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1- PURPOSE AND SCOPE

This Standard Operating Procedure covers the infrastructure requirements for Compressed Gas Cylinders. In particular, the storage infrastructure requirements of a designated minor gas storage area; and for the storage and gas usage in a laboratory.

The document also provides an overview of gas supply (reticulation) system requirements within the laboratory in relation to the precautions that need to be taken in the design of the system.

The use of gas monitors and sensors to monitor the atmospheric risk in the storage area and the laboratory is also discussed.

This document provides an overview only and should be used in conjunction with the appropriate standards, documentation and advice. Refer to Section 8 for a list of relevant standards and documentation. The specific requirements for cryogenic liquids, LPG, LNG, Acetylene, Chlorine and Ammonia gas are not covered in this document and need to be further researched by the user.

For toxic gases and for pyrophoric flammable gases it is important to seek further advice from the Technical Laboratory Manager as advice and guidance will need to be sought from a suitably qualified engineer.

This document forms part of a series of documents on compressed gas cylinder handling:

- Flowchart Gas cylinder requisition, installation, use, maintenance & disposal
- Risk Assessment Compressed gas cylinder use
- Guideline Evaluation of atmospheric risk from gases in enclosed workspaces
- Atmospheric risk analysis tool
- SOP Infrastructure requirements for compressed gas cylinders
- SWI Transport of gas cylinders
- SWI Installation, use and disconnection of compressed gas cylinders
- SWI Safety inspection and maintenance for compressed gas cylinders and lab infrastructure
- SWI Waste gas and of gas cylinder disposal
- SWI Emergency procedures for situations involving gas cylinders
- Checklist Installation of gas cylinders
### 2- DEFINITIONS

**Table 2.1: Gas hazard Classifications**

<table>
<thead>
<tr>
<th>Gas Type</th>
<th>Dangerous Goods Class</th>
<th>Australian Standards Definition</th>
<th>Hazard Statement</th>
<th>Precautionary Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammable Gas</td>
<td>Division 2.1</td>
<td>A gas which will burn in air at a pressure of 101.3 kPa</td>
<td>Extremely Flammable Gas</td>
<td>Contains gas under pressure; may explode if heated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store in a well-ventilated place</td>
</tr>
<tr>
<td>Non-Flammable, Non-Toxic Gas</td>
<td>Division 2.2</td>
<td>A gas which is non-flammable, non-toxic, non-oxidising and is resistant to chemical action under normally encountered conditions</td>
<td>Asphyxiant in high concentrations</td>
<td>Contains gas under pressure; may explode if heated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store in a well-ventilated place</td>
</tr>
<tr>
<td>Oxidising Gas</td>
<td>Division 2.2/2.5</td>
<td>A gas which gives up oxygen readily, removes hydrogen from a compound or readily accepts electrons</td>
<td>May cause or intensify fire; oxidizer</td>
<td>Contains gas under pressure; may explode if heated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store in a well-ventilated place</td>
</tr>
<tr>
<td>Toxic Gas</td>
<td>Division 2.3</td>
<td>A gas that is known to be:</td>
<td>Contains gas under pressure; may explode if heated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>a) Toxic or corrosive for humans so as to pose a hazard to health;</td>
<td></td>
<td>Toxic if inhaled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Presumed to be toxic or corrosive for humans because it has an LC50 value equal to or less than 5000 ppm</td>
<td></td>
<td>Store in a well-ventilated place</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store locked up</td>
</tr>
<tr>
<td>Corrosive Gas</td>
<td>Division 2.3</td>
<td>A gas that is known to be:</td>
<td>Contains gas under pressure; may explode if heated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>a) Toxic or corrosive for humans so as to pose a hazard to health;</td>
<td></td>
<td>Causes severe burns and eye damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presumed to be toxic or corrosive for humans because it has an LC50 value equal to or less than 5000 ppm</td>
<td></td>
<td>Toxic if inhaled</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Corrosive to respiratory tract</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store in a well-ventilated place</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store locked up</td>
</tr>
</tbody>
</table>
3- GAS AND GAS CYLINDER HAZARDS

- Manual Handling
  The three contributing factors to the hazard of manual handling gas cylinders are: Gas cylinders are generally heavy (a large G size cylinder has an empty weight of 50-60 kg, filled with carbon dioxide, the weight is ~90 kg); the cylinders are also relatively unstable due to the base diameter being much smaller than the height of the vessel which means they are prone to toppling due to the high centre of mass; and the round surface of the cylinders also makes them difficult to secure and handle.

- Pressure
  The gas in the cylinder is usually kept under pressure. This introduces the possibility that there could be: a gas leakage to the atmosphere, pneumatic shock which can lead to combustion of flammable gas or components in the case of oxidizing gas, an explosive rupture of the container which could blow the confining structure apart, cause injury or damage due to flying projectile parts of the container and the associated hazards of a leak. A sudden release of gas can also cause injury e.g. burns, eye damage, pressure injection into bodily tissue and the loud noise can cause hearing damage.

- Temperature
  High temperatures can result in the softening/weakening of the gas cylinder, could result in rupture due to increase in pressure (with the potential for over pressurization) of the cylinder and could result in the ignition of the gas e.g. if flammable. Some cylinders may suffer embrittlement if the temperature is dropped below -20°C. Care required to avoid exposure to cryogenic liquids.

- Density effects
  Gases heavier than air preferentially accumulate in lower areas of the workplace and can travel large distances without dilution or dissipation (they disperse less readily). This can be a hazard for fuel gases such as LPG and carbon dioxide. Gases lighter than air preferentially accumulate near the ceiling. The density of the gas also varies with temperature so the characteristic of being lighter or heavier than air can be reversed e.g. liquid Nitrogen spill or leak will act initially as a heavier than air gas. This characteristic affects the hazards listed below.

- Flammability
  Flammable gas can ignite and under certain conditions cause an explosion. For flammable gases to ignite, they need to be mixed with air or an oxidizing gas in the appropriate proportions and the temperature needs to be elevated above the ignition temperature. If a flammable gas mixes with air without igniting and is confined, if the concentration enters the flammable range, ignition will cause an explosion. Pyrophoric gases may spontaneously ignite and burn in air or other oxidants. A hazardous atmosphere for these gases is defined as a concentration above 5% of the LEL (lower explosion limit).

- Reactivity (includes corrosively)
  If the gas is reactive there are three possible hazards: Decomposition where some gases decompose in a manner that generates heat and so could lead to explosive decomposition; Corrosion where some gas corrode the gas cylinder, piping and apparatus and can destroy living tissue; and reaction with elastomeric components can cause leaching, embrittlement, cracking or swelling with the potential for the development of leaks and contamination.

- Toxicity
  Toxic gases are destructive to human body tissues and functions. They can affect humans to varying degrees from mild irritation to a severe reaction/ injury or death. Predominantly the method of exposure is inhalation, however some gases can be absorbed through the skin or chemically attack skin, eyes and mucous membranes. Symptoms due to exposure can take 24 hrs or more to develop depending on type of gas.

- Asphyxiant
  Gases (other than air or oxygen) will displace air and thus oxygen when entering the atmosphere. If the oxygen level is reduced below 18%, it is potentially dangerous and a threat to life. 19.5% is the minimum safe level of oxygen concentration (below which is defined as a hazardous atmosphere) while 20.9 % is the normal level of oxygen in the atmosphere.

- Oxidizing
Oxidizing gases will react with flammable gases and other combustible materials in a combustible manner. Some oxidizing gases support combustion more vigorously than air or oxygen. Some organic materials such as oils, greases and plastics may react explosively with oxygen and more powerful oxidants such as fluorine.

- **Oxygen-Enriched Atmospheres**

In oxygen enriched atmospheres, the flammability of substances is enhanced and some substances that are non-flammable in air become flammable (including some fire-resistant materials). Also, ignition sources that would normally be regarded as harmless can cause fire. Oxygen enrichment increases the risk of fire, the rate of propagation and the intensity of the fire. Concentrations of oxygen above 23.5% should be avoided. A hazardous atmosphere for excess oxygen in air is defined as above 23%.

- **Cold Hazard**

Gases that cool when depressurized or are kept at low refrigerated liquid temperatures can cause frostbite or cold burns; brittle fracture of materials; moisture or liquid ingress can cause valves to leak and rupture pipes when warmed. Safety relief devices on refrigerated liquid gas cylinders can vent cold gas and freezing liquid from safety relief valves.

### 4- PERSONAL PROTECTIVE EQUIPMENT

Table 4.1: Recommended Personal Protective Equipment when using Gas Cylinders

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Boots/Enclosed Footwear</td>
<td>Protect feet from being crushed by a falling or slipping cylinder</td>
</tr>
<tr>
<td>Leather Gloves</td>
<td>Leather gloves required to protect:</td>
</tr>
<tr>
<td></td>
<td>• fingers from crush injuries and cuts from metal damage on cylinder</td>
</tr>
<tr>
<td></td>
<td>• fingers and hands from sudden release of gas from cylinder valve.</td>
</tr>
<tr>
<td></td>
<td>Note: gloves may hinder the handling of the cylinder due to a loss of</td>
</tr>
<tr>
<td></td>
<td>dexterity. Choose suitable gloves.</td>
</tr>
<tr>
<td>Safety Glasses</td>
<td>Protect eyes from a sudden release of gas from cylinder valve and</td>
</tr>
<tr>
<td></td>
<td>over-pressure safety valves.</td>
</tr>
<tr>
<td>Hearing Protection</td>
<td>Protect ears from the noise of a sudden release of gas from cylinder</td>
</tr>
<tr>
<td></td>
<td>valve or over-pressure safety valves</td>
</tr>
</tbody>
</table>

Other options for Personal Protective Equipment include:

- Portable oxygen or gas monitors- to detect potential gas leaks
- Anti-static and/or flame-retardant shoes and clothing and anti-spark tools – where there is an ignition risk from flammable or oxidizing gases
• Insulated leather gloves, coveralls, eye protection and face shield – for exposure to cold
• Face shield and safety glasses, chemically resistant gauntlets, apron and boots for Toxic gases (specifically corrosive gases)

Emergency Personal Protective Equipment includes:
• First aid equipment including eye wash and shower
• Fire extinguishing equipment

Emergency service personnel will need the following Personal Protective Equipment to enter a hazardous atmosphere:
• Self-contained breathing apparatus (SCBA) or an air-line respirator where there is asphyxiating atmosphere or if there is a toxic or corrosive gas leak and
• HAZMAT suit and chemically resistant gauntlets for toxic or corrosive gas leaks.

5- STORAGE INFRASTRUCTURE REQUIREMENTS FOR COMPRESSED GAS CYLINDERS

Gas cylinders need to be stored in a secure area where there is no access for unauthorized persons to protect untrained people from hazards and prevent theft. Ideally the storage area should be external to the building and the gas reticulated through piping to the laboratory, alternatively a well signed, dedicated and ventilated storeroom is recommended.

This section outlines the requirements for minor storage of gases where the quantities are so small or scattered and separated that they present little risk, add little to a buildings fire load, are unlikely to significantly assist the spread of fire from place to place and will not in an emergency unduly hinder emergency personnel or contaminate the surrounding area by release of toxic gases. For classification as minor storage, the storage of gases in cylinders cannot exceed the quantities outlined in Table 5.1. Refer to AS4332 for more detail about the building requirements for minor gas stores.

Note that quantity is referenced as the water capacity of the gas cylinder, not the released quantity of the gas e.g. a G size cylinder is 50L water capacity and a D size cylinder is 9.5L.

Table 5.1: Maximum quantities of gases permissible for classification as minor storage (AS4332 Table 2.1)

<table>
<thead>
<tr>
<th>Class of Gas</th>
<th>Maximum Aggregate Water Capacity (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>500 (200 - under review)</td>
</tr>
<tr>
<td>2.2</td>
<td>2000</td>
</tr>
<tr>
<td>2.2/5.1</td>
<td>1000</td>
</tr>
<tr>
<td>2.3</td>
<td>50</td>
</tr>
</tbody>
</table>

5.1 Location of Gas Cylinder Installation

The cylinder needs to be located in a space within the area that is (AS4332, AS/NZ 2243.6:2010 4.2.5):
• Away from emergency exits, egress routes and in a low traffic area to reduce the chance of mechanical and physical damage. A minimum of 1m from any opening in a building (AS2243.10 6.5).
• Dry and clean with a non-combustible floor e.g. concrete which is level or slightly sloping to allow drainage to keep cylinder dry.
• Away from direct sunlight, and any sources of heat. The temperature of the cylinder should not go below 0°C (where mixtures may separate) or above 65°C (where heat damage may occur). Oxygen and Hydrogen cylinders need to be stored below 45°C. Check the SDS for the gas.
• Away from sources of ignition (e.g. electrical equipment, direct fired heaters, naked flames, sparks, welding, ignition systems for machines and hot surfaces) and free from fire risk. The recommended separation distance is at least 50 cm and is dependent on the precautions taken. This separation is required for flammable and oxidizing gases and recommended for other gas types.
• Clear of combustible materials, vegetation and refuse by a distance of greater than 3m.
• At an appropriate segregation distance from other incompatible gases or chemicals where needed (Refer to Section 5.1.2).
• The amount of flammable and toxic gases should be kept to a minimum.
• Full and empty cylinders need to be stored separately; oldest stock should be used first.
5.1.1 Ventilation

The storage area needs to be well ventilated, where the ventilation system should (AS4332 Section 4.3):

- Have the capacity to dilute and/or remove any vapor or gas to levels within the workplace exposure limits and below any possible explosive limits.
- Provide sufficient fresh air from the outside to reduce risk of asphyxiation.
- Ventilate the atmosphere within the space at both high and low levels: high ventilation is needed for gases that are less dense than air for gases such as hydrogen and helium and low ventilation is needed for gases that are denser than air for gases such as Carbon dioxide and LPG.
- The ventilation extraction needs to be to the outside away from building doors and windows, air conditioning intakes, sources of ignition and areas where people congregate.

For mechanical ventilation, the capacity of the system should be 0.005 m³/s for every square meter of floor space and the air velocity should be 5 m/s. Refer to AS4332 4.3, and AS1668.2 for details of natural and mechanical ventilation requirements.

5.1.2 Wall Brackets

The cylinder needs to be stored in a vertical position and secured in place with a chain or a safety strap in appropriately sized wall brackets. The wall brackets need to hold the body of the cylinder and be placed at a height at least 2/3 of the height and at 1/3 the height of the body of the cylinder (Do not restrain the cylinder around the neck or valve).

![Figure 5.1: Example of a properly restrained gas cylinder](http://www.boc-gas.com.au/en/images/BOC%20Guidelines%20for%20Gas%20Cylinder%20Safety-AUSTRALIA-NO-RRP-FA-web_tcm351-82369.pdf)

5.1.3 Signage

There needs to be appropriate signage for the gas cylinder storage area, area where gas is being used and the reticulation pipework. At the entrance to the gas storage area and the gas usage area, the signage needed includes:

- Danger: No Smoking No Ignition Sources.
- Appropriate Hazard warning signs: GHS pictograms and or a caution/warning/danger notice indicating compressed gas hazards. Dangerous Goods Diamonds no larger than 50mm x 50 mm are also acceptable.
- A list of the gases stored in the area is recommended.

Oxygen and oxidizing gas systems need to also be labelled with ‘Oxygen’ ‘Use No Oil or Grease’, ‘Open valves slowly’ at each cylinder supply and outlet point (AS4289 Section 2).

For the appropriate hazard warning signs for the gas, refer to SDS Sections 2 and 14 which will have the GHS label elements and the DG diamonds needed for the gas. For signage requirements see AS1216 which provides details
for the class labels for dangerous goods and AS1319 provides the requirements for the safety signs for the occupational environment.

**NOTE**: DG Class diamonds for below minor storage quantities must not exceed 50 mm x 50 mm. DG Class diamonds for above minor storage or placard quantities must be a minimum of 100 mm x 100 mm.

For gas reticulation pipelines, there needs to be either a sign adjacent to the pipework, markings on the pipework (see AS1345-1995) or schematic layouts displayed prominently indicating the gas being used.

### 5.1.4 Segregation

When incompatible hazardous chemicals come into contact with each other, the chemicals can react to cause fire, an explosion or release vapors which may be toxic, flammable or corrosive. For this reason, incompatible chemicals including gases need to be segregated prior to use in the experiment. According to AS4332 -2004, the segregation of gases within a store should be as follows:

- Gases of Class 2.1 need to be segregated from those of Class 2.2/5.1 by at least 3 m
- Gases of Class 2.3 need to be segregated from those of Class 2.1 or 2.2/5.1 by at least 3 m.

Gases of Class 2.2 can be placed between the segregated gases, in effect segregating them. A screen wall 0.5 m higher than the gas cylinders with a fire resistance level (FRL) of 240/240/240 can be used to increase the segregation distance (refer to Figure 4.3 AS4332).

Gases also need to be segregated from other chemicals and a Segregation Guide for all Classes of Chemicals is shown in Figure 5.2. The chart shows that flammable liquids need to be either kept apart by 3 m from Class 2.2 gases or separated by 5 m from Class 2.1 gases. A more detailed chart can be found at:


Refer to Sections 7 and 10 of the SDS for the gas to determine the specific requirements for the gas being stored.
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## Figure 5.2: Segregation Guide for Chemicals

The chart is from AS3833 Fig 6.1 (reformatted by ChemAlert). It illustrates the segregation requirements for various classes of chemicals, including compressed gases, flammable liquids, flammable solids, oxidizing substances, toxic substances, and corrosive substances. The chart uses symbols to indicate whether two classes are compatible, require segregation, or must be kept apart.

### Notes:

1. In all cases, the MSDS or supplier of the goods should be consulted.
2. The segregation of dangerous goods of Division 1.4S may be necessary. Consult the MSDS or supplier of the goods.
3. Combustible liquids shall be segregated in the same manner as flammable liquids of Class 3.
4. Dangerous goods of Class 9 should be segregated in accordance with MSDS.
5. If the dangerous goods have a Subrisk of another Class, then the segregation requirements of the Subrisk need to be determined and more stringent segregation requirements applied.
6. Where smoke detectors are to be stored, their supplier should be consulted and any specific storage and handling recommendations followed.
5.1.5 Emergency Equipment

Ensure that there is an adequate supply of water available for first aid, firefighting or dilution of corrosive material in case of leakage.

A first aid kit and first aid instructions suited for the gases being kept at the location needs to be provided in a clean area. Where corrosive or toxic gases are used, an accessible safety shower and eyewash facilities needs to be available (AS4332:2004 Section 5.5). Refer to the SDS Section 4 for the gas to determine specific first aid kit requirements for the gas e.g. for fluorine gas, calcium gluconate gel needs to readily available.

For fire protection, outdoor stores of gas cylinders with aggregate capacity of less than 1000l, needs a water hose connection and a garden hose of sufficient length to reach the store. Where the capacity is between 1000 and 2000l, a hose reel or one 2A 60B fire extinguisher is required in addition to the water hose connection and the garden hose (Refer to AS4332:2004 Section 7 for more detail).

5.2 Additional requirements for Gas Cylinder Installation in a Laboratory

According to AS2243.10 Section 4.2, and AS2243.3 Section 7.7, Gas cylinders cannot be stored in a laboratory unless in use and then only when an outdoor location (interpreted in this case as a designated gas storage area) is not practical. A cylinder is defined as in use when it has a regulator attached and is connected to a gas supply system and where the gas is used at least monthly. When not in use, store the gas cylinder in a designated gas storage area. Toxic gas cylinders cannot be kept in any laboratory unless in use and the presence of the gas needs to be clearly indicated in signage at each entrance to the room. Toxic gases should preferably be kept outside the laboratory in a suitable defined gas cylinder storage area.

Where the gas cylinder is stored in the laboratory, assessment of the hazards due to the inadvertent release of the gas needs to be made. Assessment of this risk is covered in Guidance Note ‘Evaluation of atmospheric risk in an enclosed workspace’. According to AS2243.10 Section 4.3.2, Gas cylinders stored in a laboratory should be the minimum size consistent with the operations of the laboratory, taking into account:

- Purpose of use.
- Hazards posed by specific gas.
- Rate of consumption.
- Ease of supply/replacement.
- Manual handling required to move cylinder.

‘The volume of a gas cylinder meant for use by being bought into the laboratory, shall not exceed 70l’ (AS2243.10 Section 4.3.2), for comparison a G size cylinder is approximately 50l internal volume.

5.2.1 Ventilation for toxic, highly reactive and flammable gases when stored in a laboratory

When using toxic, pyrophoric, highly reactive or flammable gases that need to be stored within the laboratory, a gas cabinet can be used to meet ventilation requirements for personal safety. Gas cabinets provide forced air extraction ventilation that can be safely discharged via an exhaust system. This type of ventilation system can be used to maintain the exposure levels below the exposure standards given in the SDS for toxic gases and below the lower explosion limit in the case of flammable gases.

The gas cabinet needs to be equipped with automatic shutoff when leaks are detected or when gas flow exceeds preset levels and provide purge facilities. A flammable gas cabinet with fire resistance, water sprinklers and other fire suppression systems can be used for flammable, pyrophoric and highly reactive gases. It is important to take into account that toxic gases emitted from exhaust systems can be an exposure hazard for workers near the exhaust outlet so appropriate treatment may be required e.g. scrubbing or dilution.

Refer to SWI ‘Disposal of Waste Gas and of Gas Cylinders’ for further information. It is also important to take into consideration that Emergency services prefer that gas cabinets are not used due to the difficulty of management in a fire, so this option is only to be used where a suitable designated gas cylinder storage area is not available.

Figure 5.3: Gas cabinet with fire resistance of 90 min for temperature increase of 50K

(http://www.labsystemsgroup.com/products/category/chemical-and-sample-storage)
5.3 Requirements for laboratories where gas will be used

Laboratories and other areas where gas use is planned need to be secure and with no access for unauthorized persons so as to protect untrained people from hazards.

Equipment to be used with the flammable gases, such as a mass flow controller must be intrinsically safe and suitable for use in hazardous atmospheres e.g. a hazard zone 1 or 2. If not intrinsically safe all equipment must to be kept outside the hazard zone.

Assessment of the hazards arising from inadvertent release of the gas needs to be made according to Guidance Note ‘Evaluation of atmospheric risk in an enclosed workspace’.

Signage needs to be installed as outlined in Section 5.1.3 of this document. Assessment of the need to segregate chemicals prior to use in the experiment must be done as outlined in Section 5.1.2.

6- GAS RETICULATION SYSTEM REQUIREMENTS (GAS SUPPLY SYSTEMS)

This section covers both the reticulation of gas from the designated gas storage area to the laboratory and the reticulation of gas within the laboratory. Note that for toxic, flammable and pyrophoric gas and gases with toxicity due to the serious hazards involved it is required to consult the Laboratory Manager who will contract specialist engineers to advise/supply the reticulation system. Where reticulation is required from the gas storage area to the laboratory, check that there are appropriate facilities for the type of gas available e.g. there is a regulator and piping for the gas signed as suitable for the gas from the gas storage area to the laboratory. If not, consult the Laboratory Manager who will consult with Property to get the facilities installed as this type of reticulation requires engineering advice. Building reticulation systems need to be designed, installed, tested, inspected, commissioned and maintained according to appropriate standards and codes by competent and qualified engineers.

The principal components of a reticulation system can include source of gas, purging systems, pressure reducing regulators, flow limiting devices, overpressure protection devices, flow control valves, isolation valves, non-return valves, pipework, vacuum pumps and filters.

An overview of the main components is given in sections 6.2 to 6.6. Purging is discussed in section 6.7. Useful guides for the components and designing a system for the reticulation of gas within the laboratory, include BCGA CP4 and 18, Scotts Design & Safety Handbook (see section 8 below for references). Training is required for the installation of the reticulation system in a laboratory.

The general safety requirements for a gas reticulation system are set out below (DR AS2243.2:2018 Section 4.3.2, AS2243.6:2010 4.2.3 and BCGA CP18):

- Design and manufacture of a gas reticulation system needs to consider allowable pressure, tube size, operating temperature and materials of manufacture and chemical compatibility of materials with the gas and be designed to prevent cross-contamination of incompatible gases.
- Non-return valves need to be fitted where a pressure buildup in the system may cause the gas flow to reverse (see figure 6.2).
- The use of catch-pots or an inert gas purge facility needs to be considered where condensate may accumulate in gas lines.
- Isolating valves shall be placed at appropriate locations in the gas piping system and be labelled. Valves need to be located in well ventilated areas away from air intakes. An isolating valve is usually placed as close to the gas cylinder as practical in an accessible position.
- All gas pipes and outlet points need to be clearly identified. Where there is danger of explosion due to an incorrect connection, use non-interchangeable connectors.
- Pipework needs to be rigorously cleaned and capped at open ends to prevent contamination. Some examples of the problems of contamination are:
  - risk of fire for oxidizing gases,
  - moisture leading to corrosion,
  - particulate contamination affecting valve seats.
- Where permanent piping is not practical, flexible hoses can be used where the hose length is kept to a minimum, the hose is of the appropriate type and pressure rated for the purpose.
- The venting of gases or lines shall be carried out with care. Refer to ‘SWI 4 Disposal of Waste Gas and of Gas Cylinders’
Special requirements for a gas reticulation system:

- For pipelines that are either:
  o carrying toxic and pyrophoric gases and gases with toxicity,
  o are in inaccessible places and
  o where gas quality is critical, all joints need to non-mechanical e.g. made by welding, brazing or soldering.
- Flame arrestors shall be fitted where flammable and oxidizing gases could mix inadvertently
- Metallic gas lines shall be used for flammable and oxidizing gases. (Pipework needs to be non-flammable)
- For toxic gases, gases with toxicity, and flammable gases venting, and over-pressure valves need suitable local exhaust ventilation. Refer to SWI Disposal of Waste Gas and of Gas Cylinders.
- Pipework carrying flammable and toxic gases needs to be routed outside buildings where practical or purged sleeving should be considered.

Specific precautions for flammable gases include (AS2243.2:2018 Section 4.4):

- The pipework needs to be earthed to prevent static discharge which may cause ignition.
- Electrical wiring shall conform to AS/NZ3000

Specific precautions for oxidizing gases include (AS4332):

- The pipework needs to be degreased and free from particulate contamination as a small particle in a high velocity stream can cause ignition. More powerful oxidants such as fluorine need further measures. Refer to BCGA CP18 p38 for further information. For this reason, only equipment that has been delivered from the manufacturer cleaned, sealed and certified as being suitable for use with oxidizing gases shall be used. Where there is onsite fabrication, once assembled, the equipment needs to be certified as clean and suitable for oxidizing gas
- Lubricants and sealants cannot be used in the connection of equipment unless certified as oxidizing gas compatible

Specific precautions for toxic and corrosive gases:

- Adequate precautions for the specific gas shall be taken before use. Investigate the appropriate precautions: contact the gas supplier and refer to the SDS.
- Safety requirements and emergency equipment need to be in place and readily available.

### 6.1 Compatibility of materials with the gas

Commonly used gases and compatible materials are listed in the table below. Refer to the SDS Section 10.5 for specific information on materials that are incompatible with the gas.

<table>
<thead>
<tr>
<th>Gas Type</th>
<th>Incompatible Materials</th>
<th>Material suited for pipework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>Moist CO₂ is corrosive Properties of some plastics and rubbers affected (e.g. leaching, embrittlement)</td>
<td>Acid resistant materials e.g. Stainless Steel Copper/copper alloy Plastic (within limitations) For jointing glass filled PTFE, compressed fibre.</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Explosive with peroxides, oxidizing agents and metal catalysts Embrittlement of steels</td>
<td>Copper Bronze Stainless Steel (possibility of embrittlement under cyclic conditions) For jointing all commonly used materials suitable except soft solder. As hydrogen is extremely penetrative, jointing must be more stringent e.g. back-brazing of screw joints may be necessary</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Combustible materials such as oil and grease can spontaneously ignite at low temperatures Materials that will burn in air will burn more vigorously Metals can be ignited and will continue to burn in pure oxygen under specific conditions of temperature and pressure</td>
<td>Copper or copper alloys Steel (where the flow rate is restricted to 15m/s at 20 bar) According to AS4289: All non-metallic materials need to have a self-ignition temperature greater than 300 - 400°C For jointing glass filled PTFE (oil free), compressed fibre</td>
</tr>
</tbody>
</table>
### Inert gases e.g. Nitrogen, Argon, Helium

| Compatibility with most commonly used materials |
| Copper/copper alloy |
| Steel |
| Plastic (within limitations) |
| For jointing all commonly used materials suitable except soft solder. For Helium jointing must be more stringent e.g. back-brazing of screw joints may be necessary |

### Methane

| Oxidising agents, acids |
| Do not use natural rubber flexible hose |
| Violently incompatible with oxygen, halogens, metal halides |
| Copper/copper alloy (not for methane with acetylene components) |
| Steel |
| For jointing all commonly used materials suitable except soft solder. |

### 1% Fluorine, balance Neon

| Combustible materials, reducing agents, alkalis, metals |
| Stainless Steel |
| Joints welded, braised or hard soldered |

### 6.2 Pressure Reducing Regulator

The pressure regulator is used to reduce and control the pressure from the gas cylinder to that required for the process/experiment. Regulators do not control the gas flow. When choosing a regulator, it is important to take into account the:

- Compatibility of the regulator with the gas: The materials of the regulator that are wetted (in contact with the gas) need to be compatible. Typical materials used in the construction of regulators include:
  - For Non-corrosive gases: Aluminum, Brass, Stainless Steel, Buna-N, PCTFE, Neoprene, Teflon, Viton, Nylon
  - For Corrosive gases: Aluminum, Stainless Steel. Monel, Nickel, PCTFE, Teflon
  (A stainless steel diaphragm is advantageous in a high purity gas service rather than an elastomeric diaphragm as the stainless steel is non-contaminating)
- Gas cylinder (supply) pressure,
- Pressure required for the experiment,
- Accuracy of the delivery pressure required for the experiment. For example: a 2-stage regulator is used where consistent delivery pressure is needed as the delivery pressure is independent of the gas cylinder pressure.

![Figure 6.1: Schematic diagrams of a single stage and two stage regulators. Scott Design+Safety Handbook](image-url)
6.3 Over-pressure protection devices

Over-pressure relief devices include:
- Pressure sensor with automatic shutoff and/or vent valve. The automatic shutoff is the preferred option of toxic and pyrophoric gases;
- Spring loaded relief valve – reseats after excess pressure relieved;
- Bursting disc – will vent entire gas content of system;
- Fusible plug – triggered by excess temperature and will vent entire gas content of system;
- Barometric lute – low pressure applications.

Ensure that the device vents to a safe place e.g. for toxic gases the over-pressure device needs to have appropriate exhaust ventilation such as a fume cupboard.

6.4 Flow Limiting Devices

a) A Flow limit safety shutoff valve – this valve stops potentially dangerous leaks by automatically shutting off all flow from the cylinder when the flow rate exceeds a preset level. The valve is installed between the cylinder outlet and the pressure regulator inlet. For very toxic and pyrophoric gases supplied from a remote store, remotely operable isolation valves need to be fitted as close to the gas cylinder as possible.
b) Flow limiting device – a flow restricting orifice fitted in the valve outlet of the cylinder (check with gas supplier that this can be fitted to the valve). Also recommended for very toxic and pyrophoric gases.

![Image of a flow limit safety shutoff valve and Check valve in a gas system]

Figure 6.2: Schematic of the positioning of a flow limit safety shutoff valve and Check valve in a gas system. Note: some cylinders are fitted with a non-return (Check) valve which can be recognized by a ‘pin’ being visible in the bore or protruding from the bore of the cylinder valve outlet as shown in the second figure. Scott Design+Safety Handbook, BOC Guidelines for Gas Cylinder Safety.

6.5 Valves

The three main types of valves used in a reticulation system include:
- a) Flow control valves- control gas flow through the supply system to the experiment. They can be used to open or isolate the gas supply or control the flow rate.
- b) Isolation valves – a means of positive isolation.
- c) Non-Return valves (Check valves) – permit flow in one direction only. Required to prevent backflow of gas into the gas cylinder.

6.6 Flash Back Arrestor

A flashback is a flame, travelling at supersonic speed in the opposite direction to normal gas flow. Where oxidizing or flammable gases are used, a flashback arrestor needs to be fitted on the downstream side of the regulator to prevent flames travelling back into the cylinder in case of ignition of the gas. A second flashback arrestor fitted at the gas system end near the experiment provides optimum protection to protect pipework. Flashback arrestors have a sensitive non-return valve that stops the gas flow, a fine sintered filter that quenches the flame and a
thermal cutoff valve to stop the flow of gas before ignition upstream. The flashback arrestor needs to be suited to the gas and the pressure rating of the system.


### 6.7 Purging of the gas supply system

Purging is used to remove air, moisture and residual gas from the system when commissioning or changing the gas cylinder. Purging is also used to reduce the gas concentration to a safe level prior to opening the system or in an emergency.

Three purging techniques are commonly used:

1) **Evacuation**

2) **Cycle or Dilution Purging** — system is alternately evacuated and pressurized with an inert purge gas. Refer to 'Installation of Gas Cylinder’ SWI. This type of purging is the most effective to attain high purity.

3) **Dynamic or Diffusion Purging** — inert gas is purged through the system at a sufficient flow rate for a suitable length of time.

For safety purposes:

- The oxygen content of gas supply systems prior to the introduction of flammable gas should not exceed 1%v/v
- Flammable gas systems need to be purged until the concentration of flammable gas in the purge gas is less than 25% of the Lower Explosion Limit.
- Toxic gases need to be purged to ensure that if the piping is disconnected that the concentration of the Toxic gas would not be a health hazard ie the concentration needs to be below the Time Weighted Average in the SDS.

The construction of purging systems for ‘Dilution Purging’ are described in SWI Installation, Use and Disconnection of Compressed Gas Cylinders.

### 7- GAS MONITORING AND SENSORS

Gas monitoring with sensors enables the detection of hazardous atmospheres where the hazards of asphyxiation, toxicity, flammability and oxygen enrichment may occur. If your Risk Assessment identified that hazardous atmospheres may occur if there is a gas leak, then gas monitoring will be required. Refer to Guidance Note ‘Evaluation of atmospheric risk in an enclosed workspace’. According to DR AS2243.2:2018 Section 4.3.2:
concentration of toxic, flammable or hydrocarbon gas in the atmosphere of the laboratory area shall be monitored where the use of an automatic alarm system with remote sensors is preferred. Sensors need to be fitted in appropriate locations in regard to the density of the gas.

Gas monitors come in three forms:
- A fixed system that is permanently installed in the laboratory. The central control box is located outside the laboratory with the sensors inside the laboratory installed where a leak is most likely to occur/be detected. See Table 5.6.
- A personal gas detector that is carried by the person.
- Transportable unit – for short term laboratory work or where fixed gas monitoring systems may not be suitable.

As well as providing an audible and visible alarm system, fixed gas monitoring systems provide the options to interface with control systems to:
- Shut down the gas supply and/or experiment
- Control access to the area, lockout the laboratory to prevent access
- Boost mechanical ventilation to restore safe atmospheric conditions
- Shut off electricity supply
- Send an alert message to University Security

Advice on the type of gas monitor, number and location of sensors needs to be sought from an appropriately qualified engineer.

Table 7.1: Gas monitoring system: sensors, function and position

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Function</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Oxygen depletion: Flashing Lights below 19.5%</td>
<td>Face level/breathing zone</td>
</tr>
<tr>
<td></td>
<td>Alarm sound below 18% (Evacuation Level)</td>
<td>For Liquid Nitrogen sources of leak locate the sensor 300 mm above floor level</td>
</tr>
<tr>
<td></td>
<td>Oxygen enrichment: Alarm sound when increases above 23% (AS4332)</td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>Flashing lights when concentration increases above 5000ppm or 0.5% (TWA)</td>
<td>300mm off floor level</td>
</tr>
<tr>
<td></td>
<td>Alarm sound when concentration increases above 30000ppm or 3% (STEL)</td>
<td></td>
</tr>
<tr>
<td>Flammable gas</td>
<td>Alarm at 15% of LEL</td>
<td>Dependent on density of the gas e.g. near the roof for hydrogen and near the floor for LPG</td>
</tr>
<tr>
<td>Toxic gas</td>
<td>Alarm at the TWA exposure standard and at the STEL exposure standard</td>
<td>Dependent on the density of the gas</td>
</tr>
</tbody>
</table>

8- SUPPORTIVE DOCUMENTATION

8.1 Safe Work Documentation:
Flowchart Gas cylinder requisition, installation, use, maintenance & disposal
Risk Assessment Compressed gas cylinder use
Guideline Evaluation of atmospheric risk from gases in enclosed workspaces
Atmospheric risk analysis tool
SOP Infrastructure requirements for compressed gas cylinders
SWI Transport of gas cylinders
SWI Installation, use and disconnection of compressed gas cylinders
SWI Safety inspection and maintenance for compressed gas cylinders and lab infrastructure
SWI Waste gas and of gas cylinder disposal
SWI Emergency procedures for situations involving gas cylinders
Checklist Installation of gas cylinders

8.2 Australian Standards:
AS1345-1995 Identification of the contents of pipes, conduits and ducts
AS2030.5-2009 (Amt 1) Filling, Inspection and Testing of refillable Cylinders
DR AS2243.2:2018 Safety in laboratories Part 2: Chemical aspects
AS/NZS 2243.6:2010 Safety in laboratories Part 6: Plant and equipment aspects
AS/NZS 2243.10-2004 Safety in Laboratories Part 10: Storage of chemicals
AS 2865 Confined spaces
AS/NZS 3833-2007 The storage and handling of mixed classes of dangerous goods, in packages and intermediate bulk containers
AS4267-1995 Pressure Regulators for use with industrial compressed gas cylinders
AS4289-1995(2016) Oxygen and acetylene gas reticulation systems
AS4332 The storage and handling of gases in cylinders
AS 4289-1995 Oxygen and acetylene gas reticulation systems
AS/NZS 4452-1997 The storage and handling of toxic substances
AS4603-1999 (2016) Flashback arrestors – Safety devices for use with fuel gases and oxygen or compressed air

8.3 Government Regulations and Codes of Practice:

safe work australia ‘Managing risks of hazardous chemicals in the workplace Code of Practice’
Publication date: 25 May 2018. Downloaded 30/11/2018

safe work Australia ‘Model Work Health and Safety Regulations’
Publication date 28 Nov 2016. Downloaded 30/11/2018

safe work Australia ‘Labelling of workplace hazardous chemicals Code of Practice’
Publication date: 26 Oct 2018. Downloaded 30/11/2018

SafeWork NSW ‘Labelling of workplace hazardous chemicals code of practice’
Publication date: April 2016. Downloaded 30/11/2018

National Transport Commission ‘Australian Code for the Transport of Dangerous Goods by Road and Rail’
Publication Date: 7 May 2018 Downloaded 30/11/2018


8.4 Safety Data Sheets


Information on fluorine:
cameochemicals.noaa.gov/chemical/764

8.5 British Compressed Gas Association

http://www.bcga.co.uk/pages/index.cfm?page_id=6&title=publications

British Compressed Gas Association ‘Guidance Note 3: Safe Cylinder Handling and the application of the manual handling operations regulations to gas cylinders’ Rev 3 2016, viewed 23 October 2018

8.6 Industry Information

Australia New Zealand Industrial Gas Association
http://www.anziga.org/publication

BOC Australia Guidelines for Gas Cylinder Safety, viewed 24 October 2018

Scott Specialty Gases ‘Gas system design +safety handbook’ viewed 30 November 2018


Gascon Systems, viewed 30 November 2018

Matheson Tri.Gas ‘Instruction manual Purging high purity gas delivery systems’ Viewed 30 November 2018
https://www.mathesongas.com/pdfs/litCenter/InstructionManuals/Instructions-Purging.pdf

8.7 Universities

University of Sydney ‘Working with gases’ viewed 30/11/2018
https://sydney.edu.au/whs/docs/WHS_CHE_GUI_1_Working%20with%20Gases.pdf

properties.curtin.edu.au/local/docs/guidelines/GasManagementGasStoreDesign-V01.pdf

9- CONTROL AND REVIEW OF STANDARD OPERATING PROCEDURE

Standard Operating Procedures must be reviewed following any incident, accident or near-miss, or the system has been identified as not effective; if adopted by a new work group; if the equipment is relocated, updated or replaced,
or if there has been an industry product safety alert involving all or part of the process components; or within 5 years of the date of implementation.

If any part of this Standard Operating Procedure changes, please refer to the authorisation signatory for updating as soon as possible.

APPENDIX 1: PLACARDING REQUIREMENTS

Where stored quantities of gas exceed that listed in Table 5.2, placarding needs to be used instead of signage and notification to Property and The WHS Unit must be made for regulatory notification purposes. Note that quantity is referenced as the water capacity of the gas cylinder, not the released quantity of the gas e.g. a G size cylinder is 50L water capacity and a D size cylinder is 9.5L.

Table A1: Extract showing Placard quantities for each dangerous goods code.


<table>
<thead>
<tr>
<th>Dangerous Goods Code</th>
<th>Hazard</th>
<th>Placard quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 except aerosols</td>
<td>Flammable Gases</td>
<td>200L</td>
</tr>
<tr>
<td>2.2 except aerosols</td>
<td>Inert, non-toxic</td>
<td>1000L</td>
</tr>
<tr>
<td>2.3</td>
<td>Acute toxicity and/or skin corrosion</td>
<td>50L</td>
</tr>
<tr>
<td>2.1 and 2.2 aerosols</td>
<td></td>
<td>5000L</td>
</tr>
</tbody>
</table>

USERS OF GAS ACKNOWLEDGEMENT

Users of gas who will be undertaking the work or laboratory experiments involving the use of gas and/or gas cylinders have read and understood this document:

ASSESSED AS COMPETENT:

<table>
<thead>
<tr>
<th>Name/Position</th>
<th>Date</th>
<th>Assessor:</th>
<th>Date</th>
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Historical notes:
<table>
<thead>
<tr>
<th>Version and Date</th>
<th>Author Name/Position</th>
<th>Reason for review</th>
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Notes: