO_2): -78°C

6.9.1. Use of Cryogens

The following information applies to the use and handling of cryogenics:

- use appropriate personal protective equipment, including insulated gloves, lab coat and eye protection (goggles and a face shield) during any transfer of cryogenic liquid;

- use only equipment, valves and containers designed for the intended product, service pressure and temperature;
- inspect containers for loss of insulating vacuum. If the outside jacket on a container is cold or has frost spots, some vacuum has been lost. Empty the contents into another cryogenic container and remove the damaged unit from service;
- transfer operations involving open cryogenic containers, such as Dewars. The transfer must be conducted slowly to minimize boiling and splashing of the cryogenic fluid;
- ice or other foreign matter should not be allowed to accumulate beneath the vaporizer or the tank;
- excessive ice buildup could result in the discharge of excessively cold gas or structural damage to the cryogenic container or surroundings;
- all cryogenic systems, including piping, must be equipped with pressure relief devices to prevent excessive pressure build-up. Pressure reliefs must be directed to a safe location. Do not tamper with pressure relief valves or the settings for the valves;
- hot air, steam, or hot water should be used to thaw frozen equipment. Exception: Do not use water to thaw liquid helium equipment.

6.9.2. Cryogen Hazards

The main hazards related to using low-temperature liquefied gases are:

- cold burns, frostbite and hypothermia from the intense cold;
- asphyxiation in oxygen-deficient atmospheres;
- fire in oxygen-enriched; air
- liquid oxygen condensation;
- over pressurization from the large volume expansion of the liquid;

6.9.2.1. Cold Burns, Frostbite and Hypothermia

It is essential that protective clothing (such as cryogenic gloves and goggles) are worn where there is a risk of contact with the cryogenic liquid or cryogenically-cooled materials. Avoid direct skin contact with cryogenic liquids or compressed gases escaping from the cylinder as contact with these extremely cold surfaces can cause cold burns and frostbite, and low air temperatures can cause hypothermia or provoke asthma. In the event of skin contact with a cryogenic liquid, do not rub skin; place the affected part of the body in a warm water bath (not to exceed 40°C). If a burn is significant, seek medical attention.

6.9.2.2. Asphyxiation – Liquid Nitrogen, Argon and Helium

Releasing liquid nitrogen, argon or helium may produce local oxygen-deficient conditions, which will result in asphyxiation. Release may be caused by a leak, a spill, or simply during the process in which the gas is used. A cryogenic liquid expands by orders of magnitude upon vaporization (Table 6.9.2.2.1). For example, one liter of liquid nitrogen becomes 24.6 cubic feet of nitrogen gas. Oxygen deficiency monitors shall be used whenever the risk of asphyxiation is present.

Table 6.9.2.2.1: Volume expansion of cryogenic liquids

Cryogenic liquid	Ratio Gas / Liquid Volume
Oxygen	842
Nitrogen	682
Argon	822
Helium	738
Carbon Dioxide (solid)	845

6.9.2.3. Fire Hazards from Oxygen-Enriched Conditions

If the environment is enriched with oxygen, the potential likelihood and intensity of fire is increased. Many materials which are not usually combustible in air will burn fiercely in an oxygen-enriched environment. The required energy to ignite these materials will be reduced; the higher the oxygen concentration in the air, the lower ignition energy required. These materials can be ignited with a level of energy that would not be considered sufficient in normal atmospheric air. Some materials may auto-ignite in oxygen-rich atmospheres.

6.9.2.4. Liquid Oxygen Condensation

Liquid nitrogen and helium are cold enough to condense oxygen from the air, leading to a risk of combustion. Vessels should be insulated to minimize this risk. It is recommended to exclude combustible materials.

6.9.2.5. Over Pressurization

Cryogenic systems must be designed with adequate pressure relief measures such as valves. This prevents a dangerous build-up of pressure as the liquid condenses into gas in a sealed system. Vessels and piping shall sustain at least 150 percent of maximum pressure relief.

6.9.3. Cryogens and Magnetic Fields

Superconducting magnets use liquid nitrogen and liquid helium coolants. Aside for the risks associated with the magnetic field, there are additional hazards associated with the cryogenic liquids.

A superconducting magnet can lose super conductivity due to damage, physical shock or other reasons. When this occurs, the magnet's coil heat up and the cryogenic liquid that surrounds it(helium or nitrogen) boils off rapidly into the surrounding space – this is referred to as quenching (loss of the magnetic field).

Low-oxygen alarms are required in rooms where instruments with superconducting magnets are located. In the event of a quench, all personnel should leave the area and not return until oxygen levels return to normal.

6.10. Liquefied Petroleum Gases (LPG)

6.10.1. Definition and Associated Hazards

A liquefied petroleum gas (LPG) is a flammable mixture of hydrocarbon gases (butane, iso-butane, propane, propylene, butylene and other hydrocarbons of low molecular weight refined from petroleum) within a pressurized container which exists both as a liquid and a gas at 20°C (68°F). LPGs are mainly used as a fuel in heating appliances and vehicles.

It is important not to store LPG cylinders inside flammable liquid storage cabinets. Storage and usage of LPG is covered in NFPA 58, *Liquefied Petroleum Gas Code*, while storage of flammable liquids is covered in NFPA 30, *Flammable and Combustible Liquids Code*.

LPGs are not flammable liquids; they are flammable liquefied gases.

This distinction is very important as flammable liquids and flammable gases have different storage conditions. A flammable liquid storage cabinet is designed to protect flammable liquid containers from fire for 10 minutes to allow for safe evacuation. **LPGs usage is severely restricted in buildings because of their rapid evolution of gas from leaks**, which is more significant than the evolution of vapours from flammable liquids.

LPGs are usually denser than ambient air and will flow to the ground like a liquid when there is little air movement. As a result, LPGs may accumulate in lower areas (e.g. basements, pits) and will remain there for long periods of time if they cannot flow away. This leads to potential ignitable concentrations to be formed.

Most LPGs are odorless, but LPGs such as propane and butane, are odorized with small amounts of organosulfur compounds allowing leaks to be detected quickly. Ethyl mercaptan, tetrahydrothiophene, and ethyl methyl sulfide are some of the organosulfur compounds employed in this application.

6.10.2. LPG Laboratory Use

The *National Fire Code of Canada (including Quebec modifications)* and the *CAN/CSA-B149.2 Propane Storage and Handling Code* prohibit the use and storage of LPG cylinders within buildings. However, NFPA 58 allows certain amounts of LPG to be used depending on the building classification.

If a LPG is used for research purposes in university laboratories, the following rules shall apply:

- the cylinder must be “in use” (see section 11.1);
- the cylinder must be at least 20 feet away from cylinders containing oxidizing gases;
- a leak test shall be performed every year, and after replacing a cylinder, and/or any modification of the installation;
- if the LPG is used in a process involving gas combustion, a carbon monoxide (CO) detector must be installed;
- a leak-detection system (e.g. propane or LPG detector) (Figure 6.10.2.1) must be in place and tested annually or;
- the cylinder must be placed in a continuously mechanically ventilated gas cabinet.

Figure 6.10.2.1: LPG gas / CO detectors
(ref: www.amazon.com; www.kiddecanada.com; e-controls.net)

Any use or storage of LPG cylinders within laboratories must be assessed and approved by EHS.

SECTION B: Safe Handling

7. Receiving Gas Cylinders

Many gases cannot be seen or smelled, so the primary means of identification of a cylinder’s contents is the label. ***Never identify the product by the color of the cylinder*** as the colour coding system of gas cylinders is not standardized and should not be used to verify the contents in a compressed gas cylinder.

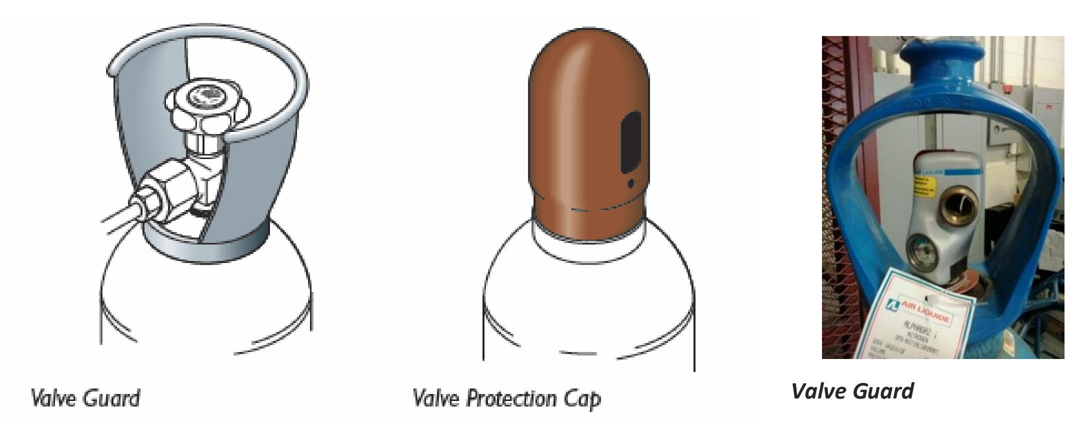
The following guidelines should be followed when receiving a gas cylinder:

- Read the cylinder label to confirm the gas received is the gas purchased. Gases are usually identified by cylinder neck (or shoulder) and body labels that meet the WHMIS/GHS, DOT and TDGR requirements (refer to Figure 7.1 and Table 7.1). Verify the Transport Canada/Department of Transportation (TC/DOT) cylinder markings to confirm the pressures contained in the cylinders. The label is the primary means of identification of the cylinder contents. If the label is illegible or missing, DO NOT use the cylinder. Return it to the gas company for a satisfactory replacement. Manufacturers are required, by law, to label their cylinders in order to identify the gases they contain, therefore, the label should be used to accurately identify the contents of a cylinder.
- Inspect the cylinders for any obvious damage such as cuts, gouges, burn marks, corrosion and dents. Cylinders showing deterioration should not be used; the cylinder surface should be clean.
- Cylinders with neck threads should have a cap in place over the valve. Remove the cap by hand. Never use a screwdriver, crowbar, or other leverage device to remove the cap. Some other high-pressure cylinders are fitted with valve guards or other non-removable, ergonomic caps. They replace traditional screw-on caps and should never be removed (Figure 7.2).
- Check the cylinder valve to be sure it is not bent or damaged. A damaged valve could leak, fail, or not provide a tight connection.
- Ensure the valve is free of dirt and oil, which could contaminate the gas. Dirt particles propelled in a high-velocity gas stream could cause a spark, igniting a flammable gas. Oil and grease can react with oxygen and other oxidizers, causing an explosion.
- The SDS for the contents of each cylinder must be provided with the gas cylinder.

Figure 7.1: Typical WHMIS/TGDR cylinder shoulder and body labels
(ref: Concordia University)

Table 7.1: TGDR label of types of Gases - Class 2

Description	TGDR Class	TGDR Label / Placard
A gas which will burn in air at a pressure of 101.3 kPa absolute.	2.1	
A gas which is non-flammable, non-toxic, non-oxidising, and is resistant to chemical action under normally encountered conditions.	2.2	
A gas which gives up oxygen readily, removes hydrogen from a compound, or readily accepts electrons.	Oxidizing gases	
A gas that is known to be: a) toxic or corrosive to humans as to pose a hazard to health; or b) presumed to be toxic or corrosive to humans because it has an LC_{50} value equal to or less than 5000 mL /m^3 (ppm).	2.3	



Valve Guard

Figure 7.2: Cylinder valve-protecting devices.
(ref: BOC Gases – AU : SPRM 2009 : Section 12 : Gas Cylinder Safety)

8. Handling Requirements

Compressed gas cylinders should be handled only by those familiar with the hazards and who are trained in the proper handling techniques. Cylinders containing compressed gases are heavy and difficult to move. Improper handling of compressed gas cylinders can result in sprains, strains, falls, bruises, or broken bones. Other hazards such as fire, explosion, chemical burns, poisoning, and cold burns could occur if gases accidentally escape from the cylinder due to mishandling.

9. Personal Protective Equipment (PPE)

Standard workshop or laboratory PPE, including safety eye wear and a lab coat, are required when using compressed gases. Refer to the SDS for details on the safe handling of the material. Gloves may also be required, depending on the chemical or physical hazards of the gas. Additionally, when moving or transporting a gas cylinder, hard-toed shoes are required.

When working with flammable gases (acetylene, hydrogen, LPG), only cotton clothing should be worn. Man-made fibres should not be worn as they generate static electricity sparks which can ignite flammable gases.

10. Indoor Transportation

Respect the following precautions to prevent injuries caused by improper handling of compressed gas cylinders when moving cylinders from a storage area into the laboratory or workshop:

- Obtain proper training and information before using a gas cylinder.
- Never drag or physically carry cylinders (lecture cylinders may be carried).
- Never lift cylinders by the cap.
- Do not drop or bang cylinders against each other.
- Use a suitable hand truck or cart designed for the transport of cylinders (refer to Figure 10.1) and secure the cylinder (s) with a chain or belt. DO NOT roll a cylinder on the floor.
- Secure cylinder caps during transport.
- Do not move a cylinder with a regulator connected to it.
- Leave the cylinder cap in place until the cylinder is secured and ready for use.
- Only transfer cylinders or cryogenic liquid containers outside buildings using Distribution Services.

Figure 10.1: Examples of hand-trucks designed for the transport of gas cylinders.
(ref: Matheson - Safe Handling of Compressed Gases in the Laboratory and Plant 2011)

11. Proper Storage

After cylinders are received, they should be stored in a detached and well-ventilated or open-sided building. Storage buildings or areas should be fire resistant, well ventilated, located away from sources of ignition or excessive heat, and dry. Such areas should be prominently posted with the names of the gases being stored.

Indoor storage areas should not be located near boilers, steam or hot water pipes, or any sources of heat. Outdoor storage areas should have the proper drainage and should be protected from the direct rays of the sun in localities where high temperatures prevail. Subsurface storage areas (e.g. basements) should be avoided. Cylinders should be protected against tampering by unauthorized personnel.

11.1. Cylinders in Use

Cylinders, when in use, shall be connected to gas delivery systems designed by a qualified person. A compressed gas cylinder shall be considered to be "in use" if it is:

- Connected through a regulator to deliver gas;
- Connected to a manifold being used to deliver gas; or
- A single cylinder secured alongside a cylinder connected to gas delivery system which serves as the reserve cylinder for that system.

Cylinders not "in use" shall not be stored in the laboratory or workshop unit.

11.2. General Storage Guidelines

Compressed gas cylinders can be stored either on outside or inside locations following strict rules in regards to their respective class. Full details on safe storage of compressed gas cylinders can be found within the following regulations and standards:

- Regulation Respecting Occupational Health and Safety
- Propane Installation Code, CAN/CGA B149.2-M91
- NFPA 45 Standards on Fire Protection for Laboratories Using Chemicals
- NFPA 55 Compressed Gases and Cryogenic Fluids Code
- NFPA 58 Liquefied Petroleum Gas Code
- CAN/CSA W117.2-M94 → NFPA51
- National Fire Code of Canada (including Quebec modifications)

Below are some general guidelines when storing compressed gas cylinders:

- storage areas must be clearly identified by visual signage (WHMIS or TDG placards);
- in an upright position;
- within a well-ventilated, well-illuminated area, away from direct sunlight or heat sources and from combustible materials; cylinder temperatures should not exceed 50°C (125°F);
- not in depressions such as basements, or on ledges where they can fall and become damaged;
- separated according to gas type;
- separated from empty cylinders and clearly identified;
- away from corrosion; corrosion may be from excess water, acids, salt, chemicals, or chemical fumes such as from industrial processes.
- capped when not in use.

Do not store gas cylinders:

- in elevators, stairways, exits or exit routes;
- at less than 1m (3.2 ft.) from exit doors;
- in damp areas, near salt, corrosive chemicals, fumes, heat or exposed to the weather without roof housing;
- under external staircases, emergency stairs, ramps or other access points;
- longer than one year without use.

It is preferable to secure cylinders with chains inside a protected barrier (such as inside steel guardrails) or inside a cage to prevent accidents. Storing cylinders in “islands”, where multiple cylinders are chained to a wall, should be avoided (Figure 11.2.1).

Figure 11.2.1: Proper and improper ways to store gas cylinders.
(ref: waltbeattie.com; en.wikipedia.org)

11.3. Storage in Laboratories

The storage of cylinders in laboratories must be minimized, and should be confined to only those cylinders in use. Cylinders and any connected piping system must be solidly fixed and protected against any mechanical damages.

According to NFPA 55, the amount of hazardous compressed gases permissible within a Laboratory Work Area is outlined in Table 11.3.1.

NFPA 55 does not set limits for the laboratory storage of non-flammable or inert gases (e.g. argon, nitrogen). However, the National Fire Code of Canada mentions that the amount of dangerous goods kept in a laboratory should be restricted only to the amount required for normal operation.

Table 11.3.1: Maximum Allowable Quantities (MAQ) for hazardous gases

	Compressed Flammable Gas (e.g. Hydrogen, Methane)	Compressed Oxidizing Gas (e.g. Oxygen)	Compressed Toxic Gas (e.g. Carbon Monoxide)
Amount Allowed per 500 ft^2 of Laboratory Work Area	6 ft^3 internal cylinder volume	6 ft^3 internal cylinder volume	0.3 ft^3 internal cylinder volume
Maximum Number of Standard Cylinders	4 cylinders (9"x51" cylinder)	4 cylinders (9"x51" cylinder)	1 lecture bottle
Lecture Bottle Limits	In addition to the maximum internal volumes above, the total number of lecture bottle cylinders shall be limited to 25 per Laboratory Work Area.		

11.4. Indoor Storage

When the cylinder has reached its destination (laboratory or workshop), it should be placed in a holding cage or secured to a wall, a bench, or some other stable support with a chain or appropriate sturdy strap above the midpoint, but below the shoulder (Figure 11.4.1). Laboratory cylinders less than 18 inches (46 cm) tall may be secured by approved stands, wall brackets, placed in a cylinder stand, rack or cabinet.

Figure 11.4.1: Examples of gas cylinders indoor storage.
(ref: Concordia University)

Some brackets are designed to chain 2-3 cylinders maximum. The bracket needs to be securely attached to the wall to hold the weight of the cylinders: 2 cylinders in parallel or 3 cylinders in a triangle.

Polyester, polypropylene or nylon cylinder straps of 1.5 in (3.8 cm) will resist fraying better than the older straps that are made out of fabric. If a steel chain is used, the recommended chain link must be at least 1/4 inch in diameter.

The following are not strong enough to hold cylinders:

- small diameter chain and chain with flat links (less than 1/4 inch in diameter);
- straps that are frayed or are starting to fray;
- copper or other metal wires;
- rubber tubing;
- strings or ropes;
- “bungee” ties or cords.

The use of a laboratory fume hood does not provide a safe storage area except for when the cylinder is being used.

11.5. Outdoor Storage

Cylinders stored outside must be located in an enclosure that:

- has a concrete slab or a non-combustible platform;
- is surrounded by a firmly anchored fence that discourages climbing and unauthorized entry, not less than 1.8 m (5.9') high;
- has gates that are locked when the storage area is not staffed;
- if the outdoor storage contains flammable, poisonous or corrosive gases, its location (Fig. 11.5.1) should be no less than:
  - 1.5 m (4.9') from any building opening, if the aggregate capacity of the expanded gas is not more than 170 m^3;
  - 7.5 m (24.6') from any building opening, if the aggregate capacity of the expanded gas is more than 170 m^3, but less than 500 m^3;
  - 5 m (49.2') from any building opening, if the aggregate capacity of the expanded gas is more than 500 m^3.

In order to calculate the aggregate capacity of the expanded gas stored in the area, consult the compressed gas supplier. The gas supplier should be able to provide information on the expanded volume ratio for each type of gas they sell. Once calculated, the expanded quantity of gas from each cylinder must be added together to determine the aggregate capacity of the expanded gas stored in the area.

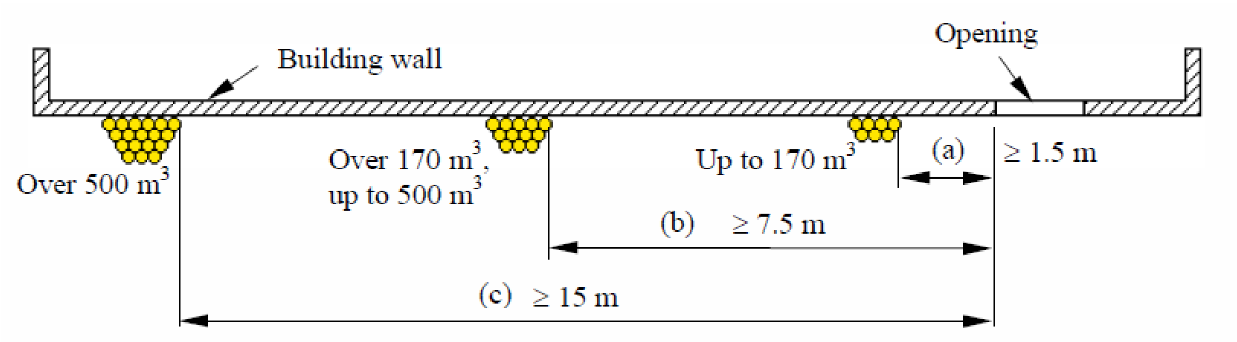


Figure 11.5.1: Examples of gas cylinders outdoor storage.
(ref: Ontario Fire Code; Section 5.6, Office of the Ontario Fire Marshall)

11.6. Additional Storage Requirements for Specific Classes of Gases

11.6.1. Toxic Gases

Toxic gas cylinders not in use may be stored indoors, if the room:

- is isolated with 1-hour rated firewalls from the rest of the building;
- has an external wall;

- has external access to the building with an automatic shut-off system when not in use;
- is ventilated directly outdoor.

More details about indoor storage of toxic gases can be obtained from the National Fire Code of Canada (including Quebec modifications). Please contact EHS office at ehs@concordia.ca or at X4877 before storing any compressed gas cylinders inside any university buildings.

Cylinders in use of toxic gases that are greater than lecture bottle size (typically 12–18 inches (300–460 mm) long and 1–3 inches (25–76 mm)) and have NFPA 704 health hazard ratings of 3 or 4 (refer to **Appendix I**), along with cylinders of gases that have a health hazard rating of 2 without physiological warning properties, located in laboratories must be installed or located in a continuously mechanically ventilated gas cabinets (refer to Figure 11.6.1.1), compliant with NFPA 45 and NFPA 55.

Figure 11.6.1.1: Examples of gas cylinder ventilated cabinets.
(ref: Air Liquide – Design and Safety Handbook for Specialty Gas Delivery Systems)

In order to contain potentially dangerous gases, ventilated compressed gas storage cabinet exhaust systems should be designed with the capacity of 45.7 to 61 linear meters (150 to 200 linear feet) per minute of air to pass through the cabinet with the access window open.

Lecture bottle-sized cylinders of the following gases located in laboratory units shall be kept in a continuously mechanically ventilated enclosure:

- all gases that have a health hazard rating of 3 or 4;
- all gases that have a health hazard rating of 2 without physiological warning properties.

This section shall not apply to gases that have a health rating of 3, as rated in NFPA 704, if they are rated as such by virtue of it being a cryogen, with no other health hazards.

11.6.2. Flammable Gases

Cylinders containing flammable gases should be stored at least 6.1 m (20 ft.) away from all flammable, combustible or incompatible substances, such as cylinders containing oxygen or other oxidants. Storage areas that have a non-combustible wall at least 5 feet in height and with a fire resistance rating of at least 30 minutes may be used to segregate gases of different hazard classes in close proximity to each other (Figure 11.6.2.1).

As for toxic gases, **EHS strongly recommends that flammable gas cylinders rated 4 according to the NFPA 704 that are greater than a lecture bottle size should be placed into approved continuously mechanically ventilated gas cabinets.**

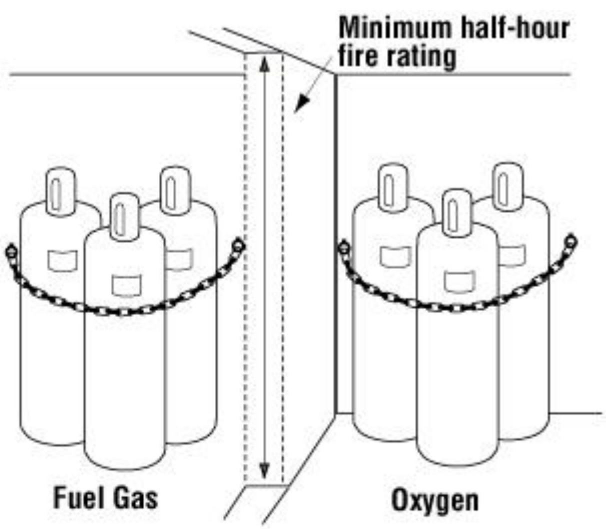


Figure 11.6.2.1: Segregation of flammable gases from incompatible gases.
(ref. www. ccohs.ca)

Flammable gas cylinders must be located in a room that is:

- separated from the remainder of the building by a gas-tight fire separation having a fire resistance rating of 2h;
- located on an exterior wall of the building;
- directly accessible from the exterior of the building;
- equipped with self-closing devices;
- constructed in order to prevent migration of gases from the room into other parts of the building;
- provided with natural or mechanical ventilation;
- free of fuel fired appliances or high temperature heating elements;
- used for no purpose other than the storage of compressed gases.

For gases lighter than air (refer to Table 5.6.1), storage is permitted outside of a room meeting the above specifications when that room is:

- in a building that has no sprinkler system or is built of combustible materials, the aggregate capacity of expended gas outside of the room is not more than 60 m^3, or;
- in a building that has a sprinkler system or is built of non-combustible materials, the aggregate capacity of expanded gas outside of the room is not more than 170 m^3.

More details about indoor storage of flammable gases can be obtained from the National Fire Code of Canada (including Quebec modifications).

11.6.3. Liquefied Petroleum Gases (LPGs)

11.6.3.1. Outdoor Storage

Except when used for research purposes, LPG cylinders shall not be stored inside any University rooms or buildings. LPG cylinders not "in use" shall not be stored inside University buildings and will be stored externally according to the following recommendations:

- at least 1.5 m (5 ft.) from any doorway or opening in a building frequented by the public where occupants have at least two means of access;
- at least 3 m (10 ft.) from any doorway or opening in a building or sections of a building that only have one mean of access;
- at least 6.1 m (20 ft.) from air intakes of air conditioning or ventilation systems;
- at least 1 m (3 ft.) from other flammable compressed gas containers;
- at least 6 m (20 ft.) from containers or dispensers for flammable and combustible liquids, or oxidizing, corrosive, or toxic gases;
- LPG cylinders shall not be stored on building roofs;
- LPG cylinders shall not be stored or installed under any fire escape, stairway, or ramp used as a means of egress from a building.

If empty LPG cylinders that have been in service are stored indoors, they shall be considered as full cylinders and must therefore be stored outside buildings.

11.6.3.2. Indoor Storage

If LPG cylinders are used or stored within a University laboratory, it must be installed or located in a continuously mechanically ventilated gas cabinets (refer to Figure 11.6.1.1), compliant with NFPA 45 and NFPA 55 (refer to section 6.10.2).

Otherwise, rooms in which LPG cylinders are stored shall be constructed in accordance to the following requirements:

- the walls, floors, and ceilings of a cylinder storage room that is within, or adjacent to, other parts of a building shall be constructed of material having at least a 2 h fire-resistance rating;

- a portion of the exterior walls or roof shall have explosion relief to the outdoors of not less than 1 ft^2 for each 50 ft^3 (0.1 m^2 for each 1.4 m^3) of building volume. The type of explosion venting shall be one of the following:
  - (a) an open area;
  - (b) an outwardly opening sash;
  - (c) explosion relief panels; or;
  - (d) single-strength glass.
- each opening from a cylinder storage room to another part of the building shall be protected by a swinging door having a 1.5 h fire-resistance rating. All doors shall be casketed to prevent escape of LPG;
- each cylinder storage room shall be ventilated to the outside air with vents located at the top and the bottom of a wall. The vents shall be distributed to obtain maximum air circulation across the floor, and the ratio of the size of each opening to the size of the floor area shall be 1:500. A vent opening shall not be less than 3 m (10 ft.) horizontally from any air intake of any appliance, air-moving equipment, or other opening into a building, and not less than 7.5 m (25 ft.) from any source of ignition;
- storage within that building or room shall be limited to LPG containers, other flammable gas containers and related equipment.

11.6.4. Oxidizing Gases

Oxidizing gases cylinders (e.g. oxygen) must be separated by at least 6 m (20 ft.) distance or by a non-combustible barrier at least 1.5 m (5 ft.) high with a fire resistant rating of at least 1/2h) from:

- flammable or combustible liquids;
- easy ignited materials (e.g. wood, paper, packing materials);
- oil and grease;
- LPG (fuel gas) cylinders;
- reserve stocks of calcium carbide.

11.6.5. Pyrophoric Gases

Cylinders of pyrophoric gases (e.g. silane) greater than lecture bottle size that are located in laboratory units shall be kept in approved continuously mechanically ventilated gas cabinets equipped with sprinklers.

Lecture bottle-sized cylinders of the pyrophoric gases located in laboratory units shall also be kept in a continuously mechanically ventilated enclosure, such as a fume hood or ventilated storage cabinet.

11.6.6. Corrosive Gases

Steel cylinders are typically used for more corrosive products, therefore these cylinders should not be stored for extended periods due to the risks caused by valve corrosion and leaking. A full emergency shower and emergency eye-wash station must be available close (within 10 sec reach) to any areas where corrosive gases are being stored and used.

11.6.7. Aerosols

The National Fire Code of Canada divides aerosols in 3 levels, according to *NFPA-30B Manufacture and Storage of Aerosol Products*.

Examples of Level 1 aerosol products include shaving cream, spray starch, window cleaners, alkaline oven cleaners, rug shampoos, some air fresheners and some insecticides. These aerosols are less hazardous than Level 2 or Level 3 aerosols.

Examples of Level 2 water-miscible flammable base aerosol products include most personal care products such as deodorants (except for oil-based antiperspirants), and hair sprays. They may also include antiseptics and anesthetics, some furniture polishes and windshield de-icers. Level 2 aerosols are less hazardous than Level 3 aerosols.

Examples of Level 3 aerosol products include some automotive products such as engine and carburetor cleaners, undercoats and lubricants; some wood polishes, paints and lacquers; some insecticides; and oil-based antiperspirants.

Most of aerosol cans found in laboratories or workshops essentially belong to Level 3 aerosol products. For storage purposes, these aerosols are considered as class IA flammable liquids (according to NFPA-30) because of their propellant gases that are mainly flammable (propane, iso-butane, butane, etc.). Therefore, aerosol cans should be stored inside flammable cabinets that meet the construction specifications of the *NFPA 30 Flammable and Combustible Liquids Code*.

Figure 11.6.7.1: Storage of aerosol cans (ref. www.justritemfg.com)

11.6.8. Segregation of Incompatible Gases

Incompatible compressed gas cylinders must be segregated according to Table 11.6.8.1.

General segregation requirements are:

- flammable gases must be stored away from oxidizer gases;
- inert gases can be stored with flammable or oxidizer gases;
- propane must be located at least 1 m (3 ft.) away of any flammable compressed gas and at least 6 m (20 ft.) away from containers of flammable, combustible, oxidizing, corrosive or toxic liquids.

Table 11.6.8.1: Segregation of incompatible gases

Classes	Flammable	Inert	Toxic	Corrosive	Oxidizer
Flammable		Compatible	Incompatible – do not store together	Incompatible – do not store together	Incompatible – do not store together
Inert	Compatible		Compatible	Compatible	Compatible
Toxic	Incompatible – do not store together	Compatible		Incompatible – store 1 m away	Incompatible – store 1 m away
Corrosive	Incompatible – do not store together	Compatible	Incompatible – store 1 m away		Incompatible – store 1 m away
Oxidizer	Incompatible – do not store together	Compatible	Incompatible – store 1 m away	Incompatible – store 1 m away	

12. Compressed Gas Cylinder Set-Up

12.1. Regulators

All cylinders containing gas under pressure are fitted with a cylinder valve which **MUST NOT** be removed or tampered with at any time as this will compromise the safety of the cylinder. Each valve outlet is specially threaded to receive commercially available pressure regulators. Gas regulators are used to reduce the high pressure of a compressed gas cylinder to safe and useable pressures. They are designed for use with a specific gas, within prescribed pressure ranges.

Always use the proper regulator for the gas in the cylinder as they are designed to provide the correct flow rate for that particular gas. Using the wrong regulator may cause some gases to react with the materials inside the regulator; for example: materials used in some regulators are not designed for oxygen and could ignite causing a fire or explosion.

The Compressed Gas Association (CGA) has developed a system to help prevent using the incorrect regulator on a compressed gas cylinder. Each cylinder and regulator has a connection fitting that is designated by a CGA number (refer to **Appendix III**). These CGA connectors will have an identifying notch in them or a line inscribed around the circumference. The main components of a typical gas cylinder and regulator assembly are shown in Figure 12.1.1.

For safety reasons, flammable gases and non-flammable gases have their cylinder valve outlets threaded on the opposite hand. This prevents the connection of the incorrect regulator to cylinder valve outlets. Left-hand thread valve outlets for flammable gases are screwed LEFT-HAND (anticlockwise to tighten). They are identifiable by their notched appearance (refer to Figure 12.1.2). Cylinders containing flammable gases like acetylene, hydrogen, propane and mixtures containing fuel gas all have left-hand threads.

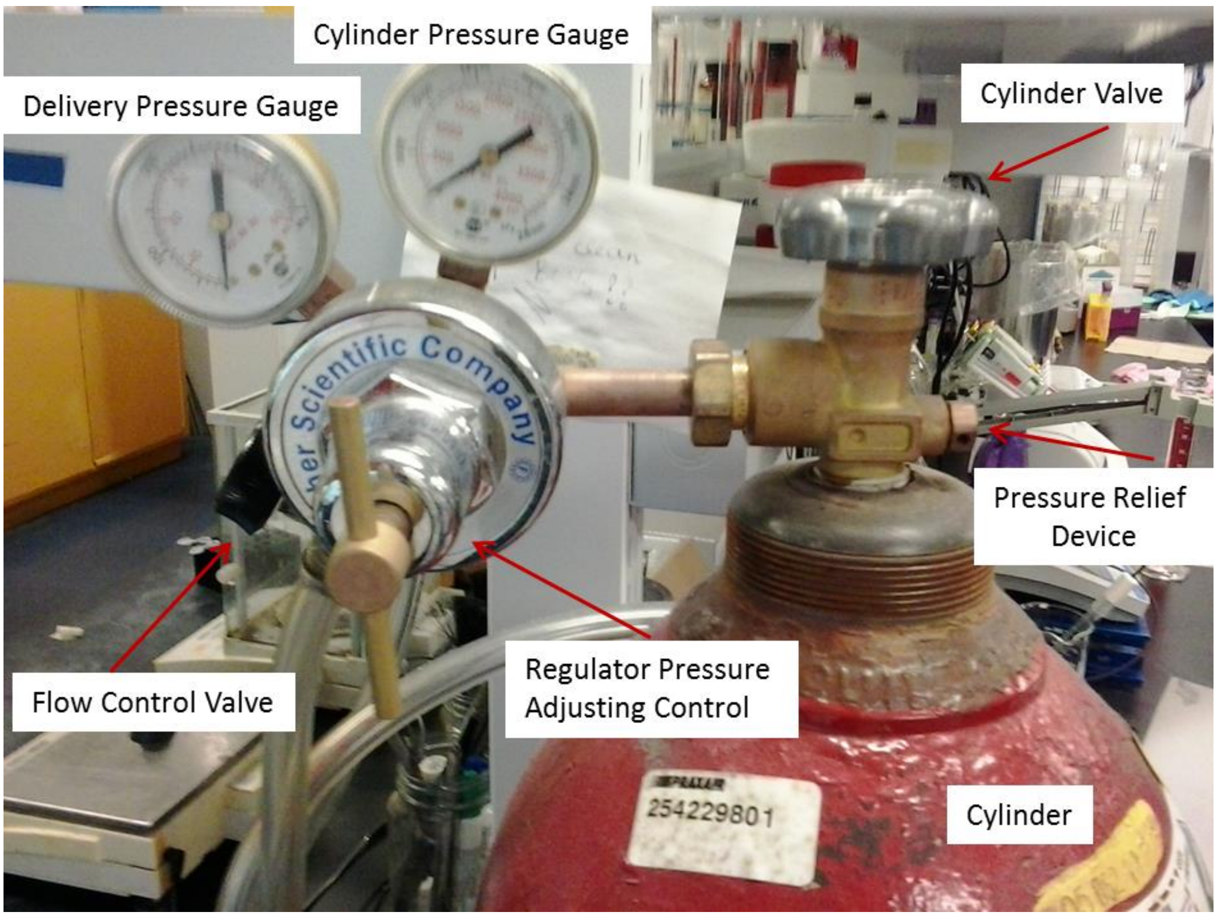


Figure 12.1.1: Typical gas cylinder and regulator assembly.
(ref: Concordia University)

Valve outlets for non-flammable gases are screwed RIGHT-HAND (clockwise to tighten). Cylinders containing non-flammable/ non-toxic gases all have conventional right-hand threads. Non-flammable gases can be oxidising e.g. oxygen, or non-flammable, non-toxic e.g. nitrogen, argon and air.

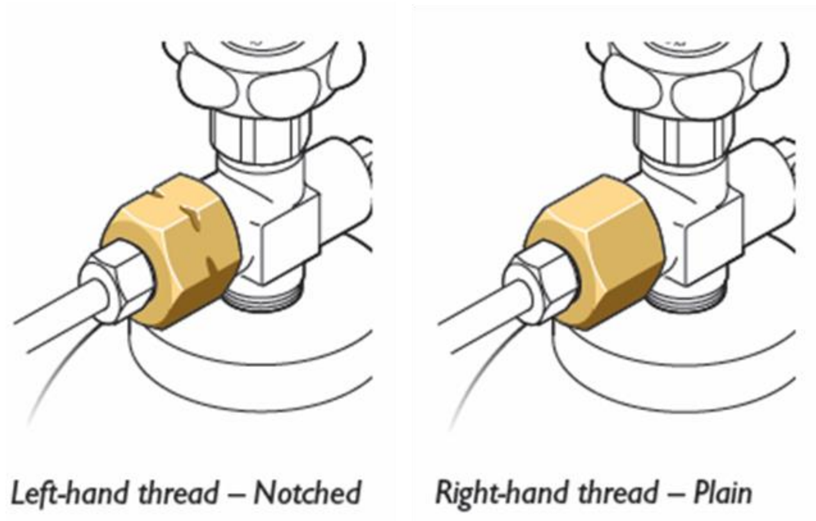


Figure 12.1.2: Left- and right-hand threaded valve outlets.
(ref: BOC Gases – AU : SPRM 2009 : Section 12 : Gas Cylinder Safety)

Never use Teflon™ tape on CGA fittings (straight thread) where the seal is made by metal-to-metal contact. Use of Teflon™ tape causes the threads to spread and weaken, increasing the likelihood of leaks. Small pieces of tape can also become lodged in the valve mechanism resulting in possible valve failure.

Some high-pressure gas cylinders have an integrated pressure gauge equipped with a lever-activated valve for fast gas shut-off (such as those offered by Air Liquide, SMARTOP™) (Figure 12.1.3).

Figure 12.1.3: SMARTOP™ from Air Liquide.
(ref: Air Liquide – Design and Safety Handbook for Specialty Gas Delivery Systems)

Lecture bottles use universal threads and valves, some of which are interchangeable. It is best to label all equipment associated with type of gas it is used with to prevent unintentional mixing of incompatible materials.

12.1.1. Medical Gas Cylinders

Medical gas cylinders (e.g. oxygen) may have valves configured with a pin index safety system (Figure 12.1.1.1). This system uses a unique configuration of holes and pins that must match precisely in order to eliminate connection of the wrong cylinder to equipment. The system incorporates two holes in specific positions on the cylinder valve below the outlet port. Unless pins and holes are aligned, the port will not seal and gas will not pass. Pin index valves are usually fitted in small cylinders which are commonly connected directly to specific equipment such as anesthesia machine.

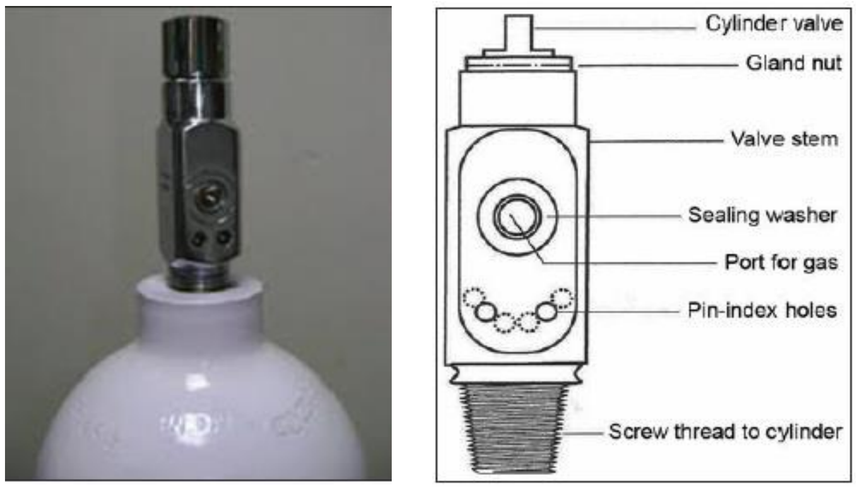


Figure 12.1.1.1: Pin index valve.
(re:. Srivastava, U., Indian J of Anesthesia, 2013, Vol. 57 (5), pp. 500-506)

12.2. Pressure Relief Devices

Most cylinders are fitted with a relief device (Figure 12.2.1). In a situation where excess pressure is encountered, it is designed to discharge cylinder contents either completely or to discharge the excess pressure. The discharge is normally accompanied by a high pitched noise. There are three types of commonly used pressure relief devices:

- burst disc (most common)
- fusible plug (e.g. acetylene)
- pressure relief valve (e.g. LPG)

Burst disc: In the event of overpressure, this valve is designed to burst, leaving an open passage for gas contents to escape completely. For example: carbon dioxide (CO_2) cylinders are fitted with a burst disc which operates at approximately 207 bars and is located on the cylinder valve.

Fusible plug: The fusible plug is designed to melt, releasing contents completely. For example: acetylene cylinders are fitted with fusible plugs which melt at approximately 100°C.

Pressure relief valve: These valves are designed to relieve excess pressure and close again after releasing the excess pressure. For example: LPG cylinders may be fitted with pressure relief valves which operate at approximately 26 bars.

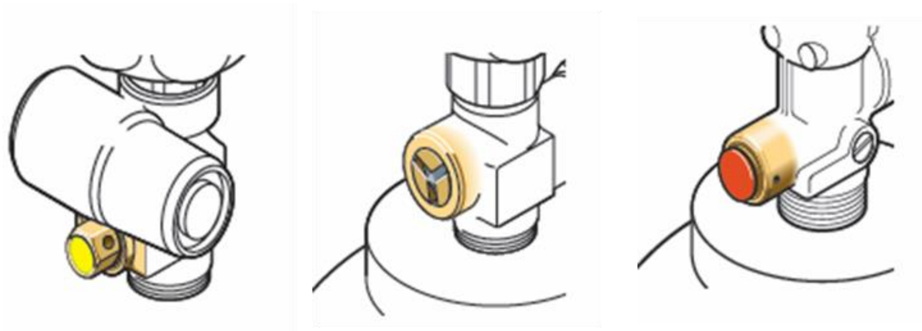


Figure 12.2.1: Pressure relief devices (from left to right): burst disc, fusible plug and pressure relief valve. (ref: BOC Gases – AU : SPRM 2009 : Section 12 : Gas Cylinder Safety).

12.3. Compressed Gas Cylinders Set-Up Guidelines

- Secure cylinders to a wall, a cylinder-rack or an appropriate bench in an upright position, using a chain or a cylinder belt (wires are not acceptable) above the midpoint, but below the shoulder.
- Cylinders in the laboratory shall be equipped with a pressure regulator designed for the specific gas and marked for its maximum cylinder pressure.
- Never use homemade adaptors or force connections between the cylinder valve and gas handling equipment.
- Do not apply any lubricant, jointing compound or tape to cylinder valves, fittings or regulator threads unless specified by the manufacturer.
- The regulator system shall be equipped with two gauges to show both the cylinder pressure and the outlet pressure.
- Where the source cylinder is outside of the laboratory, a station regulator and gauge shall be installed at the point of use to show outlet pressure.
- Cylinders shall have a manual shutoff valve.

12.4. Valve and Regulator Requirements

To safely use compressed gas valves and regulators:

- Be sure the regulator pressure control valve is released (i.e., closed) before attaching it to cylinders.
- Do not stand in-line with the regulator and valve outlet when attaching the regulator to the cylinder.
- Close valves on gas cylinders when not in use.

- Remove all pressure from regulators when not in use (by opening equipment valves downstream after the regulators are closed).
- Do not install shut-off valves between pressure relief devices and the equipment they protect.
- Use pressure relief valves in downstream lines to prevent high pressure buildup in the event that a regulator valve does not seal properly and a tank valve is left on.
- Vent relief valves to a fume hood or ventilated compress gas storage cabinet, when using flammable or toxic gases.
- Pressurize regulators slowly and ensure that valve outlets and regulators are pointed away from all personnel when cylinder valves are opened.
- Fully open valves during cylinder use. A fully open valve improves the internal seal and helps prevent packing leaks.
- Never apply excessive force to pry off caps. Return a cylinder to the supplier to remove "stuck" caps.
- Never apply excessive force when trying to open valves.
- Never allow flames or concentrated heat sources to come in contact with a gas cylinder.

12.5. Testing for Leaks and Faults

Leaks may develop in any part of a gas system, but particularly at joints. It is important that all equipment is regularly checked and corrective actions are taken before use. As a matter of routine, always check for leaks when a compressed gas cylinder is an integrated assembly of workplace equipment (Figure 12.5.1).

To check for leaks, the following steps should be followed:

1) Prepare a soapy water solution or 50% glycerin-water solution; commercially LDF (Leak Detection Fluid) can also be used. Always ensure the solution being used is compatible with the gas in the system (e.g. some LDFs are incompatible with oxygen as their residues could cause spontaneous ignition).
2) Pressurize the system.
3) Apply the solution to all connections (e.g. cylinder valve, regulator connections, other connections) observing for the formation of bubbles. If there is bubbling or foaming of the leak detection fluid during testing, this indicates that there is a leak.
4) Depressurize the equipment and verify the connections where bubbles formed. Retest.
5) If no bubbles are formed, the system is not leaking and may be used.
6) If a leak cannot be corrected, the system should not be used. Notify your supervisor.

Figure 12.5.1: Leak test on gas cylinder valves.
(ref: pubs.usgs.gov)

Additional safety tips:

- If a regulator is defective or if a pressure gauge is broken, replace it immediately.
- Have hose or tubing shows signs of deterioration, replace it immediately.
- Keep equipment clean. In particular oxygen regulators must be kept in a clean area when not in use.
- NEVER use a flame when testing for leaks
- NEVER tighten equipment while the equipment is under pressure

13. Road Transportation

13.1. Regulations

The transportation of compressed gas is regulated by the government. The Transportation of Dangerous Goods Regulations (TDGR) stimulates all requirements for the safe transportation of compressed gases, for both safe transport and public safety.

Unless exempted or shipped in limited quantities, all shipments of compressed gases must include:

- Dangerous goods shipping document (bill of lading);
- Safety marks on the small means of containment (the cylinder), including UN number, shipping name, class and TDGR label;
- Placards attached on all four sides of the transportation vehicle when a load of dangerous goods exceeds a gross weight (i.e., both cylinder and gas) of 500 kg or for any quantities of toxic gases (class 2.3);
- TDGR training for anyone handling, offering to transport or transporting compressed gas cylinders.

All gas transportation exemptions are described in Part 1, sections 1.32 to 1.32.3 of the TDGR.

Transportation of Dangerous Goods Regulations

Always contact EHS prior to transporting any compressed gas cylinders by road vehicles.

The recommended method of transporting cylinders (i.e., gas cylinders and cryogenic receptacles) is by a professional gas transport company. Occasionally, there might be a need to use other transport systems; it is essential to follow safety instructions for both full and empty cylinders.

All cylinder valves must be protected against damage by screwing on cylinder caps, with the exception of those cylinders on which the valves are protected by a permanently installed cylinder collar. Small gas cylinders on which no permanent valve protection is fitted, and those which have no cylinder cap that can be screwed on must be transported in cylinder cases or boxes designed for that purpose in order to protect the valves.

Some gases, such as ***liquefied petroleum gases (e.g. propane), carbon dioxide (CO_2) and acetylene should not be transported lying down*** as the gas in these cylinders is in liquefied form, or as in the case of acetylene dissolved in acetone. Consequently, there is a high risk of a leak coming from the valve threads. The escaped gas can then collect in sufficient quantities to form an explosive or asphyxiant mixture inside the vehicle.

13.2. Gas Cylinders

Before loading a cylinder into an enclosed vehicle:

- tighten (do not over-tighten) the cylinder valve and check that it is properly closed;
- use the valve outlet sealing nut when available;
- carefully check for gas leaks, (using approved leak detection fluid – see your gas supplier). Never transport a cylinder if a leak has been detected during loading;

Never transport cylinders with regulators or other equipment attached. Do not remove any valve protection device (if fitted) during transport.

13.3. Open Vehicles

While transporting cylinders adequate ventilation is very important. Ideally, open vehicles or trailers designed for the transport of gases should be used. These vehicles should be fitted with a gas tight bulkhead separating the driver from the load.

13.3.1. Positioning the Load Correctly

The load must be correctly positioned on the vehicle to maintain its stability. The load restraint equipment and the vehicle body and attachments must be strong enough for each type of load carried, and must be in good working condition (refer to Figure 13.3.1.1)

When transporting gas cylinders upright:

- Secure all cylinders, to keep them from moving during transport; consider all possibilities that may arise such as traffic accidents;
  - Restrain cylinders by latching them to the vehicle body or constraining them in a purpose-built frame. If transporting cylinders upright against a headboard the total weight of the cylinders should not exceed 250 kg;
- Apply at least two horizontal straps, as shown below.
- Limit the number of cylinders to be transported;
- Do not cover thee cylinders;
- Acetylene and LPG cylinders must always be transported in an upright position;
- Ensure that the content labels on the cylinders can be clearly read;
- Never drop cylinders or submit them to shock;
- Where possible, use mechanical lifting devices and carts to move cylinders;
- Wear safety shoes or boots, safety glasses or goggles, and leather protective gloves when handling cylinders;
- Smoking is strictly forbidden when loading, transporting or unloading any cylinder, whether it contains flammable gas or not.

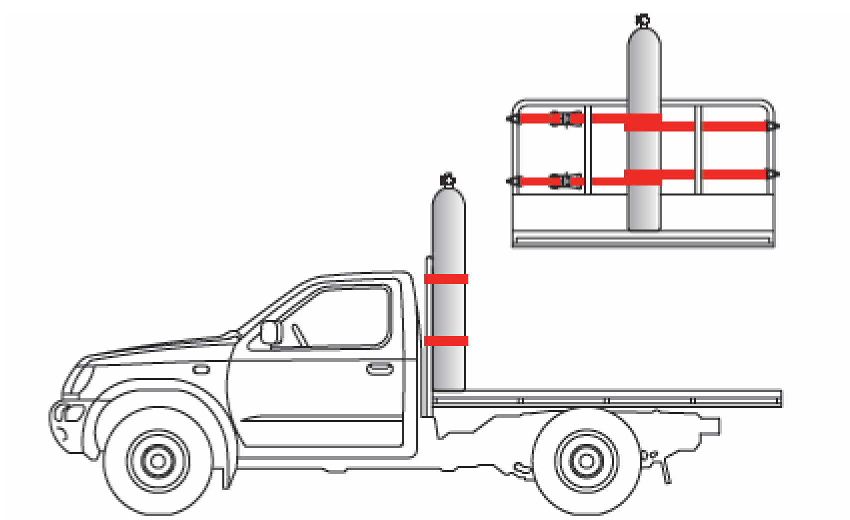


Figure 13.3.1.1: Proper cylinder load on open vehicles.
(ref: BOC Gases – AU : SPRM 2009 : Section 12 : Gas Cylinder Safety)

13.3.2. Transporting Cylinders Lying Down

When transporting cylinders lying down (Figure 13.3.2.1):

- Place the cylinders lengthwise on the deck;
- Place the cylinders on blocks to prevent them from rolling sideways and to provide more grip to stop them from sliding;

- Position the cylinders with the valves facing rearwards, with the base blocked against the headboard or another strong part of the load;
- Apply at least one tie-down strap, as shown below.

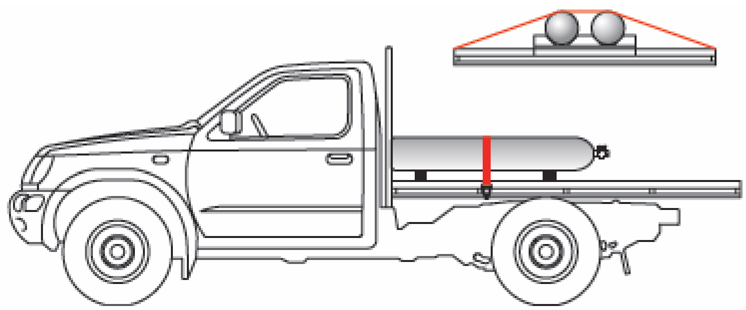


Figure 13.3.2.1: Transport of cylinders lying down.
(ref: BOC Gases – AU : SPRM 2009 : Section 12 : Gas Cylinder Safety)

Proper cylinder load security on a vehicle designed for cylinder transportation is crucial to avoid potential accidents (Figure 13.3.2.2).

Figure 13.3.2.2: Improper transport of compressed gas cylinders.
(ref: Messer France S.A.S., Transport de gaz dans des véhicules non ADR)

13.4. Enclosed Vehicles

If there are no other practical methods of transport, enclosed vehicles may be used however the following recommendations must be followed:

- Do not transport cylinders containing toxic or flammable gases in enclosed vehicles;
- The vehicle should have a gas tight bulkhead separating the driver from the load;

- Do not transporting cylinders in the passenger compartment;
- Unload the cylinders as soon as possible after arrival at destination (ventilation decreases considerably when the vehicle is stopped or parked);
- Do not store or leave cylinders unattended in vehicle overnight or for long periods (more than 1 hour);
- Do not use the cylinders in an enclosed vehicle;
- Carry a fire extinguisher suitable for vehicle fires.

13.4.1. Vehicle Ventilation

The loading compartment of the vehicle must be sufficiently ventilated. This is not an issue if the loading compartment is an open space (e.g. open pick-up truck). It is more difficult to ventilate the enclosed vehicle compartment used to transport cylinder (example: the box of a cube truck). If the loading compartment is covered or enclosed it should be possible to provide diagonal ventilation at the front and rear, preferably at the top and bottom. It is recommended to provide 1/10 of the area of the enclosed portion for all gas cylinders being transported at the same time due to the incoming and outgoing air opening. A Mechanical or passive air venting system can be used. A ventilation opening of approximately 100 cm^2 (10 cm X 10 cm) is considered to be sufficient to properly ventilate the enclosure.

Permanently installed gill-type or rosette ventilation openings can be used as long as they:

- provide the enclosed vehicle compartment used to transport cylinders with permanent upper (incoming air) and lower (exhausted air; most gases are heavier than air) openings;
- permanently vent to the outside of the vehicle in the event of leaks from any transported cylinder;
- vent in a direction away from potential ignition sources;
- are unobstructed.

Figure 13.4.1.1: Examples of ventilation openings for trucks.
(ref: Concordia University)

13.4.2. Positioning the Load Correctly

When transporting cylinders inside vehicle compartments used to transport cylinders, the following requirements are to be followed (Figure 13.4.2.1):

- the truck floor should be smooth;
- the gas cylinders should be vertically fixed on side rails to avoid any risks of falls;

Figure 13.4.2.1: Proper cylinder load inside closed vehicle.
(ref: Messer France S.A.S., Transport de gaz dans des véhicules non ADR)

13.4.3. Compressed Gas Transportation Storage Cabinets

Another option for carrying gas cylinders is using a closed-type vehicle that uses a separate gas storage cabinet (refer to Figure 13.4.3.1) that is vapour-tight from the rest of the vehicle. The gas cabinet must be secured to the vehicle, and be big enough to store all cylinders carried in the vehicle, including empty cylinders. It must be designed to ensure that gas from leaking cylinders cannot accumulate inside the cabinet and is vented outside the vehicle. The cabinet door must be securely sealed whenever cylinders are stored in the cabinet.

Compressed Gas Transportation Storage Cabinets must have:

- one or more permanent vents or drains positioned at the bottom of the cabinet (either floor or side), with an internal diameter of at least 25mm;
- vents cannot be blocked when the cylinders are in the cabinet;
- a way of securing cylinders in an upright and stable position (e.g. straps);
- a visible TDGR label on the outside;
- regular inspections and maintenance of door seals and vents.

Compressed Gas Transportation Storage Cabinets must also be installed and maintained in accordance with the manufacturers' instructions.

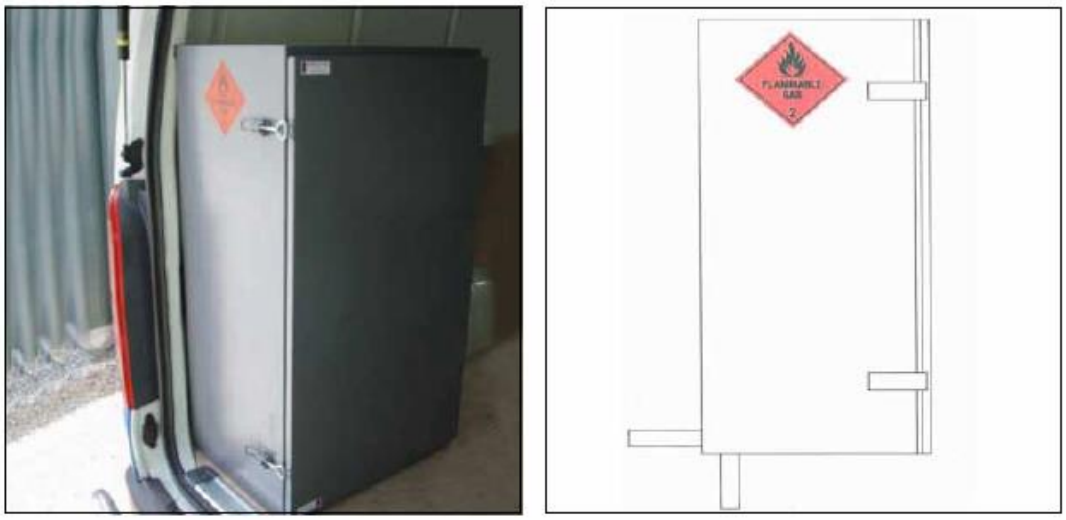


Figure 13.4.3.1: Gas cabinet for cylinder transportation.
(ref: WorkSafe Victoria - Storing gas cylinders in vehicles, March 2012)

13.5. Transporting Compressed Gas Cylinders in a Passenger Vehicle

The university prohibits the transportation of compressed gas cylinders inside a passenger vehicle. When compressed gas is required as part of university sanctioned activities, appropriate transportation is required. In the event that a compressed gas cylinder must be transported in a passenger vehicle, please contact the EHS office at ehs@concordia.ca or at X4877.

13.6. Transportation of Cryogens

The transportation of cryogenic gases (e.g. liquid nitrogen) via road delivery vehicles is a potentially hazardous activity because of evaporation of the gas into the vehicle. The cryogen container should not be in the same compartment as the driver and passengers, which means that hatchbacks, minibuses and most vans are not suitable. To avoid the effects of leaking cryogenic gas from the storage compartment into the passenger compartment, the driver should keep a steady flow of air into the car.

Cryogenic gases (e.g. liquid nitrogen) must always be transported using appropriate receptacles. There are two types of portable cryogenic receptacles, both must be safely secured in an upright position, with a secondary container to prevent spills (Figure 13.6.1).

Open Dewars that continuously vent into the atmosphere:

- an oxygen-deficient environment will be created, therefore good ventilation must be provided;
- never transport or use open Dewars with oxygen.

Closed vessels with pressure-relief devices:

- these Dewars usually have clips for their lids, having a pressure-relief valve located on the lid;
- ensure that these vessels are in good condition, and that valve(s) are in the correct position for transport.

Figure 13.6.1: Open and pressure-relief Dewar containers.
(ref: cmr-direct.com; www.camlab.co.uk)

Here are some safety guidelines to consider when transporting cryogenic gases by road vehicles:

- the container must be secured to prevent movement during travel;
- there must be a constant airflow into the passenger compartment of the vehicle;
- the driver must be made aware of the hazards associated with cryogens such as liquid nitrogen;
- the driver must be given adequate instruction and training (e.g. TDGR) on the hazards, precautions, and emergency procedures;
- the driver must wear clothing that covers and protects the skin when handling cryogenic gases.

13.6.1. Transportation of Liquid Nitrogen

Liquid nitrogen has a boiling point of -196°C. According to Section 2.14 of the TDGR, Class 2.2, Non-flammable and Non-toxic Gases, consists of gases that are transported at an absolute pressure greater than or equal to 280 kPa at 20°C, or refrigerated liquids, and that are not included in Class 2.1, Flammable Gases, or Class 2.3, Toxic Gases.

The limited quantity exemption for liquid nitrogen (UN 1977) is only 125 mL. Small amounts of many dangerous goods going for testing or analysis may be exempt, but if they are cooled with liquid nitrogen, the nitrogen is regulated. Therefore, any shipment of liquid nitrogen that exceeds the limited quantity must include:

- Dangerous goods shipping document with the required information on it:
    - Shipping Name: NITROGEN, REFRIGERATED LIQUID
    - Class: 2.2
    - UN number: UN 1977
    - Packing Group: None
- Safety marks on the small means of containment (class, shipping name, UN number, TDGR label);
- TDGR training for anyone handling, offering to transport or transporting liquid nitrogen.

13.6.2. Transportation of Liquefied Petroleum Gases (LPGs) and Propane

Liquefied petroleum gases (LPGs) include the followings:

- BUTANE (UN1011)
- BUTYLENE (UN1012)
- ISOBUTANE (UN1969)
- ISOBUTYLENE (UN1055)
- LIQUEFIED PETROLEUM GASES (UN1075)
- PROPANE (UN1978)
- PROPYLENE (UN1077)

Carrying any LPG gas cylinders inside a vehicle is prohibited except in an area with exterior ventilation. Gas cylinders installed outside, at the rear of the vehicle, must be protected by extending the bumper beyond the cylinder using material whose resistance is at least equivalent to that of the bumper.

In an open vehicle, LPG cylinders must be transported in an upright position and secured so that the label displayed on the cylinder is visible from outside the vehicle (Figure 13.6.2.1).

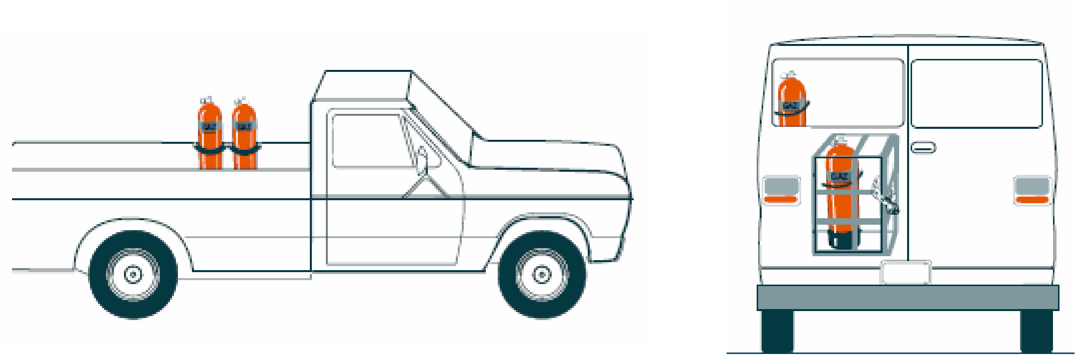


Figure 13.6.2.1: Transport of LPG cylinder in open and closed vehicles.

(ref: Bulletin de la Corporation des maîtres mécaniciens en tuyauterie du Québec, Dossier Spécial, Obligations relatives aux matières dangereuses, juin 2005)

In an enclosed vehicle, cylinders must be transported upright and secured. In a passenger vehicle, it must be secured upright on the rear floor with the window open or in the trunk inside a tote box and with the trunk partially open to ensure proper ventilation. Never leave LPG cylinders sitting for long periods of time in a passenger vehicle.

For propane, personal TDGR exemption permits the transportation of cylinders for personal use between the place of fill and people's home.

The maximum number of propane cylinders that can be transported is five in open vehicles, as long as the total combined mass of the propane and cylinders does not exceed 500 kg.

In enclosed vehicles, the maximum number of cylinders that can be transported is five, as long as each individual cylinder weighs a total of less than 30 kg (66 lbs). A full, typical barbeque cylinder weighs approximately 17 kg (34.5 lbs).

If the limits are exceeded in either open or enclosed vehicles, the vehicle must be placarded as per the placard requirements, carry the appropriate supporting documentation and the people operating the vehicle must be appropriately trained.

14. Compressed Gas Cylinder Disposal

Most of compressed gas cylinders can be shipped back to the manufacturer for refilling. However, proper identification of the contents of all cylinders is required and this is the responsibility of the cylinder owner, so the manufacturer labels on cylinders must be maintained.

Return cylinders with at least 30 lbs of pressure to reduce the risk of foreign materials entering the empty vessel. When a cylinder is empty, an "Empty" tag or sign should be placed on it and the cylinder should be placed in the "empty cylinder section" of the cage located at the loading dock of the respective building (Loyola: SP; SGW: EV or Hall). The manufacturer and/or distributor should then be contacted for pick-up.

Most lecture bottles and small LPG cylinders (e.g. propane torch) (Figure 14.1), along with aerosol cans, are not refillable and should be discarded at atmospheric pressure as chemical waste by contacting EHS at hazardouswaste@concordia.ca.

Figure 14.1: Examples of lecture-size bottles and small non-refillable LPG cylinders.
(ref: www.free-stock-illustration.com; www.usersites.horrorfind.com)

15. Gas Cylinders and Magnetic Fields

15.1. Magnetic Field Risks

Superconducting magnets may generate extremely strong magnetic fields (e.g. NMR spectrometers, MRI). Many instruments have internal shielding, which reduces the strength of the magnetic field outside of the instrument. Magnetic objects, including steel gas cylinders, may be pulled into a magnetic field, a potentially dangerously situation. A flying magnetic object may hit someone; gas cylinders may strike with fatal force. Do not attempt to pull away objects that have been pulled onto a magnet; the object may shift, pinching fingers.

Prudent practices require posting warnings on entrances (Figure 15.1.1), cordoning off the area at the 5 Gauss line, and limiting access to areas with more than 10 to 20 Gauss magnetic field to trained staff (Figure 15.1.1). Never bring a compressed gas cylinder within the 5 Gauss line of a superconductor magnet.

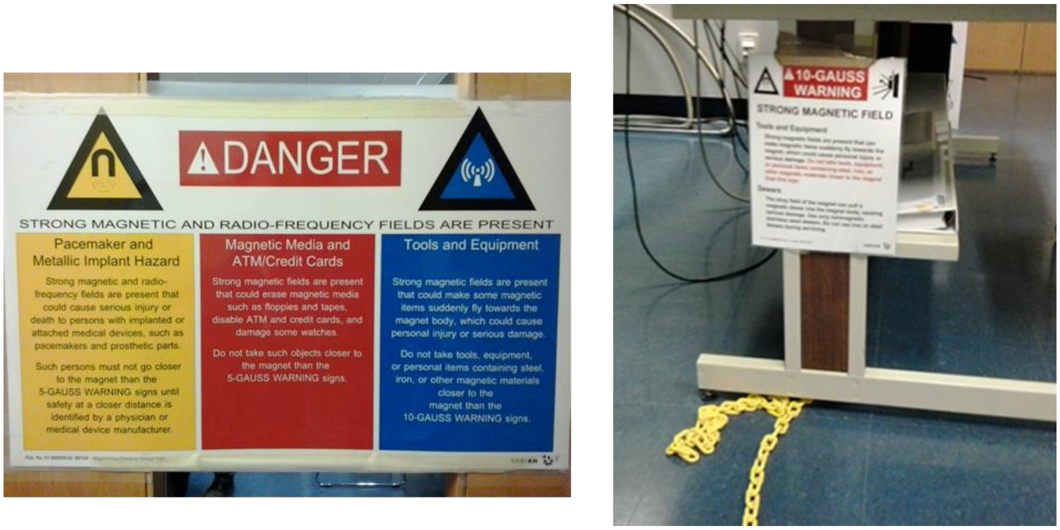


Figure 15.1.1: Examples of warning signs for strong magnetic fields and 10-Gauss warning field zone.
(ref: Concordia University)

15.1.1. Magnetic Resonance Imaging (MRI) Environment

Compressed gas cylinders, cylinder valves, cylinder regulators, other assemblies included with cylinders, or any other equipment used to supply compressed gases shall not be present in the same room as an MRI device unless proven nonmagnetic and/or tested and deemed suitable for this environment.

Severe personal injury and property damage has resulted from the use of steel gas cylinders in close proximity to MRI devices; the magnetic force generated by the MRI has the ability to draw gas cylinders across rooms (Figure 15.1.1.1). If required, oxygen or medical air tanks are available made with non-ferromagnetic materials or can be tethered to the ground.

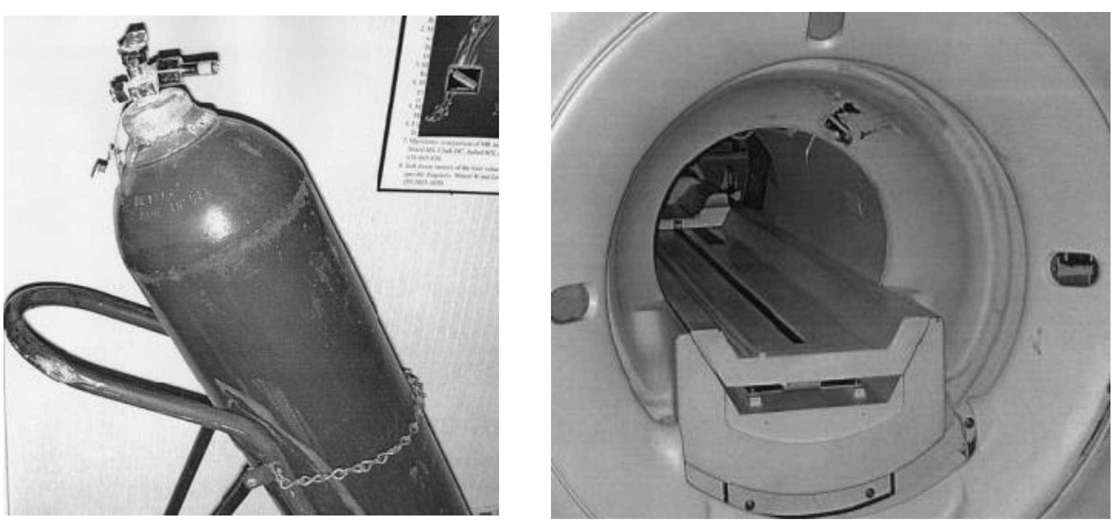


Figure 15.1.1.1: Damages from impact between an oxygen cylinder and MRI instrument.
(ref: Colletti, P. M., *J Magnetic Resonance Imaging,* 2004, 19, pp. 141-143)

16. Emergencies

16.1. Gas Cylinders and Fire

Gas cylinders involved in a fire may explode. If gas cylinders are involved in a fire, take the following actions:

- keep away, do not approach or attempt to move the cylinder;
- evacuate the area (min. 100 m);
- advise persons between 100–300 m from the cylinder to take cover;
- call Security at X3717 and provide them with:
  - location of the fire;
  - type and number of gas cylinders involved;
  - dangers associated with the gas(es);
- Gas cylinders which are not directly involved in the fire and which have not become heated should be moved as quickly as possible to a safe place – provided this can be done without undue risk.

Gas cylinders which have been exposed to excessive heat, such as fire or by accidental impingement of a flame, may fail when next filled and may result in an operator's death. Advise the supplier/manufacturer and replace the gas cylinder. Never use gas cylinders that have been exposed or damaged by a fire.

Even after a fire has been extinguished, some cylinders which have been heated can explode, particularly acetylene cylinders.

16.2. Major Leak Procedure

In the event of a major gas release or leak, try to stop the leak by closing the cylinder valve. If the leak cannot be stopped, take the following actions:

- evacuate the area, securing entrances and providing assistance to others on the way out;
- avoid creating any source of ignition;
- immediately call Security at X3717 and report the leak:
  - location of the leak;
  - type and number of gas cylinders involved;
  - dangers associated with the gas(es);
- provide Security and/or the University Hazardous Materials Response Team with details upon their arrival;
- always ensure the work area has been thoroughly ventilated before any re-entry.

17. Glossary

Absolute pressure: Based on a zero pressure reference point, the perfect vacuum. Measured from this point, standard atmospheric pressure at sea level is 14.7 pounds per square inch (psi) or 101.325 kilo Pascals (kPa). This is usually expressed as psia where the 'a' indicates an absolute measurement or kPa.

Asphyxiant gas: Any non-toxic gas which displaces atmospheric oxygen below limits required to support life. These gases are usually colorless, odorless and tasteless and include nitrogen, argon and helium.

Burst disc: A type of pressure relief device which consists of a disc, usually of metal, which is held so that it confines the pressure of the cylinder under normal conditions. The disc ruptures at a design pressure/temperature range selected for overpressure or in the case of cylinders in fires, to prevent the rupture of the container.

Compressed gas: Any contained mixture or material with either an absolute pressure exceeding 275.8 kPa at 21°C or an absolute pressure exceeding 717 kPa at 54°C, or both, or any liquid having an absolute vapour pressure exceeding 275.8 kPa at 37.8°C.

Compressed gas cylinder: A compressed gas cylinder is any metal cylinder of the type approved by the U.S. Department of Transportation (DOT) and/or Transport Canada for storage and transportation of gases under pressure, including liquefied gases.

Corrosive gas: A gas that is in contact with living tissue causes destruction of the tissue by chemical action.

Cryogenic liquid: A liquid with a normal boiling point below -150°C (-238°F).

Cylinder valve: A mechanical device attached to a compressed gas cylinder that permits flow into or out of the cylinder, when the device is in the open position and prevents flow when in the closed position.

Dewar: Is an open-mouthed, non-pressurized, vacuum-jacketed container used to hold cryogenic fluids.

Fire-protection rating: The time in hours or fraction thereof that a closure, window assembly or glass block assembly will withstand the passage of flame when exposed to fire under specified conditions of test and performance criteria, or as otherwise prescribed in the Building Code.

Fire-resistance rating: The time in hours or fraction thereof that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria or as determined by extension or interpretation of information derived therefrom as prescribed in the Building Code.

Fire separation: A construction assembly that acts as a barrier against the spread of fire and may or may not have a fire-resistance rating or a fire-protection rating.

Flammable gas: A material that is a gas at 68° F (20°C) or less at 14.7 pounds per square inch atmosphere (psia) (101 kPa) of pressure [a material that has a boiling point of 68°F (20°C) or less at 14.7 psia (101 kPa)] which:

- Is ignitable at 14.7 psia (101 kPa) when in a mixture of 13 percent or less by volume with air; or
- Has a flammable range at 14.7 psia (101 kPa) with air of at least 12 percent, regardless of the lower limit.

Flashback: The return of flame through the blowpipe into the hoses and even the regulators. It may also reach the acetylene cylinder causing heating and explosive decomposition of the contents.

Flashback arrestor: The arrestor quenches a flame front (flashback or acetylene decomposition) travelling in a direction opposite to the normal flow. Flashback arrestors often incorporate other safety features which may include non-return valves, cut off valve and safety valve.

Gauge (g): suffix to indicate the pressure relative to the local atmospheric pressure, not as an 'absolute pressure'. Indicated as directly following the usual unit measurement e.g. brag, psig, pig.

Handling: Moving, connecting or disconnecting a compressed or liquefied gas container under normal conditions of use.

Inert gas: A gas which is chemically inactive.

LDF: Leak detection fluid, applied to valve and other potential leakage points, to detect leaks e.g. VFV Leak Detector, Teepol HB7.

Lecture bottle: A small compressed gas cylinder that is typically 2-3 inches (5-8 cm) in diameter and 12-18 inches (30-45 cm) in length. These smaller cylinders are used for holding calibration gases or in applications where large quantities of gases are not required.

LEL: Lower Explosive Limit: The lowest concentration of a gas, in air, that will burn or explode when exposed to an ignition source.

Liquefied gas: A fluid within a pressurized container, other than in solution, which exists both as a liquid and gas at 20°C (68°F). Examples include propane, butane, ammonia, carbon dioxide and sulfur dioxide.

LPG: Liquefied Petroleum Gas

NFPA: National Fire Protection Association (USA)

Oxidizing gas: A gas that can support and accelerate combustion of other materials.

PPE: Personal Protective Equipment relates to clothing, footwear, hand, face and hearing protection appropriate when handling and using gases.

Pressure gauge: A device which indicates pressure.

Pressure regulator: A device used to reduce pressure from a higher pressure source such as a gas cylinder to a controllable safer working pressure range.

PSI: Pounds per square inch, a unit of pressure.

PSIG: Pound force per square inch gauge, a unit of pressure relative to the surrounding atmosphere.

Pyrophoric gas: A gas that will spontaneously ignite in air at or below 54.4°C (130°F). Examples include silane and phosphine.

SDS: Safety Data Sheets.

TGDR: Transport Canada – Transport of Dangerous Goods Regulations.

Toxic gas: A substance that has the ability to produce injurious or lethal effects through its chemical interaction with the human body.

UEL: Upper Explosive Limit: The maximum concentration of a gas, in air, that will burn or explode when exposed to an ignition source.

WHMIS: Workplace Hazardous Materials Information System.

18. References

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Selection and Use of Cylinders, Spheres, Tubes and other Containers for the Transportation of Dangerous Goods Class 2, CSA B340
NFPA 45 Standards on Fire Protection for Laboratories Using Chemicals
NFPA 55 Compressed Gases and Cryogenic Fluids Code
NFPA 58 Liquefied Petroleum Gas Code
National Fire Code of Canada (including Quebec modifications)
Ontario Fire Code, Section 5.6 Compressed Gas Cylinders, Office of the Ontario Marshall
Transport Canada – Transportation of Dangerous Goods Regulations (TGDR)
Matheson - Safe Handling of Compressed Gases in the Laboratory and Plant 2011
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Appendix I: [Flammable or Toxic] Compressed and Liquefied Gases

COMPRESSED AND LIQUEFIED GASES FLAMMABLE OR TOXIC (NFPA HEALTH 3 OR 4)

Gas	State	Flamm*	Health	Gas	State	Flamm*	Health
Acetylene	Gas	Y		**Hydrogen Bromide**	Gas	N	3
Allene (Propanediene)	Liquid	Y		**Hydrogen Chloride**	Gas	N	3
Ammonia	Liquid	Y	3	**Hydrogen Cyanide**	Liquid	Y	4
Arsine	Liquid			**Hydrogen Fluoride**	Gas	N	4
Boron Trichloride	Gas	N	3	**1,1-Difluoroethane**	Liquid	Y	
Boron Trifluoride	Gas	N	3	**Hydrogen Selenide**	Liquid	Y	3
1,3-Butadiene	Liquid	Y		**Hydrogen Sulfide**	Liquid	Y	4
n-Butane	Liquid	Y		**Ketene**	Gas	Y	
iso-Butane	Liquid	Y		**Methane**	Gas	Y	
1-Butene	Liquid	Y		**Methylacetylene (Propyne)**	Liquid	Y	
2-Butene	Liquid	Y		**Methylamine**	Liquid	Y	3
Carbon Monoxide	Gas	Y	3	**Methylbromide**	Liquid	Y	3
Carbonyl Chloride(Phosgene)	Gas	N	4	**3-Methyl-1-butene**	Liquid	Y	
Carbonyl Fluoride	Gas	N	4	**Methyl chloride**	Liquid	Y	
Carbonyl Sulfide	Liquid	Y	3	**Methyl ether**	Gas	Y	
Chlorine	Gas	N	3	**Methyl Fluoride**	Liquid	Y	
Chlorine Dioxide	Gas	N	4	**Methyl Mercaptan**	Liquid	Y	4
Chlorine Monoxide	Gas	Y	3	**2-Methylpropene**	Gas	Y	
Chlorine Trifluoride	Gas	N	4	**Natural Gas**	Gas	Y	
1-Chloro-1,1-difluoroethane	Liquid	Y		**Nitric Oxide**	Gas	N	3
Chlorotrifluroethylene	Liquid	Y		**Nitrogen Dioxide**	Gas	N	3
Cyanogen	Liquid	N	4	**Nitrogen Trioxide**	Gas	N	3
Cyanogen Chloride	Liquid	N	4	**Nitrosyl Chloride**	Gas	N	3
Cyclobutane	Gas	Y		**Oxygen Difluoride**	Gas	N	4
Cyclopropane	Liquid	Y		**Ozone**	Gas	N	4
Deuterium	Gas	Y		**Pentaborane**	Liquid	SI	4
Diazomethane	Gas	Y	4	**Iso-Pentane**	Liquid	Y	
Diborane	Gas	SI	3	**Phosphine**	Gas	SI	4
1,1-Difluoroethane	Liquid	Y		**Propane**	Liquid	Y	
Dimethylamine	Gas	Y	3	**Propylene**	Liquid	Y	
Dimethyl Ether	Liquid	Y		**Selenium Hexafluoride**	Gas	N	3
2,2-Dimethylpropane	Liquid	Y		**Silane**	Gas	SI	
Ethane	Gas	Y		**Silicon Tetrafluoride**	Gas	N	4
Ethylacetylene	Liquid	Y		**Stibine**	Gas	Y	4
Ethyl Amine	Liquid	Y	3	**Sulfur Tetrafluoride**	Gas	N	4
Ethyl Chloride	Liquid	Y		**Sulfuryl Fluoride**	Gas	N	
Ethylene	Gas	Y		**Tetrafluoroethylene**	Liquid	Y	
Ethylene Oxide	Liquid	Y	3	**Tetrafluorohydrazine**	Liquid	Y	
Fluorine	Gas	N	4	**Trimethylamine**	Liquid	Y	3
Formaldehyde	Gas	Y	3	**Vinyl Bromide**	Liquid	Y	
Germane	Gas	Y		**Vinyl Chloride**	Liquid	Y	
Hexafluoroacetone	Gas	N	3	**Vinyl Fluoride**	Liquid	Y	
Hydrogen	Gas	Y					

* : Flamm: Flammable, Y = Yes; N= No; SI = Spontaneously ignite

Appendix II: Classification of Refrigerants

Classification	Denomination	Composition or Chemical Formula (mass percentage)	Safety Classification
INORGANIC COMPOUND			
R717	ammonia	NH_3	B2
R718	water	H_2O	A1
R744	carbon dioxide	CO_2	A1
ORGANIC COMPOUND			
Hydrocarbons			
R170	ethane	CH_3CH_3	A3
R290	propane	$CH_3CH_2CH_3$	A3
R600a	isobutane	$CH(CH_3)_2CH_3$	A3
Halocarbons			
Chlorofluorocarbons (CFCs) and Bromofluorocarbons (BFCs)			
R11	trichlorofluoromethane	CCl_3F	A1
R12	dichlorodifluoromethane	CCl_2F_2	A1
Hydrochlorofluorocarbures (HCFC)			
R22	chlorodifluoromethane	$CHClF_2$	A1
R141b	1,1-dichloro-1-fluoroethane	CH_3CCl_2F	A2
R142b	1-chloro-1,1-difluoroethane	CH_3CClF_2	A2
Hydrofluorocarbons (HFCs)			
R32	difluoromethane	CH_2F_2	A2
R125	pentafluoroethane	CHF_2CF_3	A1
R134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	A1
R143a	1,1,1-trifluoroethane	CH_3CF_3	A2
R152a	1,1-difluoroethane	CH_3CHF_2	A2
Azeotropic mixtures			
R502		R22/R115 (48.8/51.2)	A1
R507		R125/R143a (50/50)	A1
Zeotropic mixtures			
R404A		R125/R143a/R134a (44/52/4)	A1
R407C		R32/R125/R134a (23/25/52)	A1
R410A		R32/R125 (50/50)	A1

Toxicity classification: **Class A** signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm; **Class B** signifies refrigerants for which there is evidence of toxicity at concentrations below 400 ppm.

Flammability classification: **Class 1** indicates refrigerants that do not show flame propagation when tested in air at 21°C and 101 kPa; **Class 2** indicates refrigerants having a lower flammability limit of more than 0.10 kg/m^3 at 21°C and 101 kPa and a heat of combustion of less than 19 kJ/kg; **Class 3** indicates refrigerants that are highly flammable as defined by a lower flammability limit of less than or equal to 0.10 kg/m^3 at 21°C and 101 kPa or a heat of combustion greater than or equal to 19 kJ/kg.

Appendix III: CGA Connection for Compressed Gas Cylinder Regulators

Gas	CGA Connection	Gas	CGA Connection
Acetylene	510	**Hydrogen**	350
Air (breathing air)	346	**Hydrogen chloride**	330
Air (industrial grade)	590	**Hydrogen fluoride**	670
Ammonia	705/240	**Hydrogen sulfide**	330
Argon	580	**Isobutane**	510
Arsine	350	**Isobutylene**	510
Butane	510	**Krypton**	580
Carbon dioxide	320	**Methane**	350
Carbon monoxide	350	**Methyl mercaptan**	330
Chlorine	660	**Natural gas**	350
Diborane	350	**Neon**	580
Ethane	350	**Nitric oxide**	660
Ethylene	350	**Nitrogen**	580
Fluorine	679	**Nitrogen dioxide**	660
Freon 12 (dichlorodifluoromethane)	660	**Nitrous oxide**	326
Freon 13 (chlorotrifluoromethane)	660	**Oxygen**	540
Freon 13B1 (bromotrifluoromethane)	660	**Phosgene**	660
Freon 14 (tetrafluoromethane)	580	**Propane**	510
Freon 22 (chlorodifluoromethane)	660	**Propylene**	510
Freon 114 (1,2-dichlorotetrafluoroethane)	660	**Silane**	350
Freon 116 (hexafluoroethane)	660	**Sulfur dioxide**	660
Helium	580	**Xenon**	580