Curtin University

Properties, Facilities & Development

Guidance for Gas Management and Gas Store Design

Details of revisions

Level	Details	Date	Initial

Contents

1 Introduction

1.1 Purpose

The purpose of this document is to outline Curtin University requirements in regard to gas management and for the facilities it is used in.

1.2 Exclusions

The following is not included as part of this guidance document:

- bulk storage tanks.
- liquefied chlorine.
- cryogenic liquids (though some basic information has been provided).
- liquefied natural gas (LNG).

2 Roles, Responsibilities and Authorities

Table 1. Provides an outline of various roles and responsibilities across campus.

Role	Responsibility for Health and Safety (from H&S Responsibilities Procedures)	Responsibility for Chemical Management	Authority
Health, Safety and Emergency Management Department	Provide specialist advice and support to areas in relation to hazardous substances, dangerous goods, regulated chemical waste disposal and controlled substances. Coordinate and administer the Curtin University ChemAlert Database. Provide specialist advice and support for the planning of emergency procedures. Coordinate any communicate between Curtin and emergency authorities for the purpose of planning.	Maintain the Chemical Management System and related guidelines. Ensure emergency planning is undertaken.	Yes – Can authorise the issue of guideline and manageme nt documents
Managers, supervisors	Undertake effective health and safety measures to ensure compliance with the Occupational Safety & Health Act 1984 and other legislative requirements.	Undertake effective chemical management measures to ensure compliance with the Occupational Safety & Health Act 1984 and other legislative requirements.	No
Individual workers/stude nts	Comply with the Occupational Safety & Health Act 1984 and all reasonable directives given in relation to health and safety at work, to ensure compliance with University and Legislative health and safety requirements.	Comply with the Occupational Safety & Health Act 1984 and all reasonable directives given in relation to chemical management at work, to ensure compliance with University and Legislative health and safety requirements.	No
Office of Research and Development –Poisons advisor	Not listed	Provide advice and guidance on the appropriate management and storage of poisons. Aid communication and coordinate with relevant authorities on Curtin's management of poisons. Maintain the Poisons Act Compliance Management Plan and related guidelines.	Advisory
University Chemical	Not listed	Provide advice to the University on	Advisory

Safety Committee		matters relating to chemical safety.	
Curtin Properties, Facilities and Development	Not listed	Manage current and future programs and facilities at Curtin. Provide ‘fit for purpose’ facilities. Ensure staff/contractors/consultants to PF&D are appropriately inducted to undertake the tasks assigned. Ensure staff/contractors/consultants act within University policies and procedures relating to chemical management	Yes
Contractors and consultants		Ensure staff are appropriately inducted to undertake the tasks assigned. Ensure staff act within University policies and procedures relating to chemical management.	No

3 Legislation and Standards

3.1 Acts and Regulations

The legislation that governs the use, storage, and handling of gases at Curtin University can be found at the following websites.

- Commonwealth law: http://www.legislation.gov.au/
- National Standard for the Storage and Handling of Workplace Dangerous Goods
- Work Health and Safety Act 2011 (Harmonised)
- Work Health and Safety Regulations 2011 (Chapter 7) (Harmonised)
- Industrial Chemical (Notification and Assessment) Act 1989
- Industrial Chemical (Notification and Assessment) Act Regulations 1990
- Standard for the Uniform Scheduling of Medicines and Poisons (SUSMP)
- Australian Dangerous Goods Code (found at: http://www.ntc.gov.au/heavy-vehicles/safety/australian-dangerous-goods-code/)
- State Law: http://www.slp.wa.gov.au/Index.html
- Occupational Health and Safety Act (1984)
- WA Occupational Safety and Health Regulation (1996)
- WA Dangerous Goods Safety Act (2004)
- WA Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2007; and
- WA Dangerous Goods Safety (Security Risk Substances) Regulations 2007

3.2 Standards, Codes of Practice and Guidance Material

The applicable standards relevant to gas management and storage at Curtin University are listed below:

- ADG Code 7.4 Australian Code for the Transport of Dangerous Goods by Road or Rail
- AS4332 the storage and handling of gases in cylinders
- AS4289 Oxygen and acetylene reticulation systems
- AS1894 the storage and handling of non-flammable cryogenic and refrigerated liquids
- AS3961 the storage and handling of liquefied natural gas
- AS/NZS1596 The storage and handling of LP Gas.
- AS/NZS2022: Anhydrous ammonia – Storage and handling.

- AS/NZS2243.1 Safety in laboratories – Part 1: Planning and Operational Aspects.
- AS/NZS2982 laboratory design and construction.
- AS/NZS60079 Part 10.1: Explosive atmospheres Classification of areas.

Codes of Practice and Guidance Notes that may apply and are available at:

- WA Department of Mines and Petroleum http://www.dmp.wa.gov.au/Index.aspx.
- Worksafe http://www.commerce.wa.gov.au/worksafe.

4 Gas Management

4.1 Dangerous goods classification

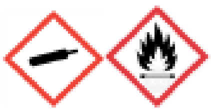
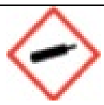
Gases that are compressed, liquefied or dissolved under pressure are classified in the Australian Dangerous Goods (ADG) Code as dangerous goods of Class 2. These include refrigerated liquefied gases, mixtures of one or more gases with vapours of substances of other classes, articles charged with a gas, and aerosols. Class 2 is subdivided as follows:

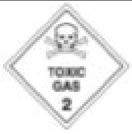
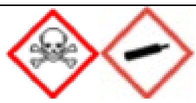
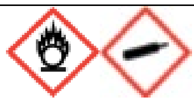
- Class 2.1 flammable gases.
- Class 2.2 non-flammable, non-toxic gases.
- Class 2.2/5.1 non-flammable, oxidizing gases.
- Class 2.3 toxic gases.

Table 2 provides a breakdown of the classification of each DG gas class and its association with the Globally Harmonized System of classification and labelling of chemicals (GHS). The GHS is a single internationally agreed system of chemical classification and hazard communication through labelling and safety data sheets (SDS). Also included are the associated pictograms.

Note: Where appropriate, the ADG Code has allocated subsidiary risks to Class 2 substances. For example, oxygen, being a gas with oxidising properties, is classified as Class 2.2 with a Class 5.1 subsidiary risk. Similarly, anhydrous ammonia is a toxic, corrosive gas and is classified as Class 2.3 with a Class 8 subsidiary risk.

Table 2. DG and GHS Classifications

Dangerous goods classes		GHS Pictogram and Classification	
	**Class 2.1** **Flammable gas** A gas which will burn in air at a pressue of 101.3 kPa	 Flammable Gases – Cat 1	H220 – Extremely flammable gas
	**Class 2.2** **Non-flammable, Non-toxic gases** A gas which is non-flammable, non-toxic, non-oxidising, and is resistant to chemical action under normally encountered	 Compressed Gas, Liquefied Gas & Dissolved Gas Refrigerated Liquefied Gas Compressed Gas, Liquefied Gas & Dissolved	H280 – Contains gas under pressure; may explode if heated H281 – Contains refrigerated gas; may

	conditions.	Gas	cause cryogenic burns or injury
	**Class 2.3** **Toxic 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 KC 50 value equal to or less than 5000ml.m3 (ppm)	 Acute Inhalation Toxicity (gas) Category 1 Acute Inhalation Toxicity (gas) Category 2	H330 – Fatal if inhaled H331 – Toxic if inhaled
	**Class 2.2/5.1** **Non-flammable, Oxidising Gas** A gas which gives up oxygen readily, removes hydrogen from a compound, or readily accepts electrons.	 Oxidising Gases – Category 1	Gases under pressure not otherwise specified H270 – May cause or intensify fire; Oxidiser H280 – Contains gas under pressure; may explode if heated

4.2 State

4.2.1 Compressed Gas

The majority of the gases used at Curtin are compressed gases. When compressed at room temperature these gases do not become a liquid, even at very high pressures. These are sometimes referred to as permanent gases. Nitrogen, air, oxygen, helium, hydrogen and argon are examples of commonly used compressed gases.

4.2.2 Liquefied gas

Some gases will change from a gas to a liquid under high pressure. These gases are usually supplied inside a cylinder in liquid-vapour equilibrium. Initially the cylinder is almost full of liquid, with gas filling the space above the liquid. As gas is removed from the cylinder, a small amount of liquid evaporates to replace it, keeping the pressure in the cylinder constant. Anhydrous ammonia, liquefied petroleum gas (LPG), chlorine, propane, nitrous oxide and carbon dioxide are examples of liquefied gases.

4.2.3 Dissolved gas

Some gases are chemically unstable, even at room temperature and pressure. These may be supplied as dissolved gases. Acetylene is an example of a dissolved gas that is routinely stored and used safely in cylinders at high pressures. This is possible because acetylene cylinders are fully packed with inert, porous filler. The filler is saturated with acetone or other suitable solvent. When acetylene gas is added to the cylinder, the gas dissolves in the acetone. Acetylene in solution is stable. A dissolved gas cylinder should NEVER be laid on its side.

4.2.4 Refrigerated liquefied gas

Some gases will change from a gas to a liquid at low temperatures. These refrigerated liquefied gases or cryogens include liquid nitrogen, argon or helium.

Dry ice or solid carbon dioxide will sublime to carbon dioxide gas.

4.3 Hazards

4.3.1 General

All compressed and liquefied gases should be regarded as hazardous, with the hazards arising from one or more of the following factors:

- Compressed state – rapid expansion takes place suddenly and with considerable force on release of the gases from their container, e.g., liquefied petroleum gas (LP gas).
- Low temperature – many gases, when released rapidly, become cold because of adiabatic expansion. Also, gases stored as cryogenic fluids are at exceptionally low temperatures upon release.
- Reactivity – gases (e.g. chlorine, oxygen, ammonia) which are normally highly reactive with certain substances tend to be much more so when released from the compressed state, by virtue of their high concentration.
- Flammability – many compressed gases are flammable and should be treated as such. Their high concentration and pressure increase the potential hazard.
- Toxicity – the toxic properties of gases, such as ammonia and chlorine increase with increasing concentration in air.
- Oxygen depletion – gas released may displace air, and this can cause asphyxiation, even though the gas may not be very toxic. Examples of these gases are carbon dioxide, helium and nitrogen.
- Density effects – heavier than air gases such as LP gas and carbon dioxide can travel large distances without dilution (or dissipation).

4.3.2 Pressure

Laboratory gases are often supplied in high pressure compressed gas cylinders (13.7 MPa) or as liquefied or dissolved gases under pressure (30 MPa). Gas can be released accidentally and rapidly disperse from broken or leaking valves, faulty regulators, connections, or tubing. Even at a relatively low pressure, gas can flow rapidly from an open or leaking cylinder.

High pressure inside a gas cylinder is a hazard. Damaged cylinders can become uncontrolled projectiles can cause severe injury and damage. Such incidents can happen when unsecured cylinders fall causing the cylinder valve to break.

4.3.3 Asphyxiant

When released in an enclosed space, an asphyxiate gas will displace an equivalent volume of air and effectively decrease the available oxygen concentration.

The percentage of oxygen in the air we normally breathe is approximately 20.9%. A safe oxygen level in air is between 19.5% and 23.5% by volume at normal atmospheric pressure. Below 19.5% oxygen in air is considered oxygen deficient. People entering oxygen deficient areas below 18%, can become dizzy, disorientated, lose consciousness, or possibly die from asphyxiation.

Some gases are heavier than air and will displace oxygen at low levels. These gases disperse less readily than gases which are lighter than air and may pose a greater risk as oxygen concentration is more quickly depleted at the breathing zone.

4.3.4 Flammable

Flammable gases can burn or explode under certain conditions. The ease at which a flammable gas can ignite in air depends on the following:

- Gas concentration – for a gas to ignite, the concentration of the gas in air must be between its lower flammable limit (LFL) and upper flammable limit (UFL).
- Ignition source – for a flammable gas to ignite, an ignition source must be present. There are many possible ignition sources within a workplace including open flames, sparks, hot surfaces, and electrical and electronic equipment that is not intrinsically safe or grounded. Some highly flammable gases, such as hydrogen can even be ignited through static electricity, which may be generated from a gas leak out of piping.
- Auto-ignition – the auto-ignition temperature of a gas is the minimum temperature at which the gas self-ignites without any obvious ignition sources. Some gases have very low auto-ignition temperatures.

Flammable compressed gases can be heavier than air. If a cylinder leaks in a poorly ventilated area, these gases can settle and collect in low areas. The gas can spread far from the cylinder and if the gas contacts an ignition source, the fire produced can flash back to the cylinder.

4.3.5 Oxidising

Oxidising gases are non-flammable, but in the presence of an ignition source and fuel can promote and accelerate combustion. Oxidising gases can react rapidly and violently (causing fire and explosion) with the following combustible materials:

- organic (carbon-containing) substances, e.g., most flammable gases, flammable and combustible liquids, oils, greases, many plastics, and fabrics.
- finely divided metals, e.g., iron, nickel, and aluminium.
- easily oxidisable substances, e.g., hydrazine, hydrogen, hydrides, sulphur or sulphur compounds, silicon and ammonia or ammonia compounds.

Nitrous oxide is an oxidising gas which has additional risk. When nitrous oxide is heated in an enclosed container, auto-decomposition can lead to explosion. Inhalation of low concentrations of nitrous oxide can lead to euphoria, while higher concentrations mixed with air can induce anaesthesia.

4.3.6 Corrosive

Some compressed gases are corrosive. These gases can burn and destroy living tissue, generally when in direct contact with skin and eyes or via inhalation. Corrosive gases can also corrode metals used in piping and apparatus.

4.3.7 Toxic

Toxic gases cause adverse health effects with exposure through inhalation, eye, or skin contact.

Health effects may include severe respiratory, skin or eye irritation through to pulmonary oedema, neurotoxicity, or death. Highly toxic gases are extremely dangerous and may cause significant acute health effects at low concentrations.

4.3.8 Dangerously reactive

Some pure compressed gases are chemically unstable. If exposed to slight temperature or pressure increases, or mechanical shock, they may readily undergo an uncontrolled chemical reaction, such as polymerisation or decomposition. These reactions may result in fire or explosion. Some dangerously reactive gases have inhibitors added to prevent these hazardous reactions.

4.4 Cryogens

Cryogens, also known as refrigerated liquefied gases, are an increased asphyxiant hazard because a large volume of gas can be generated from a relatively small amount of liquid which can rapidly change the composition of the atmosphere in a room. Cryogens also produce a low-temperature gas, which initially settles at ground level and does not readily disperse.

The other major risk associated with the use of cryogens is injury through cold burns and rupture or explosion from over-pressurisation of containers.

4.5 Gas cylinder use, storage and handling

4.5.1 Types of gas cylinders

In general, there are three types of gas cylinders:

- High Pressure Cylinders - High pressure cylinders come in a variety of sizes, refer to Figure 1 and Table 3. Some examples of gases supplied in high pressure cylinders include nitrogen, helium, hydrogen, oxygen and carbon dioxide.
- Low Pressure Cylinders - Low pressure cylinders come in a variety of sizes, refer to Figure 1 and Table 4. Some examples of gases supplied in low pressure cylinder are LPG and refrigerant gases.
- Acetylene Cylinders - Acetylene cylinders are aggregate filled, and acetylene is dissolved in acetone to get sufficient product into the cylinder. Refer to Figure 1 and Table 5. Acetylene is in a class of its own as the cylinder is filled with an aggregate material

Cylinder capacity is typically provided in ‘water equivalent capacity’ which is defined as the mass of water that will absorb or lose as the same quantity of heat as the substance for the same change in temperature. It is used to describe gas cylinder capacity because a gas cylinder is a pressure vessel used to compress and store gases at above atmospheric pressure.

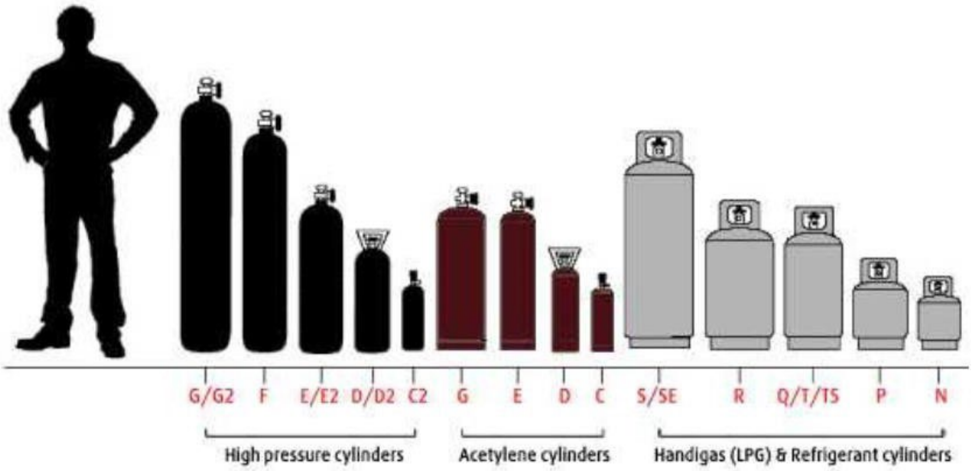


Figure 1 Cylinders (provided by BOC)

Table 3. Approximate dimensions and capacities of cylinders for high pressure industrial gases*

Dimension and unit	C	D	E	F	G
Water capacity, L	2–3	9–10	22–24	34	48–50
Height, mm	460	760	910	1295	1410
Diameter, mm	100–120	150–175	200–215	215	230–250
Empty weight-steel, km	3–5	11	28	–	50
Empty weight-aluminium, kg	3.0	10	22	24	42

**TABLE C1 from AS4332:2004*

Table 4. Approximate dimensions and capacities of cylinders for LP gas and other low-medium pressure gases*

Dimension and unit	N 5 kg	P 9 kg	Q/T 18 kg	R	S 45 kg	90 kg
Water capacity, L	11	23	44	65	108	200
Height, mm	400	500	815	840	1240	1340
Diameter, mm	260	310	310	375	375	508
Empty weight, km	6.5	9.5	20-22	28	38	70

**TABLE C3 from AS4332:2004*

Table 5. Approximate dimensions and capacities of cylinders for acetylene*

Dimension and unit	D	E	G
Water capacity, L	10	24	50
Height, mm	470-490	750-900	800-1000
Diameter, mm	150-200	200-210	265-300
Empty weight, km	16.0	25	50-60

**TABLE C2 from AS4332:2004*

4.5.2 Correct use of cylinders

The following are the recommended safe work practices when using gas cylinders:

- Always use gas cylinders in well ventilated areas. DO NOT use gas cylinders in confined spaces unless qualified to do so and the appropriate PPE is used.
- Know the gas being used and possible reaction products. Additional mechanical ventilation may be required.
- Gas valves should not be opened without a regulator attached. Ensure the correct regulator is used for the purpose.
- Always open a cylinder valve slowly.
- Ensure there is a suitable emergency response procedure in place.
- Wear appropriate PPE for the gas been used, refer to the SDS.
- Ensure connections, fittings and lines are leak tight and suitable for use.
- Ensure that flammable and oxidising gases are not used near ignition sources.
- Disconnect empty cylinders from equipment to avoid backflow issues.
- Always close the cylinder valve when not in use.
- Fit non-return valves in line, if required.
- DO NOT use a gas cylinder that shows evidence of damage or corrosion.
- If the cylinder contents cannot be clearly identified, DO NOT use. Return the cylinder to the supplier.
- 'Empty' gas cylinders should be given the same precautions as full cylinders because a gas cylinder is never completely empty; a certain amount of gas will remain in the cylinder at room pressure and temperature.

4.5.3 Gas cylinders in laboratories

Storage of size F, G and K gas cylinders inside a building should be avoided wherever possible. Gas storage will be located outside the building and reticulated into the areas where gas is required (refer to the section on reticulation for more details).

Where storage outside the building is not possible, provisions can be made for the storage of gas cylinders in the laboratory. Where these cylinders are stored in the laboratory, gas/air quality monitoring sensors will be installed and additional ventilation requirements will apply (refer to 5.8 Ventilation), unless a suitable risk assessment can be presented. These will increase the air changes per hour.

The storage of smaller gas cylinders will be considered on a case-by-case basis.

When storing and using gas cylinders in laboratories, the following procedures should be followed:

- Store cylinders in an upright position.
- Store cylinders in a dry, well-ventilated area.
- Store cylinders in cool areas away from sources of radiant heat and where possible, store cylinders in the shade to avoid exposing cylinders to direct sunlight.

- Secure cylinders using a purpose-built, non-abrasive coated chain, strap or cable that will not scratch the cylinder markings and paint work, or secure using a racking system.
- Place cylinders in a location where they will not be subject to mechanical or physical damage, heat, or electrical circuits to prevent possible explosion or fire. Keep cylinders away from pedestrian traffic.
- Full and empty cylinders should be stored separately in clearly marked areas.
- Objects should not be stored on top of gas cylinders.
- Gases denser than air need to be stored where these gases can collect in low-lying areas.
- Gas cylinders should not be located where they may block stairs, exits, ladders or walkways.
- Ensure an up to date and accurate inventory is kept. Keep gas cylinder quantities as low as possible.
- Where cylinders have been lying on their side, place in an upright position and wait 30 minutes before using.
- When the cylinder is not in use, completely close the valves and keep the valve protection devices, such as caps or guards, securely in place.
- The location of the laboratory storage should be as close as possible to the usage point.

The following additional procedures should be followed when storing flammable gas cylinders:

- Do not store near sources of ignition.
- Erect appropriate signs stating, “No Smoking”, “No Naked Lights” to preclude ignition sources from these areas.

4.5.4 Gas cylinder handling

Large gas cylinders (e.g., size G or F) that can be bulky, heavy and awkward to handle require special care and equipment in handling and securing. The average weight of a full G size carbon dioxide cylinder is over 80 kg (32 kg for the gas and approximately 50 kg for the tare weight of the bottle).

Anyone involved in the handling of gas cylinders should undertake basic induction training or have read the safe work procedures relating to the transport, storage, and use of gas cylinders.

When handling gas cylinders the following procedures should be followed:

- Wear protective footwear, safety glasses. Gloves are also recommended.
- Securely install the valve protection devices when the cylinder is not in use, such as caps or guards. The exemption is size G cylinders, as they will not have a protective cap or guard fitted.
- When moving cylinders, avoid rolling or dragging them. Use an appropriate mechanical handling device. Secure cylinders upright to a proper hand truck or cylinder cart with a restraining strap designed for the purpose. Cylinders size E and greater shall be handled using mechanical assistance.
- DO NOT restrain cylinders around their necks – restrain them around the main cylinder body at a height that will prevent them from falling over, i.e., at least halfway up.

- Avoid dropping or knocking cylinders. Prevent damage to cylinders from impact from other objects (e.g., crashing into other cylinders). Some cylinders (e.g., acetylene) may react violently after being excessively shaken, heated, or knocked.

4.5.5 Temperature

The integrity of gas cylinders can be compromised if stored at high temperatures. Excessive heat (> 65 °C) results in an increase in internal pressure.

Some gas suppliers fit cylinders with a test tag that is heat sensitive. DO NOT use a cylinder if the test tag shows evidence of heat exposure.

Avoid storing cylinders below 0 °C. Some mixtures may separate below this temperature.

4.6 High risk gases

This section is designed to provide some specific information relating to specific gases that are considered problematic or present a high risk. Any requirements or recommendations made in this section should be considered as additional to those already presented above.

4.6.1 Carbon dioxide

Carbon dioxide (CO2) presents a different risk and symptoms when compared to other simple asphyxiant gases. It is not classified as a toxic gas but CO2 can have health effects at high concentrations with the following exposure limits:

Exposure	Exposure limits
Time Weighted Average (TWA) over 8-hour day for 5 days	5,000 ppm or 0.5% v/v
Short Term Exposure Limit: 15 minute TWA (STEL)	30,000 ppm or 3% v/v
Immediate Danger to Life and Health (IDLH)	40,000 ppm or 4% v/v

CO2 gas can also be released from its solid form, ‘dry ice’. Dry ice is at −78 °C and will sublime, change from solid to gas, rather than melt. Handling this very cold material with unprotected hands may also result in cold burns.

Dry ice should not be used or stored in confined, unventilated spaces such as cold rooms. Serious consideration needs be taken when transporting dry ice in lifts, cars or other areas where CO2 may build up to a dangerous concentration. Dry ice should never be stored in sealed (air-tight) containers or coolers, particularly if made from glass. Storage in a sealed container can result in rupture or explosion of the container from over-pressurisation.

4.6.2 Oxygen

Oxygen enrichment is an oxygen concentration greater than 23.5% v/v in air. This can cause combustible materials, including clothing and fabrics, to ignite more easily and fire to spread quickly, burn faster and be very hard to extinguish.

Where oxygen or nitrous oxide is feeding a fire, an attempt should be made to stop the gas leak if it is safe to do so.

4.6.3 Acetylene

Acetylene cylinders are to be used standing vertically on their base. Acetylene cylinders are to be transported standing vertically and are designed to be used in an upright position. For this reason, always store and leave these cylinders standing vertically. Should acetylene cylinders have been stored or transported horizontally, place the cylinders in a vertical position and allow 12□24 hours before use.

4.6.4 Hydrogen

Gaseous hydrogen

Gaseous hydrogen has neither a characteristic colour nor odour. It forms the smallest, lightest molecule of any gas. As a result, gaseous hydrogen better permeates through materials, passes through smaller leak paths, diffuses more rapidly in surrounding media, and has greater buoyancy than other gases. The consequences, arising from these properties, are that released hydrogen rapidly rises and diffuses, but if confined, it can accumulate in high spots.

Hydrogen vessels and piping systems require good seals, and leaks are always a concern. Furthermore, hydrogen leaks are difficult to detect with unaided senses if they do not make an audible noise. It has been demonstrated that hydrogen can permeate slowly through confined materials. The permeation rate varies for different kinds of materials. For metals such as steel, at ambient temperature, the rate is extremely low with insignificant quantities permeating over very long periods of time. Some caution should be observed with polymeric materials, which allow greater permeation and therefore significant quantities of hydrogen can accumulate, if the flow enters a small unventilated volume. Hydrogen gas dissolved in a liquid can permeate into adjoining vessel materials.

Aspects of combustion

The principal hazard presented by hydrogen systems is the uncontrolled combustion of accidentally released hydrogen. This holds true because of the high potential for leaks and formation of combustible mixtures, the ease of ignition of these mixtures, and the potential for high-energy releases that can occur as a fire or an explosion.

Flammability limits are a convenient means for conveying the range of fuel/oxidiser mixture compositions capable of supporting combustion. They are expressed as a lower flammability limit (LFL) for the minimum amount of fuel that supports combustion, and an upper flammability limit (UFL) for the maximum amount of fuel that supports combustion and are commonly expressed on a volume fraction (percentage) basis. Hydrogen flammability limits is 4.0 to 75% volume fraction in air and detonability limits is 18.3 to 59% volume fraction in air (ISO/TR15916:2004).

There is evidence to suggest that at pressures as low as 22 bar, if suddenly released, hydrogen could spontaneously combust1.

Dispersion

Hydrogen possesses high buoyancy and greater diffusivity than other gases. Under ambient conditions, hydrogen has a density of 0,083 8 kg/m3 and a specific gravity of 0,069 6 (air = 1). Therefore, hydrogen is approximately 14 times less dense than air, making it the lightest of all gases.

In the case of gaseous hydrogen leaks, its high buoyancy affects gas motion considerably more than its high diffusivity. However, the effects of wind can dominate diffusion and buoyancy. The buoyancy of hydrogen when it is allowed to rise will create convection currents. Because of these properties, hydrogen gas readily disperses and forms ignitable mixtures with air. In an unconfined atmosphere, these mixtures quickly dilute to a level below the lower flammability limit.

Safety considerations

Safety considerations that arise from the gaseous hydrogen deflagration and detonation behaviour include understanding:

- Whether system failures can lead to hydrogen-oxidiser mixture.
- The influence of confinement both within and outside of the system.
- The consequences of formation of high pressures, high temperatures and rapid propagation of flame fronts.

Deflagrations of gaseous hydrogen-air mixtures can produce pressures as much as 8 times the initial pressure. Detonation of hydrogen-air mixtures can produce pressures as much as 16 times the initial pressure and with reflection, pressures 50 times the initial pressure. One important consideration is that the relief systems, designed to protect hydrogen systems from overpressure, rely on sensing the build-up of pressure. Because detonation waves move faster than the speed of sound, relief systems do not sense the approaching wave and cannot react in time to protect the system from the rapid pressure rise.

4.6.5 LNG

LNG is not included as part of this document. Any LNG facility will need to be designed and constructed based on the individual requirements and preferred location selected. All designs must comply with AS3961.

4.6.6 Toxic gases

In addition to the general work practices for working with gases, when using toxic gases, the following must be implemented:

- Conduct all work in a fume cupboard or with appropriate ventilation to prevent exposure by inhalation.
- Use gas monitoring to detect leaks and unexpected release.
- Lock rooms containing toxic gases when not occupied.
- Ensure the main valve on all toxic and highly toxic gas cylinders is always closed when the cylinder is not in use.
- Clearly placard that a toxic gas is present at the entrance to the work area.
- Provide respiratory protection if there is a risk of exposure to a laboratory worker which exceeds exposure limits.
- Do not work with toxic or highly toxic gases alone.
- Do not store toxic gases within the laboratory when not in use. Depending on their toxicity and expansion factors some of these gases must be stored in a continuously ventilated cabinet or be reticulated into the laboratory.

5 Gas Management

5.1 Gas store design

5.1.1 General requirements

Unless instructed by the principal or superintendent, the gas store shall meet the relevant Australian standards, the National Construction Code (NCC) and the requirements of this guidance document.

Design, installation, and commissioning shall be carried out by competent personnel with experience in the required field(s).

Equipment and systems provided shall be new, free from defects and meet with the relevant technical specifications.

5.1.2 Storage quantities

Minor storage quantities

Where feasible, the quantities of gas should be restricted to the minimum levels consistent with the operations of the laboratory, workshop, pilot plant area or any space where gas is used, handled or stored. Table 6 provides details of the maximum quantities of gases permissible for minor storage based on the guidance provided in AS4332, statutory placard quantities and WHS regulations 2011.

Table 6. Maximum Quantities of Gases Permissible for Classification as Minor Storage

Class of gas	Maximum aggregate water capacity(L)	Approximate equivalent 'G' size bottles
2.1	200*	4
2.2	1,000	20
2.3	50	1
aerosols	5,000	N/A
Cryogenic fluids	1,000	N/A

*under WHS Regs. 2011

NOTE: A 'G' size cylinder is approximately 50 L internal volume.

Dangerous goods storage quantities

Figure 2 summarises the regulatory regime for the storage of dangerous goods.

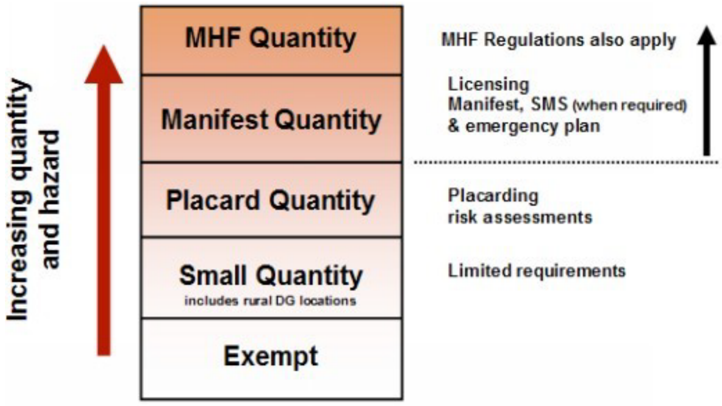


Figure 2 Schematic showing storage and handling regulatory regime (Storage and handling of dangerous goods – Code of practice)

The licensing of dangerous goods is not required until the stored volumes are above the manifest quantities stated in the WA Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2007, Schedule 1 — Quantities of Dangerous Goods (outlined in Table 7).

Table 7. Maximum Quantities of Gases Permissible for Classification as Minor Storage

Class of Gas	Placard Quantity (L)	Manifest Quantity (L)
Division 2.1 except aerosols	500 – WA only (200 under WHS Regs.)	5,000
Division 2.2 except aerosols	1,000	10,000
Division 2.3	50	500
Division 2.1 and 2.2 aerosols	5,000	10,000
Cryogenic fluids	1,000	10,000

5.2 General store requirements

Gas stores should be located outdoors, preferably in a secure cage protected from sunlight. Storage indoors is not recommended unless the building has been designed for that purpose with appropriate fire-rated walls and ventilation. Where gases are stored indoors, additional safety considerations and control measures need to be given.

The following general requirements apply to the construction of stores (as per AS4332):

- Areas in which cylinders are kept shall be:
    - Away from any artificial sources of heat, e.g., radiators, boilers, or steam pipes, except when there has been prior consultation with the cylinder supplier on the particular circumstances.
    - Kept clear of combustible materials, vegetation, and refuse for not less than 3 m from any cylinder.
- Stores shall be located on the ground floor.
- The base or floor shall be:
    - Level or, where appropriate, suitably slopped to ensure adequate drainage without compromising cylinder stability.

- Constructed of non-combustible materials, e.g., paved or constructed of suitable material which can maintain its integrity under all weather conditions.

- Any space between the ground floor and the ground itself shall either be completely filled with non-combustible, solid material or be completely open on at least two opposite sides. Materials shall not be kept or be allowed to accumulate in such a space.
- The walls and roof, if fitted, shall be clad with non-combustible materials. Where practicable, the supporting structure shall also be constructed of non-combustible materials.
- Bollards, crash barriers or other suitable protective devices shall be installed where there is a risk of cylinders being damaged by vehicular impact.
- The doors in gas cylinder stores shall open outwards or be of a ventilated roller type that can be opened from inside the store.
- A minimum fire resistance level (FRL) of 120/120/120 shall be maintained for minor stores.
- All electrical fittings shall be installed in such a manner as to prevent the possibility of their being subject to impact by cylinders.
- Electrical equipment to be used within a store containing flammable gases shall comply with and be installed in accordance with AS/NZS3000.
- Ignition sources shall not be in a store containing flammable gases.
- The possible generation of static electricity in a store containing flammable gases shall be controlled in accordance with AS/NZS1020.

5.3 Segregation and separation

The incompatibility or increased reactivity of some gases significantly increases risks if stored close to some other gases. As part of the management processes, Australian standards (AS4332 and AS4289) provide guidance on the segregation of gas cylinders. Segregation within stores should comply with the following:

- Gases of Class 2.1 (flammable gas) shall be segregated from those of Class 2.2/5.1 (oxidising gas) by at least 3 m.
- Gases of Class 2.3 (toxic gas) shall be segregated from gases of Class 2.1 (flammable gas) and/or 2.2/5.1 (oxidising gas) by at least 3 m.

Notes:

- This distance may be measured in a horizontal plane around an intervening screen wall having an FRL of at least 120/120/120, provided that its height extends at least 0.5 m above the highest cylinder in the store.
- Gases of Class 2.2 may be used to segregate the above gases.

5.3.1 Acetylene

For safe distances in the use of the designated gases, the following shall apply:

- The minimum safety distance between acetylene and oxygen cylinders shall be 3m.
- The minimum safety distance for acetylene cylinders shall be 3 m from liquid nitrogen, liquid argon and liquid carbon dioxide storage and 3m from a liquid oxygen fixed installation.

- The minimum safety distance of 3 m shall be maintained between acetylene cylinders and the following:
    - Naked flame, smoking and other sources of ignition.
    - Openings in walls of offices and workshops.
    - Work sites.
    - Car parks.
    - Flammable gas cylinders in storage or in use.
    - Site boundaries.
    - Public places.

The location of gas cylinders using non-flammable, non-toxic gases may be located adjacent to acetylene cylinders that are also in use.

For minor quantities separation distances may be measured in a horizontal plane around the end of any firewall with a fire resistance level of 120/120/120, provided that the top of the firewall is not less than 0.5 m above the top of the cylinder valve.

5.4 Outdoor minor storage

In addition to the appropriate requirements of section 5.2, outdoor minor stores of Class 2 gases in cylinders should be separated from other dangerous goods stores by a minimum distance of 3 m, in accordance with AS4332. Outdoor stores should not be located within 1 m from any door, window, air vent or duct.

5.5 Indoor minor storage

The indoor use and storage of gas cylinders should be avoided wherever possible. Where it is impractical to provide an outdoor cylinder store, in addition to the appropriate requirements of section 5.2, the keeping of cylinders indoors shall, in accordance with AS4332, be restricted as follows:

- The total capacity of gas in cylinders allowed for any indoor location must include cylinders in use, spare cylinders not in use, and used cylinders awaiting removal.
- The total capacity of the gases kept shall not exceed one minor storage quantity per 200 m2 of floor area. Where the floor area exceeds 200 m2, any storage arrangement of the gases should not result in an undue concentration of cylinders.
- Indoor minor stores of gases in cylinders need to be separated from other minor stores of gases or other dangerous goods stores by a minimum distance of 5 m.
- Except for Class 2.2 gases having no subsidiary risks, gas storage in basements should not be undertaken.
- Where cylinders are kept inside a building or a confined area, e.g., a shipping container, that building or area shall be adequately (preferably mechanically) ventilated (refer to Section 5.8 Ventilation for further details).

5.6 Stores above minor quantities

This section sets out requirements and recommendations (in addition to section 5.1) for the construction and location of stores for gases in cylinders, in quantities greater than those given for minor storage.

Where the gas store is to be located adjacent to a building or located within a building, it should, in accordance with AS4332, be separated from the remainder of the building by one or more walls, each having an FRL of at least 240/240/240. The floor above any store in a multi-storey building shall be constructed of materials having an FRL of not less than 180/180/180.

Note: Where an FRL is required, reference should be made to the NCC for guidance.

Where there is a requirement for penetrations through the wall the FRL should not be compromised, and any openings should be vapour tight.

5.7 Securing gas cylinders

Most gas cylinders should be stored in an upright position; however, some cylinders are designed to be stored on their side. Secure cylinders, if empty or in use, using a purpose-built, non-abrasive coated chain, strap or cable that will not scratch the cylinder markings and paint work or secure using a racking system. Secure cylinders upright, to a fixed structure at approximately two-thirds the height of the cylinder (a second strap one-third the height of the cylinder could also be used). (See figures 3 and 4.)

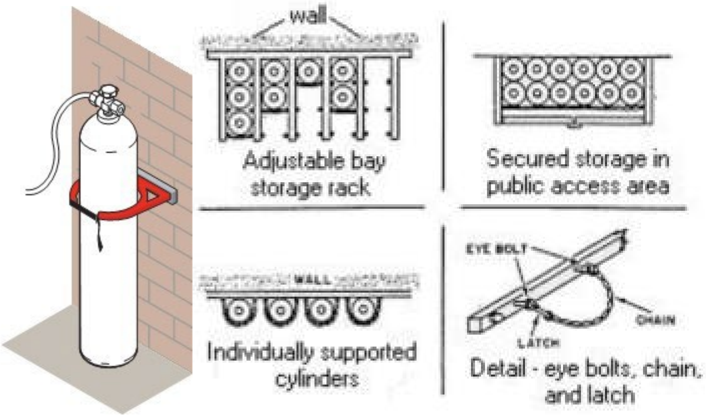


Figure 3 Correct Securing

Figure 4 Incorrect Securing

If cylinders have been lying on their side, the cylinder should be placed in the upright position and wait 30 minutes before using. If acetylene has been laid on its side, then it is recommended that the cylinder is not used for 12 - 24 hours.

5.8 Ventilation

5.8.1 General

It is a requirement of AS4332 that stores must be provided with an appropriate ventilation system. Objectives of the ventilation system are to:

- have the capability to dilute and/or remove any vapour or gas from the store to levels within workplace exposure limits and below any possible explosive levels
- provide sufficient fresh air from the outside to reduce any risk of asphyxiation
- provide air extraction at both high and low levels relative to the floor.

5.8.2 Natural ventilation

The requirements for natural ventilation are set out in AS4332 and have been summarised below. Generally, natural ventilation refers only to the outdoor storage of gas. A naturally ventilated store should have one of the following:

- Two opposing external sides that are open from floor to ceiling.
- One external side that is open, provided that the length of the open side is at least twice the distance of that wall from the opposite side.
- Vents in at least one pair of opposing external sides, provided that:
  - The distance between the opposing external walls does not exceed 10.
  - In every two-metre length of the opposing external walls, there are at least two vents; one positioned immediately above the floor and the other positioned immediately below the ceiling.
  - The total area of the vents per metre length of wall shall be at least 0.1 m2.
  - Vents shall be evenly distributed.

Care should be taken to ensure that any nearby embankments, excavations or retaining walls do not interfere with the operation of a natural ventilation system.

In order to maintain the security of the store it is recommended that the ventilation openings are covered by one of the following:

- Wire mesh or grill.
- Louvres.
- For open, external walls only, chequered brickwork, vent bricks, slotted roller doors or equivalent.
- Fire dampers, where required.

High-level ventilation shall be provided where lighter-than-air gases are present, to prevent their accumulation. Vents shall be provided in the roof ridge or at the highest points of any roof.

5.8.3 Mechanical ventilation

The requirements for a mechanical ventilation system (specifically for indoor storage) are set out in AS4332 and should comprise fans, ducts, entry and exit registers and controls and where required, fire dampers. The system shall comply with the following:

- Exhaust ventilation shall be used within the store.
- The capacity of the system, in cubic metres per second for every square metre of floor space, shall be 0.005.
- The air velocity at the air entry register shall be at least 5 m/s.
- Where localised exhaust ventilation is used, not more than 75% of its capacity shall be located at any one point. At least 25% of the capacity shall be available to ventilate the remainder of the store.
- Any air intake or exhaust duct shall terminate in the open air, at distances of at least:
  - 2 m from any opening to a building.
  - 4 m from the outlet of any chimney or flue.
  - 3 m above the ground.

- The ventilation system shall be designed to operate continuously.

Note: Refer to AS1668.2 for requirements for mechanical ventilation systems.

5.9 Clear access

The means of entry into and exit from the store shall be always kept clear. At all times, access shall be available to:

- firefighting equipment
- personal protective equipment
- clean-up materials and equipment
- the place where the manifest is kept.

5.10 LP gas

This section **only** considers the requirements for the location, design, and construction of storage areas for cylinders. Refer to AS/NZS1596 for comprehensive details on the storage and management of LP gas.

5.10.1 Minor storage

For laboratories, the maximum quantity considered as minor storage is 30 kg: with maximum individual bottles being 15 kg (36 L water capacity).

The following requirements and recommendations apply to the minor storage and use of LP gas (Figure 5):

- The use and storage of LP gas cylinders indoors, regardless of whether the cylinders are full or nominally empty, should be avoided wherever practicable. Cylinders should preferably be located out of doors.
- Cylinders in use shall be connected to an approved appliance and used in accordance with AS5601/NZS5261 or another applicable standard.
- Cylinders shall be kept upright in a well-ventilated area away from any flame, heat or other ignition sources.
- Cylinders shall be located so that they are not likely to be damaged or dislodged under normal circumstances of use. Any trolley or stand in which the cylinder is housed shall be of metal construction and of adequate stability.
- Cylinders shall be kept at least 3 m from oxidising gases, except where the cylinders of LP gas and oxidising gas form part of a portable oxy-fuel system used for welding, brazing, cutting and the like.
- Outside, a cylinder shall be at least 1 m horizontally away from an opening into any building.
- Users of LP gas should be aware of the hazards and risks of its storage and use.

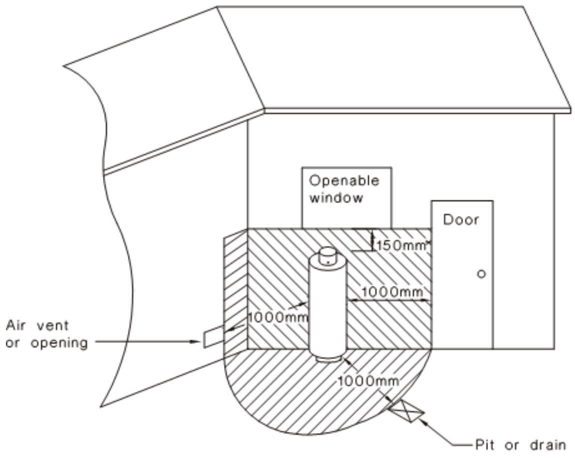


Figure 5 Outdoor cylinder location

5.10.2 General requirements (not including minor storage)

The use of LP gas cylinders indoors is not recommended. Where an outdoor cylinder and piping system cannot be provided, indoor usage of cylinders shall be restricted to portable appliances and equipment.

The distance between any cylinder and any flammable liquid storage that exceeds 250 L capacity shall be at least 3 m.

Cylinders shall be secured to prevent movement or physical damage. Valves shall be safeguarded against physical damage.

An area may be established in order to facilitate the loading and unloading of cylinders from vehicles. This area shall be outside of any hazardous area around the cylinder filling point or cylinder storage area. Cylinders shall not remain in the loading and unloading area for longer than necessary to assemble a load for transportation or to remove them to the filling area for refilling.

5.10.3 Firewalls and vapour

Firewalls and vapour barriers may be used to achieve the separation distances required to protected places and public places. Separation distances may be measured in a horizontal plane around the end of any intervening vapour barrier or firewall.

Building walls may be treated as firewalls or vapour barriers if they qualify as such. A wall on an adjacent property shall not be used as a firewall unless an agreement is in place.

A vapour barrier shall comply with the following requirements:

- The vapour barrier shall be impervious to LP gas vapour over the whole of the area around which the separation distance is to be measured.
- The vapour barrier shall be made of a non-combustible material. Its construction shall be sufficiently durable for the site conditions.

A firewall shall:

- comply with the requirements for vapour barriers.
- have an FRL/FRR of 240/240/240 (walls) and 120/120/120 (to upper floor) in accordance with AS1530.4(NZS/ISO 834).

5.10.4 Cylinders indoors

The use of LP gas cylinders indoors is not recommended. Where an outdoor cylinder and piping system cannot be provided, indoor usage of cylinders shall be restricted to portable appliances and equipment.

The following volumes and restrictions shall apply to LP gas cylinders in use indoors:

- Where the floor area is less than or equal to 200 m2, minor storage conditions and restrictions apply.
- Where the floor area is greater than 200 m2, a maximum volume of 100 L (water capacity) of LP gas per 200 m2 of floor area applies.
- Such groups of cylinders (as described in Item (b)) shall be separated by at least 10 m. Cylinders in such groups need not be manifolded and may supply different consuming appliances.

5.10.5 Cylinders outdoors

Cylinders that are installed outdoors shall be in accordance with the following requirements:

- Cylinders shall be separated from public places by 1.5 m and protected places by 3 m (up to 2,500 L water capacity).
- Where cylinders are adjacent to a building, they may be placed next to each other in a group of up to 2,500 L water capacity. Where there is more than one such group, there shall be a minimum distance of 3 m between the cylinder groups.

5.10.6 Hazardous zone

The hazardous zone surrounding a gas cylinder, as specified in AS/NZS60079.10.1:2009, shall be maintained free of ignition sources (refer to figures 6 and 7).

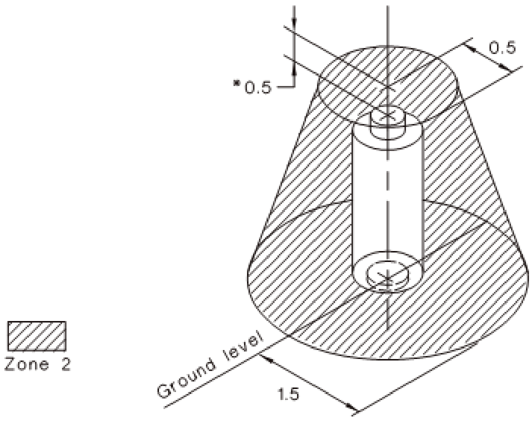


Figure 6 Exchange cylinder

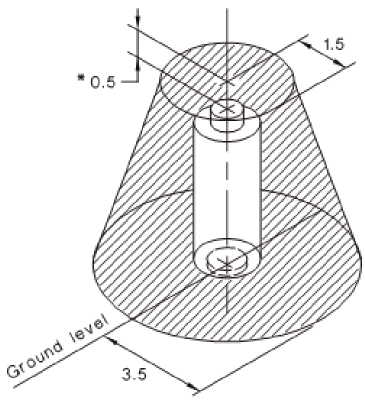


Figure 7 In-situ fill cylinder

The use of LP gas is in accordance with AS5601/NZS5261 or another relevant standard.

6 Display of Hazard Identification Information

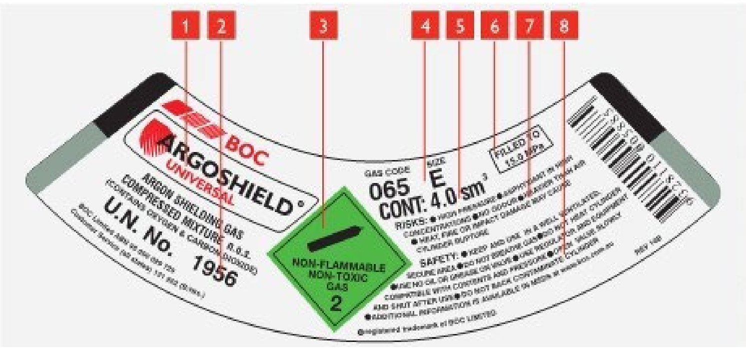
6.1 Gas cylinder labelling

Note: Cylinders should be delivered from the supplier with the correct labelling. Gas cylinders are required to be labelled with the following:

- a class label and any subsidiary risk labels
- the proper shipping names
- a four-digit United Nation's number
- the manufacturer/importer's name

Cylinder sizes are denoted by a letter code. The gas content of cylinders is measured in cubic metres, litres, or kilograms. If the volume unit is given, it refers to standard temperature and pressure of 15 °C (101.3 kPa).

NEVER alter the markings, labelling or colour coding of gas cylinders supplied.



1	Gas name and grade
2	United Nations numbering system for safe handling, transport and storage
3	Dangerous Goods Classification
4	BOC gas code and cylinder size
5	Contents of cylinder at standard temperature and pressure i.e. (15°C @ 101.3kPa)
6	Nominal filling pressure at standard conditions (for permanent gas)
7	Caution – indicated major hazards*
8	General safety information*

Figure 8 BOC Gas Labelling

6.2 Signage

At the entrance to the gas store, the following signs should be displayed:

- restricted access with a sign "Authorised access only"
- dangerous goods (DG) diamonds.

Refer to AS1216 for details of specific class labels for dangerous goods.

Refer to AS1319 for requirements of safety signs for the occupational environment.

DG diamonds shall be in the form of a square set on an angle of approximately 45° (diamond shaped). The surface of each label shall have a line of the same colour as the symbol, inside the edge and running parallel with it. This line shall be 5 mm inside the edge for a label of dimensions of 100 mm x 100 mm. For labels of other sizes, the distance of the line from the edge shall be reduced or increased in proportion to the size of the label. The store should also have restricted access with a sign “Authorised access only” (or equivalent).

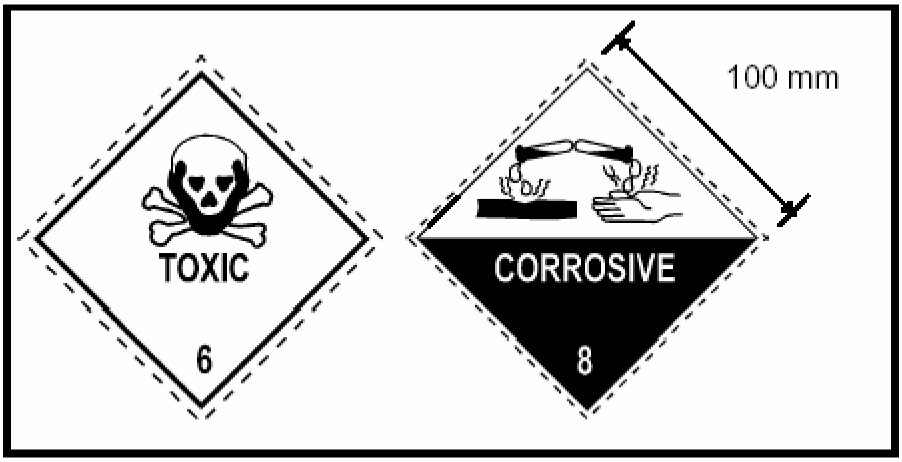


Figure 9 Example of a DG diamond

6.3 Placarding requirements

6.3.1 Principles

Placarding is required when volumes of gases exceed those identified in Table 7.

Placards provide visual warning of the hazards associated with the storage of dangerous goods at the site. This is particularly important for DFES personnel.

There are three placard types:

- an outer warning placard, known as the Hazchem placard, on the outside approaches to the site
- placards at each location of dangerous goods in bulk (e.g., tanks)
- placards at each location where packages stored and handled.
- Placards must be readily visible to DFES when approaching the location where the goods are stored or handled so they:
- need to be visible from all normal approaches to the storage location, the main entrance, or both
- must be kept legible and unobstructed.

6.3.2 Outer warning placards

The site must be marked by a Hazchem outer warning placard.

These outer warning placards must be displayed at all road entrances to the site where DFES may gain entry. Usually, this will be at the main road entrance. However, if the site consists of buildings back from the street, such that the placard at the street entrance would not be effective, the outer warning placard should be displayed at each entrance of the building that may be used by DFES.

A Hazchem outer warning placard for dangerous goods must:

- be at least 120 mm high
- display the word ‘HAZCHEM’ as shown in Figure 10, that has:

- in red capital letters at least 100 mm high
- in lettering of the kind shown in Figure 10
- on a white or silver background.

Figure 10 Hazchem sign

6.3.3 Packaged dangerous goods

Placards must be displayed on or near the storage location of bulk dangerous goods.

- A placard for bulk dangerous goods must:
  - Have dimensions not less than the dimensions shown in Figure 11.
  - show the following details for the goods in the following positions on the placard (see Figure 11):
    - In position (p) - the proper shipping name.
    - In position (q) - the UN number.
    - In position (r) - the Hazchem code.
    - In position (s) - the class label and the subsidiary risk label (if any).
- The numbers and letters used for the proper shipping name, UN number and Hazchem code must be:
  - Black on a white background.
  - If the proper shipping name takes no more than 1 line - at least 100 mm high.
  - If the proper shipping name takes 2 lines or more - at least 50 mm high.
- Despite paragraph (2), a letter of the Hazchem code may be white on a black background.
- The class label must:
  - Comply with the form and colouring specified in Chapter 7 of the Australian Dangerous Goods (ADG) Code.
  - If there is also a subsidiary risk label - have sides of at least 200 mm.
  - If there is no subsidiary risk label - have sides of at least 250 mm.
- A subsidiary risk label must:
  - Comply with the form and colouring specified in Chapter 7 of the ADG Code.
  - Have sides of at least 150 mm.

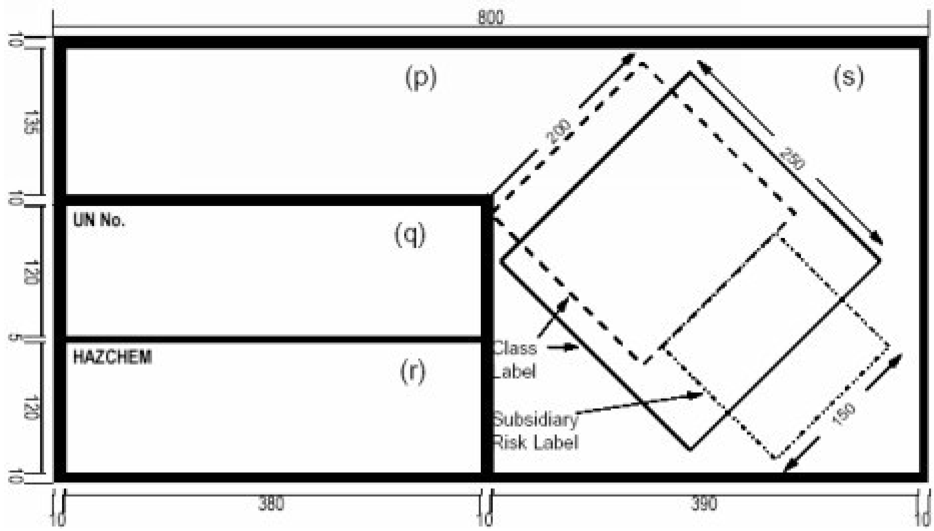


Figure 11 Template of a placard for bulk dangerous goods

Figure 12 Example of a placard for bulk dangerous goods

The class label (including mixed class labels) should be grouped. Grouping need not be in a horizontal line - it can be vertical or diagonal. If there is regular variation in the type of dangerous goods, it may be convenient to use frames for slip-in-and-out labels, such as the type commonly used on vehicles. Vehicles and loads marked in accordance with the ADG Code placards are acceptable.

A placard for packaged dangerous goods must:

- Display the class label for each of the dangerous goods to which the placard relates.
- Comply with the form and colouring specified in Chapter 7 of the ADG Code (refer to AS1216).

Each class label must have sides of at least 100 mm.

7 Gas Reticulation

The storage of size F, G and K gas cylinders inside a building will be avoided wherever possible. It is preferred to locate cylinders outside the building and reticulate into the areas where gas is required.

7.1 Suitability

The suitability for the type of gas and purity required should be considered when designing gas reticulation systems. It is integral that laboratory users are engaged in the design process to ensure the reticulation system will meet their required gas and purity needs.

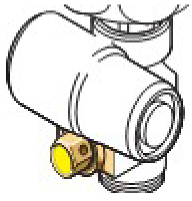
A risk assessment should include assessment of ventilation and air exchange, reticulated pressure and other safety devices fitted, such as regulators, flashback arrestors and excess flow valves.

7.2 Valves and regulators

7.2.1 Cylinder valves

The gas cylinder valve is the primary safety mechanism on a gas cylinder and shall not be tampered with. It is a device used to contain the contents of the cylinder that is under pressure. Cylinder valves are fitted with pressure relief valves of different types (depending on the cylinder) to protect against catastrophic failure of the cylinder valve. Figure 13 shows different types of cylinder valves and Figure 14 pressure relief devices.

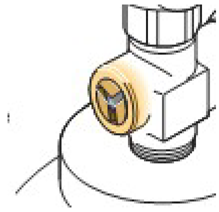
Figure 13 Oxygen and acetylene cylinder valves



Burst disc

In the event of overpressure, this is designed to burst, leaving an open passage for gas contents to escape completely.

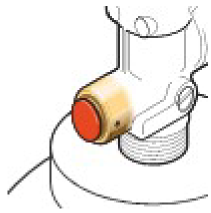
For example: Carbon dioxide (CO2) cylinders are fitted with a burst disc which operates at approximately 207 bar and is fitted on the cylinder valve.



Fusible plug

This 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 valves

This valve is designed to relieve excess pressure and close again after relieving the excess pressure.

For example: BOC Handigas™ (LPG) cylinders are fitted with pressure relief valves which operate at approximately 26 bar.

Figure 14 Pressure relief devices

Cylinder valves OPEN by turning the hand wheel or cylinder valve key anticlockwise. Always open cylinder valves slowly.

Cylinder valves CLOSE by turning the hand wheel or cylinder valve key clockwise.

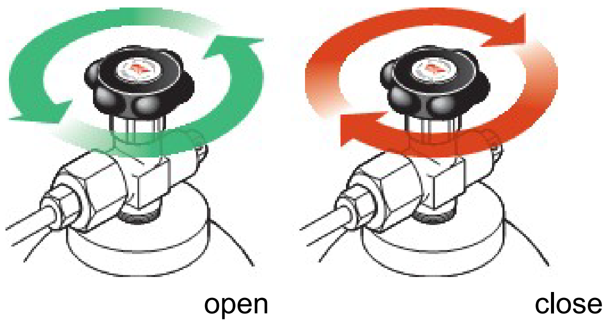


Figure 15 Operation of the cylinder valve

An opened valve should never be left against the backstop (i.e., fully opened until resistance is encountered) as in the fully opened position the cylinder valves may become stuck or seized. The valve should be turned back at least half a turn.

Close the valve by turning it clockwise and just enough to stop the gas completely. Never wrench it closed.

Valves shall never be operated without a regulator attached.

7.2.2 Regulators

The regulator is the next most important safety device to be fitted to a gas cylinder before operation/use. It allows for the high pressure of the cylinder contents to be brought down to a usable working pressure. Regulators come as single stage for short-term applications and two stages for long-term applications. Regulators are also constructed from different materials; mainly brass or stainless steel. The application will define the required regulator.

1) Outlet or regulated pressure gauge
2) Inlet of cylinder pressure gauge
3) Regulator outlet connection
4) Inlet spigot (regulator)
5) Cylinder valve
6) Regulator control knob
   Increase pressure (turn clockwise) Decrease pressure (turn anti-clockwise)

Figure 16 Standard BOC regulator

Regulators are designed to be fitted directly to the cylinder valve. No other fittings, connections or lubricants shall be used to connect a regulator to a gas cylinder valve.

Regulators for flammable gases are left-hand threaded and have a notch cut out of faces on the securing nut (see Figure 19) to distinguish them from non-flammable gas regulators.

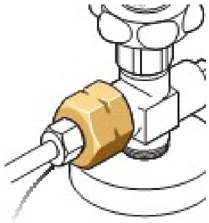


Figure 17 Flammable gas connections

When individual cylinders of the same gas are manifolded together to a common outlet, the pressure regulator must be connected to this single manifolded outlet.

Adjust using the valves downstream of the pressure regulator only and not those fitted upstream, as this will starve the regulator of flow.

7.2.3 Flashback arrestor

To prevent flames travelling back into cylinders, devices known as flashback arrestors should be fitted downstream of pressure regulators in oxygen and flammable gas systems (including acetylene, LPG, LNG, hydrogen, and flammable mixtures).

A flashback is a flame, travelling at supersonic speed, in the opposite direction to normal gas flow in oxy-fuel gas equipment. The use of flashback arrestors is required to limit the potential damage that may result if a flashback occurs. If not stopped, a flashback can melt the equipment which, in the worst case, could explode and travel back to the cylinder.

Flashback arrestors have a sensitive non-return valve that stops the gas flow and a fine sintered filter that quenches the flame. On the regulator end of the flashback arrestor, a thermal cut-off valve is built in. This valve will stop the flow of gas before ignition upstream occurs.

To ensure total safety and protection from the causes and effects of flashbacks, flashback arrestors should be fitted to each gas line, as the risk of a reverse flow of gas exists with both oxygen and fuel gas.

As per AS4839, flashback arrestors should be tested every year.

7.2.4 Excess flow valves

Excess flow valves stop the uncontrolled release of gas should there be a downstream line rupture. All gas cylinders s in use at Curtin should be fitted with excess flow valves.

7.3 Oxygen

For design purposes, the outlet of an oxygen manifold shall be a source of regulated pressure. The pressure regulating device may be built into the manifold, or the manifold may be supplied with a high-pressure oxygen outlet which complies with AS2473 for fitment of a separate pressure regulator.

Materials used in cylinder manifolds shall be compatible with oxygen at the maximum developed pressure and temperature of the cylinder contents. All piping shall be copper or copper alloys or other materials that have been proven suitable for oxygen service at the maximum working pressure.

Warning labels showing the following legends (that comply with AS1319) shall be permanently affixed on, or next to, the manifold:

“USE NO OIL OR GREASE”

“OPEN VALVES SLOWLY”

A safety relief valve shall be provided for the low-pressure side of the manifold or control arrangements. Safety relief valves for the high-pressure side of the cylinder manifold are optional.

A non-return valve and appropriately sized dry-type flashback arresters shall be installed at each outlet point if the system is used in conjunction with a fuel gas to supply an oxy-fuel application.

Refer to AS4289 - 1995 for further details on the installation of oxygen-gas systems.

7.4 Acetylene

A flashback arrester shall be fitted close to the low-pressure side of the pressure regulator. The flashback arrester shall be able to stop acetylene decomposition from either side and withstand its effect. The arrester or an additional device shall stop the fl=ow in case of a sustained flame.

Note: Care should be taken to ensure that the correct arrester is used to obtain the correct flow rate for the application.

Material selection for manifold equipment shall be based on Table 8.

Table 8. Material selection for manifold equipment shall be based on Table 8.

Material	Conditions of use
Copper and copper alloys containingmore than 70% of copper	NOT allowed.
Silver	NOT allowed.
Copper alloys containing up to 70% ofcopper	Not recommended for unpurified acetylene.
Silver alloys	Suitable for brazing, provided that the SILVER CONTENT DOES NOTEXCEED 43% and the COPPER CONTENT DOES NOT EXCEED 21% and that the GAP BETWEEN THE TWO PARTS to be brazed DOES NOT EXCEED 0.3 mm. Special care must be taken to minimise thearea of filler metal exposed to acetylene and to remove as far as practical all traces of flux.
Aluminium **Aluminium alloys** **Zinc alloys**	Not recommended for components which encountermoist acetylene contaminated with lime or ammonia (unpurified generator gas).
Zinc	Suitable as anti-corrosion protective coating.
Jointing materials	All jointing materials used shall be suitable for use with acetylene, e.g., oil-free PTFE.
Organic materials	May be used if it has been proved that they are sufficiently resistant against acetylene, solvents, and impurities.
Steels (carbon and stainless)	For pipeline and piping.

Warning labels shall comply with AS1319, and shall be permanently affixed to the manifold showing the following legends:

"ACETYLENE"

"FLAMMABLE GAS"

"NO SMOKING"

"NO NAKED FLAMES"

7.5 Hazardous area assessment

Where flammable gases are reticulated into laboratories, a hazardous area assessment should be prepared by a suitably qualified hazardous substances consultant, electrical engineering consultant or gas specialist.

It is typically recommended that there are no ignition sources within 1 m of the flammable gas reticulation outlet. However, this will be dependent on:

- suitable ventilation within the room providing adequate air exchanges reducing any potential build-up of gases within the laboratory
- appropriate regulators, flashback arrestors and safety devices, etc. are fitted in accordance with AS4289.

Consideration should also be given to following the same hazard area assessment process for oxidising gases (Class 2.2 Subsidiary risk 5.1) as well.

7.6 Emergency stop

Emergency gas shut-off must be installed in any laboratory where there is reticulated gas. The emergency shut-off will be manually operated by an emergency stop button at a location near to the main entrance/exit. If a gas detection system is installed, this alert system must be linked to the emergency shut-off such that any measured exceedances trigger both an alarm and the gas shut-off.

7.7 Gas detection

Reticulation of gas into laboratories is generally considered not to require monitoring sensors. However, a risk assessment should be undertaken and the decision not to install gas sensors must be backed by the outcomes of the risk assessments, appropriate engineered safety devices, potential release calculations, adequate room ventilation, etc.

Refer to section 9 for more details on gas detection systems.

8 Fire Protection

8.1 General

The store should be equipped with an alarm that will sound at an attended place when there is smoke, or when heat is generated.

The selected method of fire protection shall be compatible with all hazardous chemicals stored. As a minimum, there shall be one portable fire extinguisher immediately outside the door to the store. The following requirements shall apply to gas cylinders in use or in storage:

- For up to and including 12 cylinders, one 2A 60B(E) powder type extinguisher shall be available.
- More than 12 cylinders, two 2A 60B(E) powder type extinguishers shall be available.

Portable extinguishers shall be mounted so that they are easily accessible.

Any cylinder that has been heated or involved in a fire should not be used. Any such cylinder shall be labelled 'DO NOT USE □ HEATED' or similar. The supplier shall be contacted for further safety advice and to arrange a specialised pick-up and return of the affected cylinders.

8.2 Acetylene

Where four or more cylinders are stored or in use, a garden hose shall be provided and permanently attached to a water supply within 8 m of installed cylinders so that cooling can be provided if an acetylene cylinder becomes hot.

Portable extinguishers shall be mounted so that they are easily accessible to the apparatus/workstation where acetylene is being used. In addition, an approved fire blanket shall also be in an accessible position.

Any cylinder that has been heated or involved in a fire should not be used. Any such cylinder shall be labelled 'DO NOT USE □ HEATED' or similar. The supplier shall be contacted for further safety advice and to arrange a specialised pick-up and return of the affected cylinders.

8.3 Fire procedure

In the event of fire, the following apply:

- From a safe, distant, protected location, spray the cylinder with water for at least 1 hour.
- After at least 1 hour, briefly stop the water spray and carefully watch for any generation of steam from the cylinder, or signs of the cylinder surface drying out rapidly. This indicates that the cylinder is still hot.

- If steam has formed or the cylinder is drying out quickly - DO NOT APPROACH THE CYLINDER. Evacuate and cordon off the area. Immediately contact the cylinder supplier for expert advice.
- If the total surface of the cylinder remains wet, it is cool. Carefully approach the cylinder, looking for any problems such as bulging. If there is any visible distortion - DO NOT APPROACH THE CYLINDER. If the cylinder appears normal, quickly check if the fusible plug safety devices have melted and blown out, indicating that the cylinder's contents have been vented.
- Note: Fusible plugs are a screwed plug either in the cylinder valve connection on large cylinders or on the rear of the cylinder valve on small cylinders.
- If the fusible plugs have melted and vented and the cylinder shell is cool to touch, move the cylinder to a safe, well-ventilated location out of doors.
- If the fusible plugs have not vented and are still intact, quickly check the whole cylinder wall for any warmth or hot areas. Then:
    - If any area of the cylinder surface is still warm or hot to touch, evacuate and cordon off the area immediately and call the supplier or emergency services for expert advice.
    - If the cylinder is cool to touch, submerge the cylinder in a water bath for at least 24 hours.
- Tag the cylinder as "heat affected" and arrange for its return to the supplier.

Refer to AS4289 for further details on the installation of acetylene gas systems.

9 Fire Protection

A comprehensive laboratory gas monitoring system may detect gas leaks, gas releases, ventilation failures, and power failures.

A risk assessment should be carried out to determine the requirement for gas detection wherever gas is used.

9.1 Monitors

Gas monitors can be installed as fixed, portable, or transportable, single gas or multi-gas devices.

- A fixed monitoring system is permanently installed in the workplace (stationary). The detecting sensor may be hard wired or use wireless signals to a central reporting station.
- Portable or personal gas detection refers to gas detectors which are worn or carried by an individual. Typically, battery operated, portable monitors are used for toxic or combustible gas detection, as well as for oxygen deficiency monitoring in confined spaces. Portable monitors should be functionally verified prior to each use.

The type, number and location of gas monitors should be determined on a lab-by-lab basis and should consider type of gas, reticulation rate/cylinder size and potential hazards.

A gas sensor should be installed in proximity where a leak would most likely occur and is dependent on the density of the gas and activity carried out. Asphyxiant gases with density greater than air (CO2, cold nitrogen gas from liquid nitrogen) have monitor sensors located at lower levels. Room ventilation exhaust is also located at a lower level. Less dense asphyxiant gases (e.g., helium) have monitor sensors within the breathing zone. A flammable gas less-dense-than-air, such as hydrogen, may have the sensor near the ceiling.

9.2 Action requirements

A gas detection system should interface with any control system installed such that appropriate actions can be achieved. Appropriate actions could include:

- A process can shut down automatically.
- An alert message is sent to key personnel and/or University Security.
- A BMS system can also control access to an area, for example lockout particular workspaces to prevent people entering an unsafe environment.
- Ventilation that is boosted to restore safe atmospheric conditions.
- A distinct audible and visible alarm notifying people both inside and outside the room, giving them the opportunity to evacuate the area or not to enter.

A risk assessment should be carried out to determine the necessary action requirements.

The installation of sensors will require a suitable management plan detailing the action requirements should the alarm be activated.

9.3 Cryogens

At all locations where cryogenic chemicals are stored and/or decanted, unless a suitable risk assessment can be presented, gas/air quality monitoring sensors should be installed. In addition, increased ventilation should also be available. Provisions may be required for air extraction to vent direct to atmosphere.

The installation of sensors would require a suitable management plan detailing action requirements should the alarm be activated.

10 Safety Equipment

10.1 General

Access to an eye wash and a shower would be preferable.

Appropriate personal protective equipment (PPE) should be available for use:

- Protective clothing complying with AS/NZS4501.2, suitable for use with the specific dangerous goods being handled.
- Eye protection, selected in accordance with AS/NZS1337.
- Protective gloves complying with the relevant parts of the AS/NZS2161
- Safety footwear complying with AS/NZS2210. Gloves and boots shall be checked for leaks.

PPE shall be kept separate from normal clothing. After use, all personal protective clothing and equipment shall be cleaned with water or a solution appropriate for the substance. The equipment shall be dried before being put away.

10.2 First aid

A first-aid station shall be provided in a clean area. It shall comprise, as a minimum, an appropriate first-aid kit and first aid instructions, e.g., SDS, for all substances being kept or handled.

The first-aid procedures set out in the relevant SDS should be adopted.

An administrative procedure shall be in place to regularly review this advice as opinions on what constitutes an appropriate response and what antidotes, if any, are appropriate, and are continually changing.

11 Management of Leaks

11.1 Introduction

The following general procedures apply to the management of leaks. They should only be attempted by trained personnel, when it is safe to do so, and when wearing suitable personal protective equipment, and where the characteristics of the gas involved are well understood. Additional special considerations are required in confined spaces or where ventilation is poor.

11.2 Large leaks

If there is a large leak, the procedure set out below should be followed:

- Evacuate the area after providing maximum ventilation; if it is possible and safe to do so. If a flammable gas is leaking, remove or isolate any ignition sources.
- Immediately contact the gas supplier for advice, giving location and a return contact. Where appropriate, contact the emergency services.
- Consult the SDS for the hazards of the gas involved and activate the site emergency plan.
- Do not approach the gas cylinder until trained personnel and expert advice are available, especially if the gas is flammable or toxic.

11.3 Small leaks

If there is a small leak, the procedure set out below should be followed:

- If it is safe and possible to do so, quickly close the cylinder valve. 'Back off' any regulator (i.e., reduce downstream pressure to zero) and shut off any downstream valves. If a flammable gas is involved, isolate any electrical equipment. Consider evacuating the area. Note: Do not use excessive force to shut off a cylinder valve as this can damage the valve seat or break the spindle, making the leak worse.
- Ventilate the area as well as possible. Open windows and doors; and start up any existing fume extraction system.
- Turn off any air-conditioning system to prevent spreading the hazard.
- If appropriate, contact the gas supplier or emergency services for assistance.
- Consult the SDS about the characteristics of the gas.
- Wearing appropriate PPE, approach the cylinder from an upwind area and attempt to locate the leak point. An appropriate leak detection method should be used.
  Note: In many cases, soapy water or a proprietary leak-detection solution may be used. However, some gases could react with water and/or soap and make the issue worse.
- Attempt to minimise or stop the leak. The method chosen will depend on the location of the leak and type of gas, and the following should be considered:

- If the leak is on the cylinder - DO NOT attempt to repair a leaking cylinder safety device, tighten a valve into a cylinder or tighten a leaking valve gland that is under pressure.
- If the leak is through the valve seat outlet - close the cylinder valve, but do not over-tighten. If a suitable regulator is available, ‘back it off’ fully and screw it onto the cylinder valve outlet. If the cylinder has been provided with a gas-tight outlet cap or plug, screw this onto the valve outlet and close it.
- If the gas is flammable - remove all sources of ignition, sparking or static electricity from the area.
- If the gas is toxic - ensure that the correct PPE is used, including self-contained breathing apparatus (SCBA) if necessary.
- If the gas is a liquefiable gas - attempt to position the cylinder so that the leak point is in the vapour space (i.e., highest point) to prevent a liquid leak.

- Once the leak is minimised or controlled, and it is safe to do so, relocate the cylinder to a safe, well-ventilated area where any leaking gas can dissipate safely, e.g., outdoors, or in a fume cupboard with an extraction fan.
- Securely tag the cylinder as “faulty”, giving the reason and leak location.
- Arrange for the supplier of the cylinder to collect and remove the cylinder.

12 Maintenance

12.1 Cylinders

In most cases, the gas supplier (e.g., BOC) is the owner of the cylinder. As the owner, the supplier is responsible for complying with the statutory requirements relating to maintenance and periodic testing of cylinders. AS2030 details the statutory requirements in respect to design, manufacture, inspection, and filling.

12.2 Gas systems

A maintenance program is important to prevent incidents associated with gas cylinders and to extend the service life of gas systems and maximise performance.

12.2.1 Visual checks

Table 9. Visual checks.

Type of check	Description
Complete a visual check of gas line components	Regularly check valves, seals, pipes, and hoses, etc. to detect any damage, cracks, or corrosion. Replace as needed to prevent failure resulting in a gas leak. This process should be completed often if thegas is highly reactive, toxic, or corrosive or used continuously. Valves that pass visual inspection are still subject to failure. It is critical thattoxic gases are used in ventilated enclosures and have local exhaust ventilation in place for downstream pressure relief valves.
Check all cylinder-to-equipment connections	Do this before use and periodically during use. Be sure they are tight, clean, in good condition and not leaking.
Keep regulators and valves free of moisture	Systems should be purged with dry inert gas (e.g., helium, nitrogen,argon, etc.) before the gas is introduced and capped when out of service.
Undertake a commissioning check	This is for any new equipment installations which use gas. If the gasto be used is flammable, oxidising or highly toxic, check the deliverysystem first for leaks with an inert gas (nitrogen or helium) before introducing the hazardous gas.

12.2.2 Leak check

Use only compatible leak-test solutions or leak-test instruments to check for gas leaks within the system. Have the regulator under pressure (both high- and low-pressure side) and check all connections using a gas leak detector or solution. If a leak is detected, shut down the gas source, reduce pressure to atmospheric and tighten or redo connection. Then retest. In a closed system the regulator should not lose pressure if the cylinder is closed at the valve.

12.2.3 Creep test

Regulator ‘creep’ is when there is an increase in outlet pressure above a set point. Creep can occur in two ways:

- Changes in the springs within the regulator when gas flow is stopped.
- Foreign material lodged in the seat of the regulator (most common).

To prevent foreign material causing creep, ensure that the regulator connections, when not in use, are capped to prevent dirt entering the regulator. Tubing should also be flushed to remove foreign material. A pressure relief valve installed downstream of the regulator will also protect against creep.

To undertake a creep test:

- Close the regulator outlet valve or instrument valve to isolate the downstream side of the regulator.
- Close the regulator by turning the pressure adjustment knob counter clockwise until it reaches ‘stop’ or rotates freely.
- Slowly turn on the gas supply. When the regulator inlet gauge registers the full cylinder delivery pressure, shut off the gas supply.
- Turn the regulator adjusting knob clockwise until delivery pressure gauge reads approximately half scale.
- Close the regulator.
- Note the reading on the delivery pressure gauge.
- Wait 15 minutes and recheck the setting on the delivery pressure gauge. If there is any rise in delivery pressure during this time, then the regulator is defective. Remove and replace the regulator.

12.2.4 Regulator ‘dilution’ purging

It is extremely important to purge regulators and gas distribution lines when using pyrophoric, toxic, corrosive, flammable, and oxidising gases. It can also be important for non-reactive gases, particularly in analytical processes, if there is a new gas supply or new piece of gas distribution equipment introduced into the system.

The best way to purge is to alternately pressurise and depressurise the regulator with an inert gas, such as nitrogen. This is a more effective way to purge a system that may contain ‘dead pockets’ than by simply flowing gas through the system.

12.2.5 Service, repair, and replacement

Valves and regulators should only be serviced and repaired by qualified individuals. Consult valve and regulator manufacturers, gas supply companies, or valve and regulator specialty shops for these services. All regulators should be removed from service periodically and inspected with an overhaul if necessary. If the life expectancy of the regulator has been exceeded, it should be replaced to prevent failure. Regulator failure will vary considerably based on conditions of use.

Regulator maintenance or replacement can vary with the types of gases used, the length of use, and conditions of use. Manufacturers can give an indication of the life expectancy of a particular regulator and recommended valve and regulator maintenance schedules, particularly for toxic and corrosives applications. Table 10 gives a general guide to regulator maintenance.

Table 10. General schedule for regular maintenance

Service	Leak Check	Creep Test	Inert Purge	Overhaul	Replace
Non-corrosive	Monthly	Annually	N/A	5 years	10 years
Mildly-corrosive	2 x Month	6 months	At Shutdown	2 Years	4 years
Corrosive	2 x Month	3 months	At Shutdown	1-2 Years	3-4 years

Notes:

- In corrosive atmospheres, more frequent overhaul or replacement may be required.
- Neoprene diaphragms may dry out and require more frequent replacement.
- If regulators are not properly installed or used, or a poor grade of gas is used or purging not properly done, overhaul and replacement may be required more frequently.

12.3 Gas Sensors

The required maintenance schedule on monitors will vary depending on the manufacturer and gas being monitored. Maintenance may involve electronic checks, challenge tests using known gas concentrations, or full instrument calibration.

Challenge tests should always be performed when new monitors are installed or after sensor replacement to ensure proper response. Regular bump testing is recommended. This is where the monitor is exposed to a known concentration of the gas to ensure that it is functioning correctly. Bump testing does not take the place of routine calibration.

Gas detectors have a limited life span and must be replaced when specified by the manufacturer. Sensor changes, calibrations and tests should be recorded.

Permanent, fixed detection systems shall be registered on the Curtin Archibus equipment register with an appropriate maintenance regime mapped into Archibus.

Physical labels shall be provided in accordance with the Curtin labelling procedure.

13 Revision and Updates

13.1 Revision Procedure

This guidance document has been developed as a living document that reflects the changes in legislation, standards, and guidelines available. This plan will therefore be subject to periodic review and new editions published. It is important that readers assure themselves that the current management plan is being referenced and that current standards including any amendments, legislation and/or guidance are being used.

As a minimum it is intended this document will be updated every 3 years.

Throughout this document various web links have been provided to Curtin's internal documents and other third party documents. These links are subject to change with updating information. Every effort will be made to ensure internal Curtin University links remain active. Curtin University has no control over external websites and/or documentation. If a link does not work it is recommended going to the home page of the website being referenced and search for the required document.

A revision history is provided at the front of this document.

13.2 Request/Recommendation log

A log of requests/recommendations shall be maintained by the document owner.

Change requests/recommendations should be submitted in the format below via email to: propertiesbusinesssupport@curtin.edu.au

Name	Company & Position	Detail of Change Request	Urgency of Request (High, Medium, Low)