# Compressed Gas Handbook

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## 1. Introduction

Compressed gases can be more hazardous to use than liquid and solid materials because of the physical pressure of the gas in the system, low flash points of flammable gases, low boiling points and no detectable physical or chemical characteristics of many inert gases.

Compressed gases are also referred to as gases under pressure and that is nomenclature used in *The Globally Harmonised System of Classification and Labelling of Chemicals*. Both terms will be used in this document depending which is the most appropriate.

Compressed gases are used within the University for many different applications including:

**Table 1 Examples of the Use of Compressed Gases within the University**

| Application | Gases |
|---|---|
| Creating inert atmospheres for chemical and biological reactions | Nitrogen, argon and nitrogen/hydrogen mixes |
| Creating a carbon dioxide rich atmosphere in tissue growth incubators | Carbon dioxide |
| Maintaining tissues used for in vitro experiments | Oxygen, carbon dioxide/oxygen mix |
| Creating shielding atmospheres for cutting, welding, metal processing and within analytical equipment | Nitrogen and argon |
| Carrier gas for gas chromatographs | Nitrogen and helium |
| Fuel gas for analytical instruments | Acetylene and hydrogen |
| Oxidising gases used in analytical instruments | Oxygen and nitrous oxide |
| Medical Gases | Medical Oxygen, Nitrous Oxide, Air, Carbon Dioxide, Helium, Oxide/Oxygen Mixture, Carbon Dioxide/Oxygen Mixture, Helium/Oxygen Mixture |
| Calibration gases | Various |
| Cooking | Propane |
| Dispensing beverages | Carbon dioxide |

The description of the definitions, classification of the gases and the hazard communication information is based on *The Globally Harmonised System of Classification and Labelling of Chemicals.*

The control measures, inspection and maintenance procedures are based on the requirements of British Standard BS EN ISO 22434:2011 Transportable Gas Cylinders - Inspection and Maintenance of Cylinder Valves.

The handbook covers inert, oxidising, flammable and acutely toxic gases that are used by the University of Portsmouth.

Section 4 Managing Risks Associated with Compressed Gases and Cylinders provides guidelines for the preparation of risk assessments. A suitable and sufficient risk assessment must be carried out by a competent person before any work involving a compressed gas commences.

# 2. Compressed Gases

## 2.1 Definition

*The Globally Harmonised System of Classification and Labelling of Chemicals* defines gases under pressure as gases which are contained in a receptacle at a pressure of 200kPa or 1.98Bar (gauge pressure) or more at 20$^{o}$C.

## 2.2 Types of Compressed Gas

There are three types of compressed gas that are stored in gas cylinders. These are:

Non-liquefied gases: also known as compressed, pressurised, or permanent gases. These gases do not become liquid when they are compressed at normal temperatures, even at high pressures. Examples used in the University are argon, helium, nitrogen and oxygen.

Liquefied gases: are gases which can become liquids at normal temperature when they are inside cylinders under pressure. They exist inside the cylinder in a liquid-vapour balance or equilibrium. Examples used in the University are carbon dioxide and propane. There are two types of carbon dioxide cylinders, one for gas withdrawal and the other for the delivery of liquid. The cylinders are distinguished by a white strip running down the length of the cylinder which indicates liquid withdrawal.

Dissolved gases: are very unstable. The most common example is acetylene, which can explode even at atmospheric pressure. Acetylene cylinders are fully packed with an inert, porous filler that is saturated with acetone to prevent explosions. As acetylene is added to the cylinder, the gas dissolves in the acetone making the acetylene solution stable. Acetylene is used in the University.

## 2.3 Classification of Gases Under Pressure

*The Globally Harmonised System of Classification and Labelling of Chemicals* classifies gas under pressure according to their physical state when packaged, one of the four groups in table 2.

**Table 2 Criteria for Gases under Pressure**

| Group | Criteria |
|---|---|
| Compressed Gas | A gas which when packaged under pressure is entirely gaseous at -50ºC; including all gases with a critical temperature ≤ -50ºC |
| Liquefied Gas | A gas which when packaged under pressure, is partially liquid at temperatures above -50ºC. A distinction is made between:<br>(a) High pressure liquefied gas: a gas with a critical temperature between -50ºC and +65ºC and<br>(b) Low pressure liquefied gas: a gas with a critical temperature above +65ºC. |
| Dissolved Gas | A gas which when packaged under pressure is dissolved in a liquid phase solvent. |
| Refrigerated Liquefied Gas | A gas which when packaged is made partially liquid because of its low temperature. |

**Notes**

- The above categories will be referred to as 'compressed gas' throughout this manual.
- The critical temperature is the temperature above which a gas cannot be liquefied, regardless of the degree of compression.
- For information regarding compressed gases packaged as refrigerated liquefied gases, such as Liquid Nitrogen, please contact the Health and Safety Office.

### 2.4 Hazard Communication

**Table 3 Label Elements for Gases under Pressure**

| | Compressed Gas | Liquefied Gas | Dissolved Gas |
|---|---|---|---|
| **Symbol** |  |  |  |
| **Signal Word** | Warning | Warning | Warning |
| **Hazard Statement** | H280 Contains gas under pressure; may explode if heated | H280 Contains gas under pressure; may explode if heated | H280 Contains gas under pressure; may explode if heated |

### 2.5 Purity of Compressed Gases

The purity of a compressed gas is generally expressed as a grade prefixed with the letter N giving the "number of nines" in the percentage or decimal fraction. The first digit indicates the number of nines purity e.g. N4 = 99.99%. The second digit is the number following the last nine e.g. N4.5 = 99.995%.

**Table 4 Purity of Compressed Gases**

| Grade | Minimum Purity | Total Impurities |
|---|---|---|
| N2.0 | 99% | 1% or 10,000ppm |
| N3.0 | 99.9% | 1000ppm |
| N4.0 | 99.99% | 100ppm |
| N5.0 | 99.999% | 10ppm |
| N6.0 | 99.9999% | 1ppm or 1,000ppb |
| N7.0 | 99.99999% | 100ppb |

**Note**
The terms ppm and ppb are abbreviations for parts per million and parts per billion.

## 3. Compressed Gas Cylinder Identification

### 3.1 Industrial Gases

The colour coding of industrial compressed gas cylinders is defined in European Standard BS EN 1089 Part 3: "*Transportable Gas Cylinders – Gas Cylinder Identification (excluding LPG). Colour Coding"* and relates to the hazard(s) associated with the gas. The colour coding is applied to the shoulder of the cylinder and follows the European RAL colour matching system. The main purpose of the colour coding is to enable the emergency services to easily identify the type of risks associated with the contents of the cylinder. Gas cylinders should never be identified by their colour alone; the label must always be checked.

**Table 5 Cylinder Shoulder Colour Classification by Hazard**

| Gas Type | Cylinder Shoulder Colour | European RAL Number |
|---|---|---|
| Inert | Bright green | **RAL 6018** |
| Oxidising | Light blue | **RAL 5012** |
| Flammable | Red | **RAL 3000** |
| Toxic and/or Corrosive | Yellow | **RAL 1018** |

**Note**

A. Inert is considered to be a non-toxic and/or non-corrosive, non-flammable and non-oxidizing gas with an oxidising potential of less than 23.5%. Hence air with 21% oxygen is classed as an inert gas.
B. Where a gas has more than one hazardous property this may be indicated by two or more concentric bands or alternatively, the two colours painted in quarters around the shoulder.

**Figure 1 Colour Coding Styles**


Apart from medical gas cylinders and acetylene gas cylinders, the colour coding applies only to the shoulder of the cylinder, hence the colour of the cylinder body may vary between companies. The information in Table 6 is based on BOC company cylinders.

Mixtures of compressed gas are not covered by the code and the colour of the cylinder may vary between suppliers.

**Table 6 Cylinder Colours**

| Gas | Formula | Colour of Cylinder Shoulder | Colour of Cylinder Body | Type of Compressed Gas |
|---|---|---|---|---|
| Acetylene | $C_2H_2$ | Maroon | Maroon | Dissolved gas in acetone |
| Air | Mixture | Green | Grey | Compressed gas |
| Argon | Ar | Green | Green | Compressed gas |
| Butane | $C_4H_{10}$ | Blue | Blue | Liquefied gas |
| Carbon dioxide (Vapour withdrawal) | $CO_2$ | Grey | Black | Liquefied gas |
| Carbon dioxide (Liquid withdrawal) | $CO_2$ | Grey | Black with vertical stripe | Liquefied gas |
| Helium | He | Brown | Brown | Compressed gas |
| Hydrogen | $H_2$ | Red | Red | |
| Nitrogen | $N_2$ | Black | Grey | Compressed gas |
| Nitrous oxide | $N_2O$ | Dark Blue | Dark Blue | Compressed gas |
| Oxygen (Industrial) | $O_2$ | White | Black | Compressed gas |
| Propane | $C_3H_8$ | Red | Red | Liquefied gas |

### 3.2 Medical Gases

Prior to 1997, the colour coding of medical gas cylinders was specified by British Standard BS 1319C: *“Specification for Medical Gas Cylinders, Valves and Yoke Connections”*. In 1997 the European Standard BS EN 1089 Part 3: “*Transportable Gas Cylinders – Gas Cylinder Identification (excluding LPG). Colour Coding”* came into effect and BS 1319C was withdrawn.
In order to keep sufficient cylinders in circulation at all times to meet customers’ needs the conversion to the new colour will not be completed until 2025, therefore until 2025 both systems will be in use. The new type cylinders have the name of the gas or gas mixture displayed down the length of the cylinder.

**Table 7 Colour Coding of Compressed Medical Cylinders**

| Gas or Gas Mixture | Old Colours | | New Colours | |
|---|---|---|---|---|
| | Shoulder | Body | Shoulder | Body |
| Medical Oxygen | White | Black | White | White |
| Medical Nitrous Oxide | Dark Blue | Dark Blue | Dark Blue | White |
| Medical Air | Black/White | French Grey | Black/White | White |
| Medical Carbon Dioxide | French Grey | French Grey | Grey | White |
| Medical Helium | Brown | Brown | Brown | White |
| Medical Nitrous Oxide/Oxygen Mixture | Dark Blue/White | Dark Blue | Dark Blue/White | White |
| Medical Carbon Dioxide/Oxygen Mixture | French Grey/White | Black | Grey/White | White |
| Medical Helium/Oxygen Mixture | Brown/White | Brown | Brown/White | White |

**Figure 2 Old and New Colour Code for Oxygen Cylinders**


**Note**
The new cylinder has the name of the gas displayed down the length of the cylinder.

## 3.3 Lecture Gas Bottles

Lecture bottles are small compressed gas cylinders, typically 300–460 mm long and 25–76 mm in diameter. They are used where small quantities of gases or specialty gases are required. Due to the nature of gases, the bottles and fittings are manufactured using very pure metals and specialised alloys, which are not necessarly interchangable between bottles.

## 3.4 BOC Gas Genie Cylinders

**Figure 3 BOC Gas Genie Cylinders**

BOC supply conveniently sized, lightweight and easily transportable gas cylinders. These compact cylinders contain 30% more gas than conventional cylinders and feature a range of innovative safety devices including electronic monitoring of the volume of gas in the cylinder. Gas Genie cylinders require specific pressure regulators.

### 3.5 Cylinder Labels

Cylinders should always be identified by the information on the label. Labels must not be removed and any cylinders without labels must not be used and must be returned to the supplier.

Compressed gas cylinder labels identify the cylinder contents, the associated hazards and provide basic safety information in relation to its transportation and use. The label also gives supplier and emergency contact details.

Compressed gas cylinder labels should never be removed, altered or defaced.

**Figure 4 Compressed Gas Cylinder Label**


**Notes**

A. United Nations unique identification number, product name, in this case dissolved acetylene, and basic safety advice.
B. Transportation of dangerous goods pictogram for flammable gas.
C. *The Globally Harmonised System of Classification and Labelling of Chemicals* pictogram for gas under pressure and signal word in case DANGER.
D. BOC product number and emergency contact information.

### 3.6 Permanent Cylinder Markings

**Figure 5 Permanent Cylinder Markings**

In addition to labels, compressed gas cylinders have permanent markings which give manufacturing and testing details.

## 4. Managing Risks Associated with Compressed Gases and Cylinders

### 4.1 Main Hazards Associated with Compressed Gases

- Fire following the escape of a flammable gas
- Explosion of a gas cylinder which is involved in a fire
- Rapid release of compressed gas from a cylinder, releasing flying debris
- Being hit by a falling cylinder
- Injury sustained whilst manual handling a cylinder
- Skin or eye contact with a toxic or corrosive gas
- Inhalation of a toxic or corrosive gas
- Asphyxiation from the release or build-up of the concentration of inert gas
- Using the wrong gas

### 4.2 Potential Causes of Accidents Involving Compressed Gases

- Poor workplace design
- Inadequate ventilation and/or local exhaust ventilation systems
- Failure of components such as pressure hoses
- Poor installation of equipment and pressure accessories
- Failure to maintain and examine the pressure system
- Inadequate training and supervision
- Poor manual handling techniques

### 4.3 General Control Measures and Safety Procedures for Working with Compressed Gases

- Ensure that the gas cylinder has been correctly identified and is in good condition before taking receipt of it from the supplier, storing and using it.
- Where possible, site the cylinders outside the building and pipe the gas to the point of use.
- Before using cylinders, read the label information and Safety Data Sheets (SDS) associated with the gas being used.
- A Control of Substances Hazardous to Health (COSHH) assessment must be drawn up before work commences. Note that COSHH Regulations apply to inert gases.
- Use permanent pipe work distribution networks rather than rubber tubing.
- Pipe work and fittings which carry gas at a gauge pressure of 0.5bar or above are classed as Pressure Systems and as such fall under *the Pressure Systems Safety Regulations 2000.* They should be regularly maintained and tested in accordance with a written scheme of inspection by a competent person. See the Health and Safety Office Pressure Systems website for further details.
- Worn or damaged parts must be replaced immediately. Replacement parts must comply with the designer's specification.
- Ensure that the cylinders are mechanically stable and secure.
- The valve-protection cap should be left on each cylinder until it has been secured against a wall or bench, or placed in a cylinder stand, and is ready to be used.
- Cylinders should not be subjected to a temperature higher than 50$^{o}$C or direct sunlight.
- Do not place cylinders where they may become part of an electric circuit.

- Bond and ground all cylinders, lines, and equipment used with flammable compressed gases.
- Use compressed gases only in a well-ventilated area.
- Ensure the correct fittings are used with the cylinder.
- Ensure the correct spindle key and spanners are used.
- Empty cylinders should be marked as such, stored in an external store and segregated from full cylinders.
- Ensure appropriate signage and information is in place.
- When using compressed gases, wear appropriate protective equipment, such as safety goggles or face shield, rubber gloves and safety shoes.
- A risk assessment covering the physical hazards associated with the use of compressed gas must be undertaken before work commences. The assessment should cover emergency procedures and possible environmental impacts.
- The presence of compressed gas cylinders must be taken into account when conducting a fire risk assessment.
- Gas usage should be regularly monitored and should abnormally high usage occur this should be investigated.

# 5. Inert Gases

Inert gases are chemically unreactive under normal conditions and do not support life or combustion. The most common inert gases are nitrogen, helium and the elements of group 18 of the periodic table. Inert gases are odourless, colourless and tasteless and there is no physical warning of their presence.
In order to understand the hazard presented by inert gases it is useful to first consider the composition of the Earth's atmosphere, which is a complex mixture of gases, the major components of which are nitrogen and oxygen. Dependent on geographical location, other trace gases and contaminants may be present. These could include: oxides of nitrogen (NOXs), oxides of sulphur (SOXs), radon, dust and nanoparticles. Table 8 details the average composition of the atmosphere.

**Table 8 Composition of the Atmosphere**

| COMPOSITION OF THE ATMOSPHERE AT SEA LEVEL | | | | |
|---|---|---|---|---|
| **Gas** | **Symbol** | **% by weight** | **% by volume** | **Type of gas** |
| Nitrogen | $N_2$ | 75.52 | 78.09 | Inert |
| Oxygen | $O_2$ | 23.15 | 20.95 | Oxidising |
| Argon | A | 1.28 | 0.93 | Inert |
| Carbon Dioxide | $CO_2$ | 0.046 | 0.035 | Greenhouse gas and a fire extinguisher |
| Neon | Ne | 0.012 | 0.0018 | Inert |
| Helium | HE | 0.0007 | 0.0005 | Inert |
| Methane | $CH_4$ | 0.0008 | 0.00015 | Greenhouse gas |
| Krypton | Kr | 0.003 | 0.0001 | Inert |
| Ozone | $O_3$ | Variable | Variable | Toxic |
| Water Vapour | $H_20$ | Variable | Variable | |

The normal atmosphere contains 21% v/v of oxygen, if this level decreases due to displacement of oxygen by an inert gas or carbon dioxide, there will be a deficiency of oxygen for normal breathing. Leading to insufficient oxygen reaching the body's tissues and vital organs. This effect is known as asphyxiation or simple anoxia and is the cause of many gassing incidents. The asphyxiating effect of inert gases takes place without any preliminary physiological sign that could alert the victim. The action is very rapid; only a few seconds for very low oxygen contents. Table 9 outlines the effects of oxygen deficiency on people.

**Table 9 The Effect of Oxygen Deficiency on the Body**

| Oxygen Content Vol % in the Atmosphere | Effects & Symptoms |
|---|---|
| 11 – 18% | Reduced physical & mental performance. Headache, dizziness & overall body weakness. |
| 6 – 11% | Possibility of unconsciousness within a short time. Risk of brain damage & death. |
| 0 – 6% | Immediate loss of consciousness followed by death. |

## 5.1 Carbon Dioxide

Carbon dioxide ($CO_2$) is toxic in high concentrations, as well as being an asphyxiant. The table below outlines the effects of increasing concentrations of carbon dioxide on the human body.

**Table 10 The Effect of Carbon Dioxide on the Body**

| Carbon Dioxide Content Vol % in the Atmosphere | Effects & Symptoms |
|---|---|
| 1 – 1.5 % (10,000 to 15,000ppm) | Slight effect on metabolism after exposure of several hours. |
| 3 % | Increase in blood pressure & pulse rate. Reduced hearing ability. |
| 4 – 5 % | Breathing becomes rapid. Signs of intoxication. |
| 5 - 10 % | Breathing becomes laborious. Headache. Loss off judgement. |
| 10 – 100 % | Unconsciousness eventually resulting in death. |

**Notes**

A. It is recommended that the indoor level of carbon dioxide in the workplace is maintained below 1000ppm (0.1%).
B. Although carbon dioxide is toxic it is convenient to treat it as an inert gas when considering control measures.

## 5.2 Control Measures for the Safe Use of Inert Gases

In addition to the general control measures and safety procedures for working with compressed gases the following additional control measures should be taken when working with inert gases:

- Consider installing a nitrogen generator or a liquid nitrogen storage and evaporation system, particularly if large volumes or a constant supply is required. The type of system would depend on the quality of the nitrogen, flow rate and volume required.

- Consider installing an air compressor or a zero generator or a liquid air storage and evaporation system, particularly if large volumes or a constant supply of air is required. The type of system would depend on the quality of the air, flow rate and volume of gas required.
- Consider installing a liquid carbon dioxide, argon or helium storage and evaporation system, particularly if large volumes or a constant supply of gas is required.
- Ensure that the working area is adequately ventilated.
- Where large volumes of inert gas are used or high concentrations of inert gas could build up in a room hence causing oxygen depletion, an oxygen level detection and alarm system should be installed. An example of where this is necessary in the University is the nuclear magnetic resonance spectroscope laboratory, in King Henry Building. Large volumes of liquid nitrogen and liquid helium are used to cool the super conducting magnets.
- Where there is a possibility of elevated levels of carbon dioxide occurring, such as in tissue culture laboratories, then carbon dioxide level detection and alarm systems should be installed.
- If it is suspected that a room space is unsafe to enter, then the atmosphere should be checked using suitable gas detection equipment before entering.

## 6. Flammable and Chemically Unstable Gases

### 6.1 Definition

A flammable gas is a gas having a flammable range with air at 20ºC and standard pressure of 101.3kPa.

Example: methane in air at 20ºC and standard pressure has a flammable range of 5% to 15% hence is defined as a flammable gas. Combustion and flammable limits below for further details.

Examples of flammable gases used in the University are acetylene, hydrogen and propane. An example of a chemically unstable gas is acetylene.

### 6.2 Classification Criteria for Flammable and Chemically Unstable Gases

*The Globally Harmonised System of Classification and Labelling of Chemicals* classifies flammable gases in to categories 1 or 2 and chemically unstable gases in to categories A or B as shown.

**Table 11 Criteria for Flammable Gases and Chemically Unstable Gases**

| Classification | Category 1 | Category 2 | Category A | Category B |
|---|---|---|---|---|
| Flammable gases | Gases, which at 20°C and a standard pressure of 101.3 kPa that: (a) are ignitable when in a mixture of 13% or less by volume in air; or (b) have a flammable range with air of at least 12% regardless of the lower flammable limit. | Gases, other than those of Category 1, which, at 20°C (68°F) and a standard pressure of 101.3 kPa (14.7 psi), have a flammable range while mixed in air. | Not applicable | Not applicable |
| Pyrophoric gases | Flammable gases that ignite spontaneously in air at a temperature of 54ºC or below | Not applicable | Not applicable | Not applicable |
| Chemically unstable gases | Not applicable | Not applicable | Flammable gases which are chemically unstable at 20ºC and at standard pressure of 101.3kPa | Flammable gases which are chemically unstable at a temperature higher than 20ºC or a pressure greater than 101.3kPa |

### 6.3 Combustion and Flammable Limits

The normal combustion process is an oxidation reaction taking place in the vapour/gaseous phase which gives out energy (heat and light).

In order for a combustion reaction to occur, the concentration of flammable gas or vapour in air must lie between the upper and lower flammable limits; the flammable range of the gas.

**Table 12 Lower and Upper Flammable Limits for Gases Routinely used in the University**

| Gas | Lower flammable limit (LFL) V/V% | Upper flammable limit V/V% |
|---|---|---|
| Acetylene | 2.4 | 88.0 |
| Butane | 1.4 | 9.3 |
| Hydrogen | 4.0 | 75 |
| Methane | 5.0 | 15.0 |
| Propane | 2,2 | 9.5 |

### 6.4 Hazard Communication

**Table 13 Label Elements for Flammable Gases**

| | Pyrophoric Gases | Flammable Gases | | Chemically Unstable Gases | |
|---|---|---|---|---|---|
| | | **Category 1** | **Category 2** | **Category A** | **Category B** |
| **Symbol** |  |  | No symbol | No additional symbol  | No additional symbol  |
| **Signal Word** | Danger | Danger | Warning | No additional signal word | No additional signal word |
| **Hazard Statement** | H250 Catches fire spontaneously if exposed to air | H220 Extremely flammable gas | H221 Flammable gas | H230 May react explosively even in the absence of air | May react explosively even in the absence of air at elevated pressure and/or temperature. |

### 6.5 Fuel Gases

Gases such as methane, propane and butane are often referred to as fuel gases.

**Table 14 Label Elements for Flammable Gases**

| Properties | Methane | Propane | Butane |
|---|---|---|---|
| **Formulae** | $CH_4$ | $C_3H_8$ | $C_4H_{10}$ |
| **R.M.M. (M.W.) g/mol** | 16 | 44 | 58 |
| **Form** | Compressed gas | Liquefied gas | Liquefied gas |
| **Vapour Density kg/m$^3$** | 0.6 | 1.87 | 2.44 |
| **Lower Flammable Limit % in air** | 5 | 2 | 2 |
| **Higher Flammable Limit % in air** | 15 | 11 | 9 |
| **Freezing Point $^0$C** | -182.5 | -187 | -138 |
| **Boiling Point (liquid Vapour) $^0$C** | -161.5 | -42 | -5 |
| **Maximum Flame Temperature with air $^0$C** | | 1,925 | 1,895 |
| **Calorific Energy per Kg in KWH** | | 13.84 | 13.72 |
| **Cylinder colour** | Red | Red | Blue |

### 6.6 Control Measures for Flammable Gases

In addition to the general control measures and safety procedures for working with compressed gases the following additional control measures should be taken when working with flammable gases:

- Eliminate the need to use a flammable gas.
- Substitute a safer gas or technique.
- Where the work requires a hydrogen supply consider installing a hydrogen generator.
- Segregate the work.
- Ensure the ventilation is suitable and sufficient for the work to be carried out safely, the use of local exhaust ventilation such as a fume cupboard may be necessary.
- Ignition sources should be avoided or controlled. Particular attention should be paid to the possible build-up of static electricity.
- Ensure that the equipment used is suitable for use with flammable gases, intrinsically safe electrical equipment may be necessary.
- Flash back arresters and a one way valve should be used.
- Before entering or working in confined spaces, the atmosphere should be checked by suitable gas detection equipment.
- Never “snift” flammable gases indoors.

### 6.7 Pyrophoric Gases

Pyrophoric gases react violently when exposed to water and humid or dry air. Work involving these gases require special techniques and equipment and personal protective equipment. Examples of pyrophoric gases are: arsine, diborane, phosphine and silane.

Before a pyrophoric gas is ordered the Health and Safety Office should be consulted.

## 7. Oxidising Gases

### 7.1 Definition

An oxidising gas is any gas which may, generally by providing oxygen, cause or contribute to the combustion of other materials more than air does.

Compressed air has an oxgen content of 21% and is classed as an inert gas.

Examples of oxidising gases used in the University are oxygen and nitrous oxide.

### 7.2 Classification Criteria for Oxidising Gases

*The Globally Harmonised System of Classification and Labelling of Chemicals* classifies oxidising gases in a single category.

**Table 15 Criteria for Oxidising Gases**

| Category | Criteria |
|---|---|
| 1 | Any gas which may, generally providing oxygen, cause or contribute to the combustion of other materials more than any air does. |

**Hazard Communication**

**Table 16 Label Elements for Oxidising Gases**

| | Category 1 |
|---|---|
| **Symbol** |  |
| **Signal Word** | **Danger** |
| **Hazard Statement** | **H270 May cause or intensify fire: oxidiser** |

### 7.3 Control Measures for Oxidising Gases

In addition to the general control measures and safety procedures for working with compressed gases the following additional control measures should be taken when working with oxidising gases:

- Eliminate the need to use an oxidising gas.
- Substitute a safer gas or technique.
- Where the work requires a high volume or a continuous supply of oxygen, consider installing an oxygen generator.
- Grease, oil and normal PTFE tape must never be used on cylinder heads or fittings which are used in systems that carry oxygen. If PTFE tape is required, then a special grade suitable for use with oxygen is available.
- Segregate the work.
- Work in well ventilated areas.
- Ensure the ventilation is suitable and sufficient for the work to be carried out safely, the use of local exhaust ventilation such as a fume cupboard may be necessary.
- Ignition sources should be avoided or controlled. Particular attention should be paid to the possible build-up of static electricity.
- Ensure that the equipment used is suitable for use with oxidising gases.
- Before entering or working in confined spaces, the atmosphere should be checked by suitable gas detection equipment.

# 8. Acutely Toxic Gases

## 8.1 Definition

Acute toxicity refers to adverse effects following an inhalation exposure of 4 hours to a gas.

## 8.2 Classification

*The Globally Harmonised System of Classification and Labelling of Chemicals* classifies gases as one of five toxicity categories based on acute toxicity by the inhalation route according to the numeric cut-off criteria as shown in the table below. Acute toxicity values are expressed as LC50 (inhalation) values or as acute toxicity estimates (ATE).

**Table 17 Acute Toxicity Hazard Categories and Acute Toxicity Estimate (ATE) Values Defining the Respective Categories**

| Category 1 | Category 2 | Category 3 | Category 4 | Category 5 |
|---|---|---|---|---|
| 100ppm(volume) | 500 ppm(volume) | 2,500 ppm(volume) | 20,000 ppm(volume) | |

## 8.3 Hazard Communication

**Table 18 Label Elements for Acutely Toxic Gases**

| | Category 1 | Category 2 | Category 3 | Category 4 | Category 5 |
|---|---|---|---|---|---|
| **Symbol** |  |  |  |  | No symbol |
| **Signal Word** | Danger | Danger | Danger | Warning | Warning |
| **Hazard Statement** | H330 Fatal if inhaled | H330 Fatal if inhaled | H331 Toxic if inhaled | H331 Toxic if inhaled | H332 Harmful if inhaled |

Acutely toxic gases are very hazardous and should only be used by trained and competent staff. Work involving these gases requires special techniques and equipment and personal protective equipment, which may include respiratory protective equipment (RPE). If RPE is used then face fit testing should be carried out. An example of an acutely toxic gas is Hydrogen Sulphide. Before an acutely toxic gas or mixture, containing any concentration of an acutely toxi gas, is ordered the Health and Safety Office should be consulted.

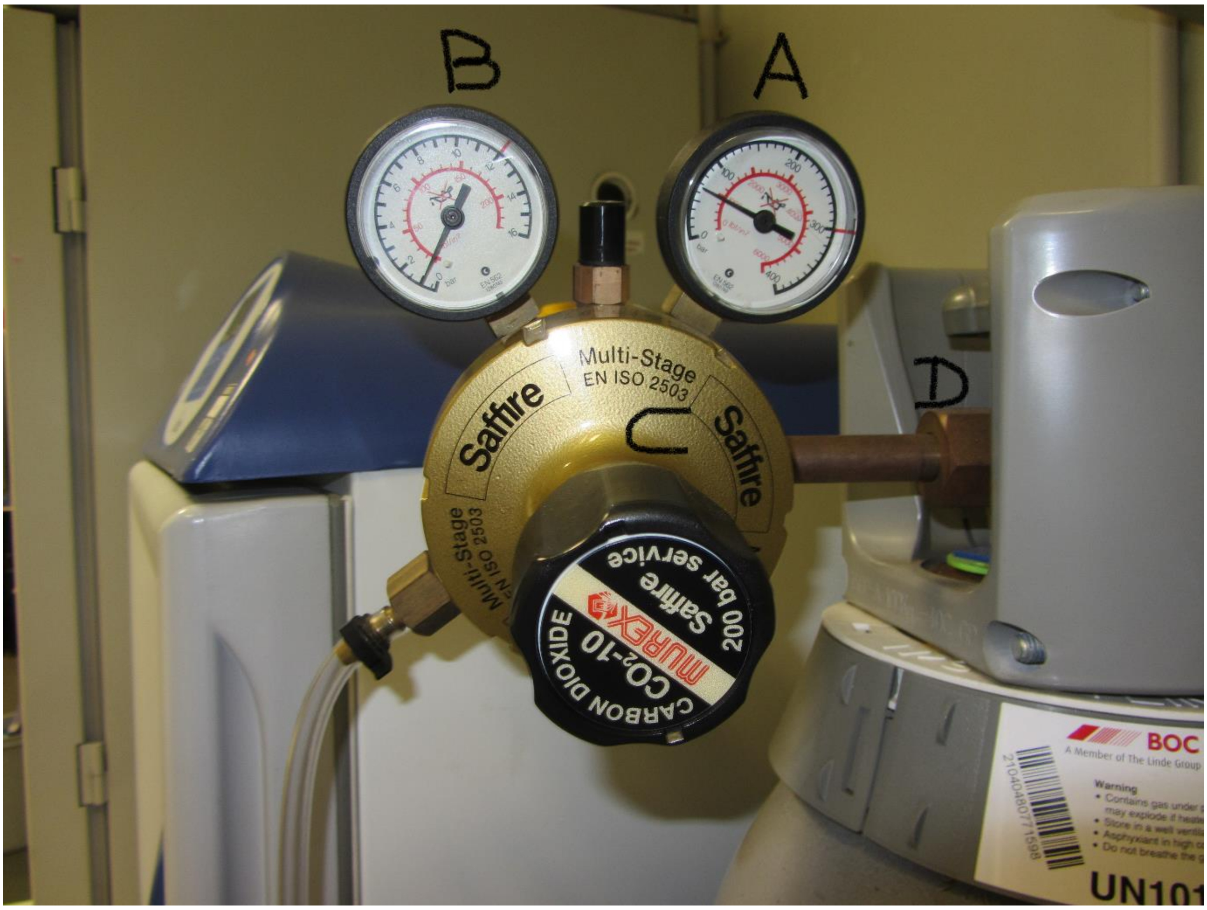
## 9. Pressure Regulators, Flow Controllers and Safety Devices

### 9.1 Industrial Gas Pressure Regulators

The pressure regulator allows the high pressure of the gas in the cylinder to be reduced 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, chromium plated or stainless steel. The application will define the required regulator. Consult the gas supplier if there is any uncertainty regarding which kind of regulator to use. Regulators are designed to be fitted directly to the cylinder valve, PTFE tape or lubricants should be used to connect a regulator to a gas cylinder valve.

Regulators for non-flammable gases have a right-hand thread.
Regulators for flammable gases have a left hand thread.

**Figure 6 Pressure Regulator for Industrial Gas**




A. Inlet pressure gauge.
B. Oulet pressure gauge.
C. Outlet pressure adjusting screw. Note type of gas regulator is suitable for and the maximum service pressure in bar is marked on the front of the screw, in this case carbon dioxide at 200bar.
D. Cylinder connecting nut, as carbon dioxide is non-flammable, the thread is right handed.

**Figure 6 Pressure Regulator for Industrial Gas Rear View**

The view of the back of a two-stage pressure regulator showing the replacement date, inlet and outlet pressure ratings and EN ISO number.

## 9.2 Propane and Butane Pressure Regulators

**Figure 7 Propane Cylinders with Regulators**

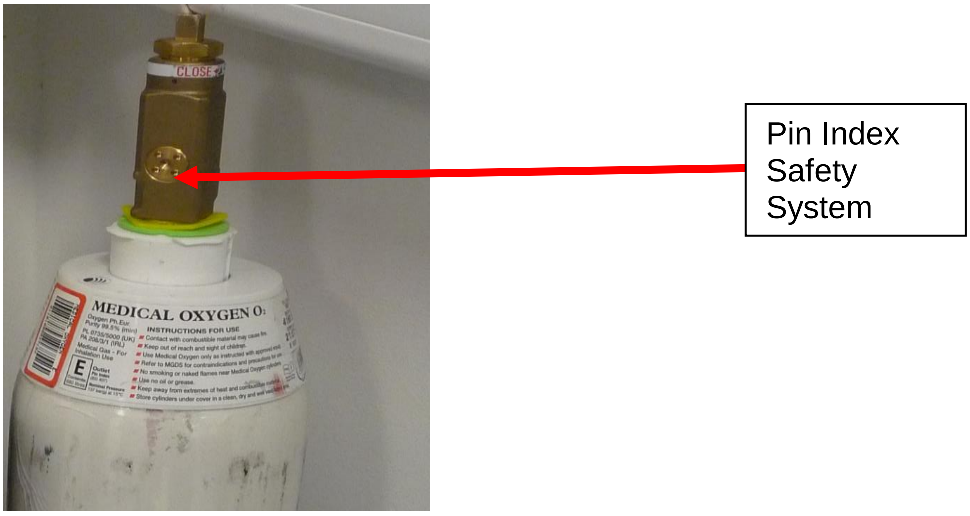

Low pressure propane screw on gas regulator.

High pressure hose connecting the cylinder to an industrial gas pressure regulator.

### 9.3 Medical Gas Pressure Regulators

Medical gas cylinders use a Pin Index Safety System which has a unique configuration of holes in the face of the cylinder valve which match precisely with the positions of the pins in the yoke fitted to the regulator or anaesthetic machine. This eliminates the risk of connecting the wrong cylinder to the equipment, preventing the wrong gas being administered to the patient.

**Figure 8 Medical Oxygen Cylinder**




### 9.4 Fitting Pressure Regulators to Cylinders

- Wear safety glasses and appropriate PPE.
- If grit, dirt, oil or water enters the cylinder valve then safety and/or quality may be compromised and gas leakage may occur. Before assembling regulators and fittings, it is extremely important to ensure there are no particles of dirt in the cylinder outlet.
  If a supply of clean compressed air or nitrogen is available this should be used to blow out any loose particles of dirt from the valve sockets. Eye protection must be worn during this operation. Where clean compressed air or nitrogen is not available, particles of dirt and residual moisture can be removed by 'cracking' open and immediately closing the valve (otherwise known as 'snifting').[1]
  When 'snifting' the following safety precautions must be adhered to:
  - Must always be done out of doors or in a well ventilated place.
  - Always wear eye protection.
  - Ensure there is no possible source of ignition within the vicinity.
  - Stand clear of the gas stream. On no account deflect the gas stream with the hand or the face.
  - Be aware of the potential noise hazard and take precautions if necessary.
  - In the case of high purity gases such as argon, it is recommended that the outlet of the cylinder valve is dried with a clean cloth before snifting.

[1] https://www.boconline.co.uk/en/health-and-safety/gas-safety/cylinder-safety/cylinder-maintenance/index.html

- ❖ **Never ‘snift’ hydrogen** as it may ignite spontaneously.
- ❖ **Never ‘snift’ flammable gas** indoors.
- ❖ **Never ‘snift’ toxic gases**: instead, carefully inspect the outlet and if there are any signs of dirt, blow it out with a jet of clean compressed air or nitrogen.

➢ Before fitting a regulator to a cylinder, the following checks should be carried out:

**Table 18 Pre Installation Pressure Regulator Checks**

| | |
|---|---|
| Is the regulator suitable for the gas being used? (Regulators are designed for use with a specific gas and to interchange them could be hazardous) | Y/N |
| Is the regulator pressure rated for the maximum gas pressure in the cylinder and the maximum pressure required from the outlet? | Y/N |
| Is the regulator over 5 years old? (Regulators should be replaced or refurbished every five years) | Y/N |
| Does the regulator appear to have been dropped or damaged or modified? | Y/N |
| Are there any signs of fire or heat damage to the compressed gas cylinder or pressure regulator? | Y/N |
| Are the gauges registering a pressure? | Y/N |
| Are the gauge glasses cracked, broken or contain a liquid? | Y/N |
| Is there any contamination by oil or grease? | Y/N |
| Are there any traces of PTFE tape or lubricants on the threads? | Y/N |
| Is there any damage to the threads? | Y/N |
| Is the cone seating (bull nose) damaged? | Y/N |

If the answer to any of the above questions is YES then the regulator must be immediately taken out of use, labelled as faulty and the technical manager informed.

In the case of propane and butane the following procedure should be used:

- ➢ Ensure the cylinder valve is closed using the spindle key and down stream valves are closed.
- ➢ Ensure the outlet pressure adjusting screw is fully wound out.
- ➢ Connect the pressure regulator to the cylinder, if necessary using the pressure regulator spanner, do not overtighten.
- ➢ Open the cylinder valve fully and then turn it back half a turn.
- ➢ Perform a leak test, using a proprietary leak test liquid or spray following the manufacturers instructions.

Fitting propane and butane regulators:

- ➢ Check that the valve hand wheel is off by turning it clockwise.
- ➢ Remove the protective plug and leave it hanging (to replace later).
- ➢ Check the bullnose connection on the regulator for any damage before connecting.
- ➢ Make sure the gas bottle connection is tight.

**Notes**

If a very high withdrawal rate of propane or butane is used frost will form on the outside of the cylinder, which may affect the flow of the gas.


Patio gas which is supplied in green, white or yellow cylinders is propane. The cylinder's valves have different size threads or types of connectors from industrial propane cylinders.

### 9.5 One-way Valves

A one-way valve, check valve or non-return valve is a valve that allows compressed gas to flow through it in only one direction thereby preventing any backward flow. One-way valves are two-port valves, which means they have two openings in the body; one for fluid to enter and the other for fluid to exit.

### 9.6 Flow Controllers

Gas flow rate controllers are devices used to measure and control the flow of gases. Electronic mass flow controllers are designed and calibrated to control a specific type of gas at a particular range of flow rates. The device will then control the rate of flow to the given set point.

### 9.7 Flashback Arrestors

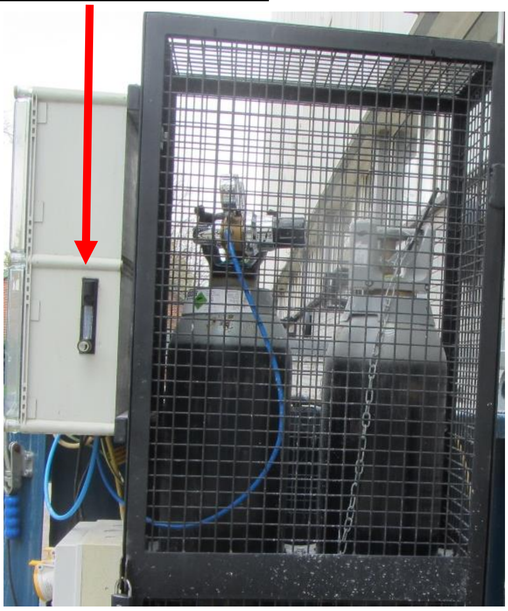
When a flammable mixture or flammable gas and air or oxygen is present in a gas line upstream of a flame, a flash back can occur in the gas line, and there is the possibility of a serious accident.
A flame or flashback arrestor is a safety device designed to prevent flashback into cylinders or pipework.

Resettable Flash Back Arrestor


Flash Back Arrestors

### 9.8 Needle Valves (Flow Controller)

**Flow Controller**



A needle valve is a type of valve having a small port and a threaded, needle-shaped plunger. It allows precise regulation of flow, although it is generally only capable of relatively low flow rates.
Needle valves are usually used in flow-metering applications, especially when a constant, calibrated, low flow rate must be maintained for some time.

### 9.9 Hoses

Hoses are designed to be used with a particular gas and have a maximum pressure rating. Hoses are colour coded for the particular gas they are designed to be used with.

| | **Hose Colour** | |
|---|---|---|
| **Gas** | | |
| Oxygen | Blue | |
| Acetylene / Hydrogen | Red | |
| Propane/ LPG | Orange | |
| Inert Gas (e.g. Nitrogen) | Black | |

- Hose must be in good condition.
- Hose lengths should be kept as short as possible.
- Hose used for hydrogen and fuel gases have left hand threads whereas hoses used for oxygen, oxidising and inert gases have right hand threads.
- Hose check valves should be fitted between the pressure regulator and the hose.
- Only correct fittings should be used to connect and join hoses.
- The pressure rating of the hose must never be exceeded.

# 10. Cylinder Storage

## 10.1 External Cylinder Stores

Cylinders which are not in use or are empty awaiting return should be stored in external purpose built facilities, which must:


- Only be used to store compressed gas cylinders.
- Be secure.
- Be a no smoking area and free from fire risk such as rubbish or ignition sources.
- Have the appropriate signage and safety notices clearly displayed.
- Be well ventilated.
- Provide protection from rain, snow and direct sunlight.
- Have a level, well drained non-slip base which is constructed of non-flammable material.
- Allow the cylinders to be stored vertically.
- Be fitted with means to securely support and store the cylinders and provide mechanical stability.
- Have sufficient space to allow safe manual handling of the cylinders.
- Have adequate lighting to allow safe cylinder handling.
- Be equipped with fire-fighting equipment.

## 10.2 Segregation

For storage purposes gases can be grouped as follows:

- Inert, oxidising and carbon dioxide
- Flammable
- Propane and butane
- Toxic gases may require special storage facilities

Full gas cylinders should be segregated from empty cylinders.

## 11 **Moving Compressed Gas Cylinders**

Compressed gas cylinders are very heavy and can be mechanically unstable therefore maneuvering them is potentially dangerous especially if they are wet and slippery.

The following precautions should be followed when moving compressed gas cylinders:

- Only staff who are trained and competent in manual handling should move compressed gas cylinders.
- A manual handling risk assessment should be in place.
- Personal protective equipment must be worn.
- The cylinder valve must be closed.
- Pressure regulators must be removed and if available protective caps fitted before moving a cylinder.
- A suitable cylinder trolley must be used.
- Cylinders may be moved a short distance by “churning”, this should be included in the training.

## 12. Damaged Cylinders

If a cylinder is damaged or has been involved in a fire the supplier must be contacted immediately for advice before moving the cylinder.