Safety Services

Guidance on Compressed Gas Safety

Reviewed 2012

University of Strathclyde Glasgow

CONTENTS

Appendices

GUIDANCE ON GAS SAFETY

1. Introduction

1.1 University Policy

It is the Health and Safety Policy of the University of Strathclyde to ensure so far as is reasonably practicable the health, safety and welfare of all its employees at work, of students while they are engaged in activities under the supervision of the University and of members of the general public who have access to University property.

It is recognised that departments throughout the University use gas bottles and gas installations as a critical part of their function, supporting both teaching and research alike. It is therefore incumbent on departments to manage the use, maintenance and inspection of these systems to ensure the safety of all those working in the department.

1.2 Aim and Scope of Guidance

This document aims to provide users and others with guidance on the safe operation of pressure systems. It provides simple practical advice on eliminating or reducing the risks associated with using pressurised gas cylinders. It does not extend to gas cylinders used in adverse or extreme conditions which will require special precautions. Specialist advice must be sought on such cylinders. It is aimed at all University staff and students using gas cylinders in their work, and especially in departments where gas cylinders are used or Estates Services, which may be involved in installation of gas supply systems.

1.3 Terminology

The legal term that covers gas cylinders is 'transportable pressure receptacle'. This is a generic term covering a number of types of pressure receptacle: tube, pressure drum, cryogenic receptacle, bundle of cylinders as well as cylinders themselves, plus the valve(s) fitted directly to the receptacle. However for the purpose of this guidance, the term "compressed gas cylinder" shall be taken to mean all these various types of pressure receptacle.

For the purpose of this guidance, the term **"handlers"** has been applied to staff and students who transport compressed gas cylinders and the term **"users"** for those who use compressed gas cylinders.

2. Roles and Responsibilities

2.1 Heads of Departments

In the context of this document, Heads of Departments are responsible for ensuring staff and students comply with risk assessments, adhere to good practice when transporting, using and installing pressurised gas equipment and for their safety training.

2.2 Individuals

All those who handle or use compressed gas cylinders must know how to identify the contents of a cylinder, be aware of the hazards, have received training and have completed, read and understood all applicable risk assessments. Personal protective equipment required by the relevant risk assessment should be worn.

2.3 Suppliers and Manufacturers

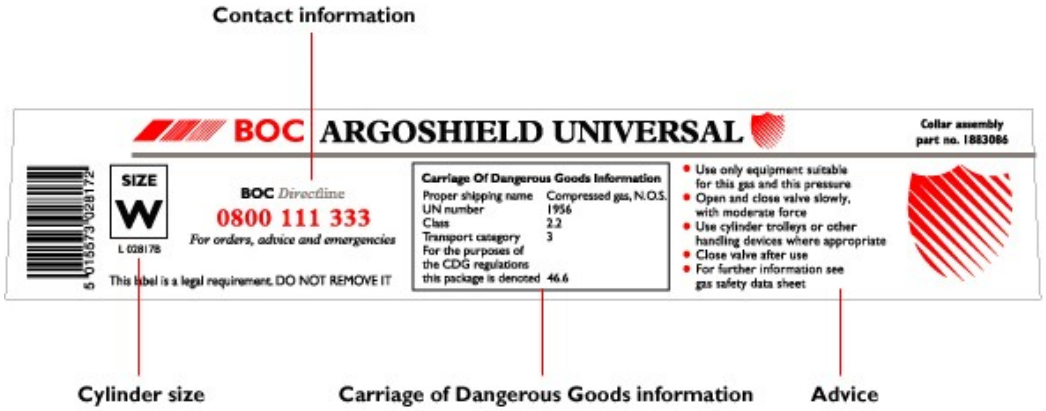
Most gas cylinders in use within the University will be supplied on a rental basis by gas suppliers and will be from a reputable supplier (e.g. BOC, Air Products etc.) who will routinely carry out suitable tests. However, if any department purchases their own cylinders, then **THEY** must ensure they are regularly tested.

All gas cylinders should have details of the relevant inspection body stamped or etched onto the shoulder area of each gas cylinder itself. Suppliers must deliver properly labelled compressed gas cylinders with safety caps in place and delivery should be accompanied with a written certificate from the supplier.

All gas cylinders must be designed and manufactured to an approved standard to withstand everyday use and to prevent danger. They will be inspected by the supplier before they are put into service to ensure they conform to the approved standard and will be periodically examined at appropriate intervals to ensure that they remain safe whilst in service. It is the responsibility of the department to verify with the supplier that such tests are carried out before cylinders are brought into use.

Figure 1: Example of a Suppliers Label:

* Multiple hazard diamonds may be applicable



3. Hazards and Accident Causes

Accidents involving gas cylinders can be very serious resulting in major injuries or death. Compressed gases are used for many different purposes including laboratory research work, medical uses (e.g. oxygen for breathing), soldering and welding, dispensing of beverages in the food sector, water treatment and for extinguishing fires. They may vary from being extremely flammable (acetylene) to being extremely inert (helium) and can be stored at extremely high pressures. If handled properly compressed gas cylinders are safe but if handled improperly, the same cylinders can present a severe hazard to individuals and the surrounding area and lead to very serious injuries or death.

Any damage, resulting from a cylinder falling over, tipping, being exposed to heat, electricity, motion, or vibration, may cause a weakness or crack in the cylinder wall leading to a number of hazards such as those listed below.

The main **hazards** from gas cylinders are:

- The pressurised nature of the contents, if suddenly released resulting in travelling cylinders, explosion, flying debris and blast impact;
- Impact from parts of gas cylinders, regulators or valves that fail;
- Contact with released gas or fluid which might be toxic (e.g. chlorine) or asphyxiating (e.g. carbon dioxide);
- Fire resulting from the escape of flammable gases (e.g. acetylene) or fluids (such as liquefied petroleum gas); and
- The weight of cylinders – as much as 80Kg.

The main **potential causes** of gas cylinder **accidents** are:

- Inadequate training and supervision;
- Poor installation, examination or maintenance;
- Faulty equipment and/or design (e.g. badly fitted valves and regulators);
- Poor handling, storage or transportation;
- Inadequately ventilated working conditions;
- Hidden damage or weakness; and
- Incorrect filling procedures from the supplier.

It is important that departments consider all these hazards and potential causes of accidents and take action to ensure that the risk of accidents involving gas cylinders is minimised. Cylinders that have been exposed to an event that could cause such weakness, must be taken out of service, appropriately labelled and returned to the supplier with information about the event.

Risk assessment

A risk assessment must be carried out to include storage, handling, transporting, labelling and use of gas cylinders as well as procedures to deal with emergencies. This will be done using the University's standard risk assessment form, S20 online. Departments should review their risk assessments especially if the circumstances for using particular cylinders change leaving the original risk assessment invalid, e.g. cylinders are being transported in lifts or being used in confined spaces.

Risk assessments must also consider the risk of asphyxiation from the lack of oxygen in the event of a cylinder contents venting rapidly. Where it is possible that oxygen levels could be reduced to below 19%, oxygen depletion monitoring should be considered as part of this process.

Below: Examples of exploded cylinders and the damage they can cause.

4. Identification and Labelling

All gas cylinders must be clearly labelled to show what they contain and the hazards associated with their contents, with a durable and non-removable label; **DO NOT** accept or use a gas cylinder if the label is unclear or missing. If the labelling on the gas cylinder becomes unclear and the contents cannot be identified, the cylinder should be marked "contents unknown" and the manufacturer contacted regarding removal of the cylinder.

DO NOT rely on the colour of the cylinder for identification, cylinder colours vary from supplier to supplier, and labels on caps have no value because many caps are interchangeable.

Gas lines leading from a compressed gas supply must be labelled to identify the gas, the laboratory or area served, and the relevant emergency telephone numbers.

Remember to **ALWAYS** read the label!
See also **Appendix 1.**

5. Storing Cylinders

5.1 Location and Storage method

Cylinders should be stored upright in a secure, safe place preferably using chains or brackets secured to a solid structure e.g. wall, to prevent them falling over. These areas should be outside and be provided with drainage, an overhead cover to protect cylinders from the elements and away from the risk of impact from vehicles. Gas cylinders should be stored within a secure, clearly marked compound or area.

Where it is not possible to store them outside, a full risk assessment will be required. Such storage areas must be well ventilated, protected from any external heat source and away from sources of ignition or flammable materials. Only the minimum number of cylinders necessary for the effective running of the department or processes should be kept. All obsolete or unused cylinders should be removed outdoors and returned to suppliers.

Corrosive materials can prove particularly hazardous if they come in contact with cylinders and care must also be taken to avoid contact with electricity or corrosive materials. Some small cylinders are not fitted with rupture devices and may explode if exposed to high temperatures.

5.2 Segregation of Gas Types

Cylinders containing the same gas should be stored in a segregated group; empty cylinders should be segregated from full cylinders. Flammable gas cylinders should not be stored with oxygen or nitrous oxide cylinders or adjacent to oxygen charging facilities nor should they be stored next to toxic gases or oxidisers, which again must be stored separately.

Oxygen cylinders should be kept a minimum of 3 metres away from cylinders of flammable gas (e.g. hydrogen, acetylene - unless these are on a trolley for oxy/acetylene cutting & welding, etc.) and combustible materials, or separated by a suitable fire break (e.g. a wall or barrier > or = 2.5 metres high) with a fire-resistance of > or = 30 minutes.

Gas cylinders containing flammable gas should not be stored in any part of a building used for other purposes.

For specific handling procedures see **Appendix 2**.

5.3 Signage

Cylinder storage areas must be identified with appropriate warning signs indicating the gas type(s) present along with any additional warnings (e.g. No Smoking) etc.

6. Handling and Use

Cylinders of compressed gases should be handled as high-energy sources and therefore as potential explosives. Observance of the following rules will help control hazards in the handling of compressed gas cylinders.

6.1 Cylinders

Always double check that the cylinder/gas is the right one for the intended use. Cylinder keys should always be available for each cylinder in use in case of an emergency.

Cylinders must always be secured in an upright position. When they are being moved, care must be taken to ensure they are not banged, dropped or permitted to strike each other or against other hard surfaces.

Cylinders should not be kept for longer than necessary and should be returned to external stores when not in regular use.

6.2 Cylinder Valves

All cylinders must be fitted with a valve and where appropriate, these should be residual pressure valves (non-return valves) to reduce the risk of back flow of water or other materials into the cylinder. These valves must be protected by a valve cap or collar, otherwise it should be designed to withstand impact if the cylinder is dropped. Never lubricate, modify, force, or tamper with a cylinder valve.

Cylinder valves must be opened slowly when connected to the gas supply. The cylinder valve **must** be closed when a gas cylinder is not in use or before attempting to stop leaks between the cylinder and regulator. Dust protection caps **must** be replaced where provided.

Do not use the valve cover to lift cylinders; they could be damaged and become detached and cause the cylinder to drop, possibly resulting in an explosion.

6.3 Regulators

Pressure-reducing regulators will always be required unless it can be proven otherwise. These regulators and associated pipework must be suitable for the type of gas and pressure being used prior to any connections being made. Regulators and pressure gauges must **only** be used with gases and pressure ratings for which they are designed and intended.

Gas regulators must be in good condition, e.g. glasses, fittings, outlets etc. must be undamaged and identified for the particular gas it can be used with. Regulators must not be connected to cylinders by the use of polytetrafluoroethylene (PTFE) type tape on the threads.

Regulators must not be adapted or repaired and routine leak-testing should always be carried out with non-corrosive gases using a suitable proprietary leak detection solution that is oxygen compatible.

All regulators should have an annual in-house inspection by a suitably qualified, competent and trained person. This information should be recorded on the regulator itself and the department must keep an inventory indicating the age and last inspection/replacement date of each regulator. A maintenance checklist is provided in Appendix 4 for use by competent individuals to carry out regulator inspections.

Cylinder regulators should be replaced every 5 years or earlier for certain gas types. Confirmation of replacement can be checked with supplier/manufacturer.

6.4 Safe Use of Oxygen/Fuel Gas Cylinders and Equipment

Fires can be caused by flashbacks, where a flame travels back to the gas cylinder. These can be avoided by following the steps below:

- Ensure appropriate risk assessments have been conducted in line with current legislation (e.g. DSEAR) and any applicable procedures e.g. permits to work;
- **Do not** use oxy/fuel gas equipment unless you have been trained;
- Always ignite the fuel gas before introducing the oxygen stream. The nozzle should be pointing upwards for acetylene, downwards for propane;
- Inspect equipment regularly and replace anything damaged or out of date. Effective maintenance and inspection is essential to ensure safety. Further advice can be found in the HSE document HSG139, Welding, Flame Cutting and Allied Processes;
- Ensure the valves, regulators and flashback arrestors are clean and free from dirt or grease;
- Fit non-return valves (often called check-valves) on the torch;
- Check for leaks before lighting up;
- Ensure the blowpipe / nozzle is not blocked;
- **Do not** use oxygen / fuel gas equipment without approved flashback arrestors. This is specified in DSEAR ACOP L138;
- Contact your gas suppliers for details on how to obtain these;
- Flashback arrestors should comply with BSEN 730; and
- If the flashback arrestor continually needs resetting, seek advice from the supplier.

If a flashback occurs:

- Immediately close both the blowpipe/nozzle valves, oxygen first. (Note: this is the opposite of normal closing down procedures);
- Close both cylinder valves;
- Ascertain the cause of the incident and examine all equipment for damage;
- Again reference should be made to document HSG139

7. Transporting and Movement of Cylinders

7.1 Transporting of Cylinders to and from University Premises by Suppliers

The transport of cylinders is regulated under The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009. These will in most instances be met by the Supplier but include:

- The vehicle suitable for the purpose and marked to show that it is carrying dangerous goods; and
- A suitably trained driver who carries the appropriate documentation about the nature of the gases.

It may be necessary to take special measures with certain types and quantities of compressed gases and fluids in order to ensure their safe carriage. If you have any doubts, seek further guidance from Safety Services.

7.2 Transporting and Movement of Cylinders within the University

Only suitably trained personnel using appropriate cylinder trolleys may transport cylinders. Only one cylinder should be transported at a time and the cylinders must be securely chained or strapped to the trolley to ensure stability and prevent falling. All regulators and hoses must be disconnected from the cylinders prior to moving them.

To protect the valve, the cover cap must be screwed on hand tight and remain on until the cylinder is in place and ready for use. Valves, shrouds and caps must not be used for lifting cylinders unless they have been designed and manufactured for this purpose.

8. Training and Competence

All staff and students who use and/or handle gas cylinders or change regulators require to be suitably trained and have the necessary skills to carry out their job safely. They should understand the risks associated with the gas cylinder and its contents.

- Users should be able to carry out an external visual inspection of the gas cylinder, and any attachments (e.g. valves, flashback arresters, and regulators), to determine whether they are damaged;
- Users should satisfy themselves that the manufacturing requirements have been carried out by examining either the written certificate accompanying the gas cylinder or the stamp or mark of the relevant inspection body on the gas cylinder itself;
- New staff or students using gas cylinders should receive induction training and be supervised closely. Training should include safe handling and storage practices, identification, signage, storage, transportation, use and emergency procedures; and
- Safety Services provides e-learning gas safety awareness training, gas safety practical handling courses and manual handling courses for all staff and students who handle and transport cylinders. Safety Services training website provides more information.

Further specialist training is required for any member of staff who examines or inspects gas regulators as part of an annual maintenance programme. Within departments this individual will be recognised as the “competent” person. Alternatively appropriately qualified external examiners may be employed.

9. Maintenance and Inspection

All gas cylinders must be periodically inspected by a competent person from the department to ensure they conform to the approved standards as well as being examined at appropriate intervals by the supplier/manufacturer to ensure that they remain safe while in service.

Anyone who examines or uses a gas cylinder should be suitably trained and have the necessary skills to carry out the job safely as well as understand the risks associated with the gas cylinder and its contents.

In addition, all pressure systems must be examined, tested and certified by a competent person annually.

Users should be able to carry out an external visual inspection of the gas cylinder, and any attachments to determine whether they are damaged. Visible indicators may include dents, bulges, evidence of fire damage and severe grinding marks, etc.

It is necessary to keep a record of any formal inspection, as well as annual inspections carried out at departmental level. These records must be maintained, easily accessible and kept within the department. These inspections must be carried out by a suitably trained person who has been deemed competent to do this. It is general industry practice to renew regulators every five years and in the case of toxic gases every two years, although if in doubt please contact the gas supplier

See also Section 11.3 for Maintenance and Inspection of Manifolds and Piped Supplies.

10. Emergency Procedures

Emergency procedures should be included as part of the COSHH assessment for gases. Appendix 2 details procedures to follow in the event of a fire, acetylene cylinders involved in a fire, a bursting disc and leakage from a cylinder. These should be considered and developed as part of the departmental procedures to deal with such emergencies.

10.1 Fire

Cylinders may burst, vent or explode when subjected to extreme temperatures so avoid "first aid" fire fighting and leave it to the professionals. Information on the contents of the cylinders must be provided to the emergency services who will deal with such situations with the supplier.

If an acetylene cylinder has been involved in a fire: KEEP AWAY, do not approach or attempt to move the cylinder or open the valve. Follow the procedure set out in Appendix 2.

10.2 Leaks from Cylinders

Procedures will include evacuation of the area, closing the valve where appropriate and increasing ventilation by opening windows if safe to do so. Refer to Appendix 2 for a simplified procedure which can be used as a basis for a departmental procedure.

11. Manifolds and Piped Supplies

Ducted gas supplies, such as those for incubators or compressed air units, are common across the University for a variety of uses. They are generally made up of cylinders stored away from the main work area and gas is piped in to a laboratory. These installations are subject to testing and maintenance and are the responsibility of the user department.

The main requirements which need to be met are those for both the Pressure Systems Safety Regulations 2000, (PSSR) and the Pressure Equipment Regulations 1999. For detailed information on these installations, departments must refer to the BCGA Code of Practice CP4, Industrial Gas Cylinder Manifolds and Gas Distribution Pipe Work. These notes do not cover systems which use acetylene. These publications can be obtained by contacting Safety Services.

11.1 Design, Construction, Installation Testing and Commissioning

It is the responsibility of designers and suppliers to ensure that pipe work systems are installed and constructed to the required specification. The **user** department is responsible for engaging those who have the competence, knowledge and experience, to meet these criteria. Estates Services should be approached for adaptations to both existing installations and also for all new installations.

When installing a gas manifold for the first time, expert advice must be sought from a specialist company to ensure it meets the strict criteria for the particular circumstances in each of the categories below.

- Installation and construction;
- The selection and suitability of component parts;
- The selection of components such as pipe, pipe bends, compression fittings, flanges, jointing materials, pipe. Materials need to meet certain standards e.g. pipe and compression fittings must be able to withstand the system design pressure and be compatible for the gas application in use;
- Jointing techniques;
- Routing options;
- Testing and commissioning procedures;
- Pipework protection options; and
- Cleaning methods.

Refer to Section 12 for a more detailed description of the considerations when installing a new gas manifold. Gas lines leading from a compressed gas supply must be labelled to identify the gas, the laboratory or area served, and the relevant emergency telephone numbers. All pressure systems must be examined, tested and certified annually by a competent person.

11.2 Provision of Information

The designer, supplier or the employer of a person who installs, modifies or repairs a pressure system must provide sufficient information to enable the user of that system to determine its safe operating limits.

Typically this may include design codes, process and instrumentation drawings or flow sheets, safe operating limits for pressure and temperature, design pressure and design temperatures, operating instructions (including emergency procedures), written scheme of examination, maintenance instructions, test certificates, declaration of conformity.

It is the **department's** responsibility to identify who will be responsible for these issues and ensure that safe operating limits and instructions are adhered to.

11.3 Maintenance

Maintenance covers items such as servicing, adjustment and performance checks through to routine safety inspections. Maintenance schedules should cover both routine and annual inspections.

Weekly checks will normally be carried out by a designated person within the department e.g. the laboratory technician. Annual checks should be carried out by a competent engineer or someone with the appropriate training, knowledge and experience.

Table 1: Example of Inspections

Weekly Inspection (by the user)	Equipment is visually in good order. Manifold, framework and chains are in good condition. Pigtails and flexible hoses are not corroded. Valves shut off and open correctly. Regulators are identified as being suitable for the gas and pressures and are not damaged. System is operating normally. Manifold house is free from oil and combustible materials and is not used as a storeroom.
Annual Inspection (by a person with appropriate experience and knowledge)	All repairs, modifications and extensions carried out conform to the Code of Practice. Changes in the vicinity of the installation do not affect operational safety. There is adequate identification of pipe work. The system is free from leaks by testing at the designated operating pressure. Filters are in good condition and are not blocked. Pipeline safety relief valve – ensure it lifts and re-seats within tolerance and that this is repeatable. Pressure measurements should be made using equipment which is calibrated and traceable to national standards.

11.4 Repair and Modification

- Any repair or modification made to a pressure system must not give rise to danger or otherwise impair the operation of any safety device or inspection facility;
- Repairs and modifications must be carried out to the same design and construction standards as the original system, so as not to reduce its integrity; and
- Systems records, flow sheets, operating instructions etc. will need to be updated following repair and modification.

11.5 Written Scheme of Examination

Under PSSR 2000, the user of an installed system shall not allow it to be operated without a Written Scheme of Examination certified by a competent person. The Written Scheme should extend to the following:

- All protective devices;
- All manifold pressure regulators (when they are a primary protective device);
- All high pressure hoses and pigtails; and
- All pipe work where a failure would give rise to danger.

11.6 Definition of the Competent Person

When choosing a competent person to carry out a written scheme the user must be satisfied that this person has the breadth of knowledge, experience and independence to carry out the functions required of them. Normally these individuals or companies will be members of the relevant national accreditation scheme. Refer to http://www.ukas.org/.

Competent Person	A user Company with its own in-house inspection department. An inspection organisation providing such services. A partnership of individuals. A self-employed person.
Functions	Advising the user in the scope of the Written Scheme Drawing up or certifying Written Schemes of Examination. Carrying out examinations under the Scheme.

11.7 Keeping of Records

Records should include the following:

- Written Scheme of Examination;
- The last report in accordance with the Written Scheme of Examination;
- Previous reports if they assist in assessing whether the system is safe to operate;
- Details of any repairs or modifications;
- Documents supplied by the designer, supplier or installer of the pressure system;
- Agreement to postpone an examination and notification to the enforcing Authority; and
- Details of any out of service periods and storage conditions.

12. Design and Installation Considerations

The British Compressed Gas Association gives minimum safety standards for the design, construction, installation, operation, examination and maintenance of industrial gas supply manifolds and associated distribution pipework (with the exception of acetylene, which has separate guidance) of up to 54mm nominal bore. The manifolds are supplied with gas from cylinders filled to a settled pressure of up to 300 bar gauge at 15^{o}C or from cryogenic containers of up to 1000 litres water capacity and maximum working pressures of up to 50 bar gauge.

The maximum distribution pipework pressures are limited to 50 bar gauge for any of the following gases: Argon, Carbon Dioxide, Helium, Hydrogen, Liquefied Petroleum Gas (LPG), Methane, Nitrogen, Nitrous Oxide, Oxygen or mixtures of these gases.

Where cryogenic containers are used, the code relates to gaseous and not liquid distribution.

12.1 Design

- The system should be designed in accordance with an appropriate published design standard or code and conform to the applicable requirements of the Pressure Equipment Regulations 1999 or the Pressure Systems Safety Regulations (PSSR), 2000;
- Flammable and oxidising gases will need to comply with The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002. A risk assessment will also be required and flammable gases will require the installation to be zoned according to a BS EN 60079; and
- Component materials which may be exposed to the gas stream should be compatible with the particular gas e.g. pipework.

12.2 Safety Distances

- The recommended Safety Distances should be observed when installing and storing gas systems. Distances will be dependent on the type of gas and installation;
- Where practicable, supply systems should be **sited outdoors** or in a specifically designed manifold room;
- Where the supply system and manifold are separately located, appropriate safety distances shall apply to both locations;
- Safety distances are measured from any point on the system, where in normal operation, leakage or spillage could occur;
- Large quantities of LPG or flammable cylinders may require increased distances than those suggested below and therefore should be checked;
- Fire resistant walls to a height of 2.5 metres, built and constructed of suitable materials may be used if the required minimum distances cannot be achieved on a horizontal plane; and
- The density of the gas must also be considered when considering safety distances.

12.3 Outdoor Location - Manifold Supply Systems

Manifold supply systems should be located outdoors if possible, especially for very toxic or pyrophoric gases.

- The site should be a secure, well ventilated enclosure (e.g. mesh cage) away from occupied areas;
- It must be protected against extremes of weather to prevent rusting and/or heating;
- Gates should not be self-locking and should open outward for easy access and egress;
- If manifolds are mounted on or against building walls, the walls should be made of suitable fire resistant material;
- The base area where the cylinders, bundles or cryogenic containers are located should be of concrete or non-porous material, oxygen compatible where applicable and of sufficient strength to take the weight of the cylinders or containers; and
- Surfaces shall be even and provide adequate drainage, so that cylinders or containers do not stand in water. Any slope should be such that cylinders are stable.

12.4 Indoor Location – Manifold Supply Systems

- If sited indoors, this should be in a specially constructed housing or in an established building which conforms with these safety requirements;
- If installed in an existing building, they should be separated from the rest of the building by means of a wall built to roof level of fire resistant material and one wall should be an outside wall;
- The walls of manifold rooms should be constructed of fire resistant materials and the floor of concrete or a similar inorganic material;
- The room should have a suitable access door designed to allow easy level access for cylinder movements and ideally have a second emergency escape door, one of which should be on an outside wall;
- The room must be well ventilated to prevent the build-up of gases if leakage should occur. If different gases are used in the same room, both high and low level ventilation may be required.
- Ideally two sides of the room should be open, preferably opposite sides. Where the room is part of an existing building, the ventilation must be arranged such that it is not into an existing building;
- The roof should be designed to prevent any build-up of lighter than air gases and where a pitched roof is used, this should be vented at the apex;
- Both the entrance and escape doors *(where fitted), should open outwards, not be self-locking and provide an easy means of escape;
- A risk assessment should be carried out to determine the level of risk which may occur in the room in the event of a leak i.e. asphyxiant, flammable or oxygen enriched atmosphere;
- Where relief valves or bursting discs are fitted to manifolds, the outlets should pipe away to safe areas;
- The outlet of any vent line should discharge into a safe area i.e. an area where gases can be discharged safely without creating an asphyxiant, flammable or oxygen enriched environment or where venting gas could impinge on materials or in proximity to people to create a hazard;
- The number of cylinders in the room should be the minimum necessary for the operation and safety distances between different gases should be observed;
- Flammable gas manifolds and pipework should be appropriately electrically earthed and any electrical systems present in the room should be in accordance with specific British Standards;
- The installation should be clearly identified with the product name and hazards, either on the outside of the manifold room or adjacent to an outside installation;
- Where there is a perceived risk at a use point from a gas escape, a risk assessment is required to establish necessary controls; and
- Connect all ducts used to exhaust hazardous compressed gas cylinders or gas-carrying components to a ventilation alarm.

12.5 Supply Systems

The supply system is the part of an installation from the outlet of the gas cylinder, cylinder pack or cryogenic container storage to the main pressure regulating equipment.

- It must be capable of withstanding maximum cylinder or cryogenic container pressure; and
- Various gas supply component parts are normally encountered for a range of gases and depending on the gas type some component parts will be essential, recommended, optional or not applicable (see Table 3).

Table: 3 Component Parts for Gas Supply Systems

Essential for all gas types	Recommended or optional (depending on gas type)
• Cylinder valves • Pigtail/flexible hose assembly • Non-return valve or isolating valve • Header • Header valve • Filter • Main regulator or auto-change with integral regulators	• Bursting disc or pressure relief valve • Purge valve • Heater • Vaporiser • Safety shut-off device • Regulator mounting block • High-pressure gauge • Low-pressure gauge and temperature control valve may or may not be required depending on the gas type in question

12.6 Distribution Systems

The distribution system is that part of the installation from the main pressure regulator equipment to the outlet point.

- The distribution system pipework should be operated at a pressure below the maximum supply pressure (i.e. 50 bar in the case of Code of Practice, CP4). The maximum allowable working pressure will be defined by design and construction and will be set out in the written scheme of examination, however systems will operate at >50bar;
- The distribution system needs to be protected against over pressurisation resulting from malfunction of the pressure regulator equipment or other abnormal circumstance; and
- Various gas distribution component parts are normally encountered for a range of gases and depending on the gas type some component parts will be essential, recommended, optional or not applicable (see Table 4).

Table: 4: Component Parts for Gas Distribution Systems

Essential and/or recommended for all gas types	Optional and/or other (depending on gas type)
• Pressure relief valve bursting disc • Outlet isolation valve • Isolating and non-return valves	• Flexible hose • Pressure gauge • Analysis valve • Alarm • Filter • Flow meter • Purge valve • Outlet point pressure regulator • Flashback arrestor and thermal cut-off valve

12.7 Pipework Design Considerations

Pipe systems should be designed:

- To avoid mechanical damage and minimise external stresses;
- To be easy to clean and purge, particularly if in oxygen and nitrous oxide service;
- As straight and direct as possible to avoid excessive pressure drop. Pressure drop will be increased due to fittings and components installed in pipework. The velocity of gas for materials of oxygen system constructions must be kept below a defined value;
- To be suitably protected if liable to external corrosion.
- With adequate support and protected where necessary from damage, vibration or corrosion;
- Sections of pipework in buildings should be kept to the minimum reasonable practicable length;
- If pipework needs to run inside buildings, it should be run in well ventilated rooms. Routings in enclosed spaces should be avoided if possible; and
- Identifying the gas conveyed.

12.8 Plastic Piping

Plastic piping should only be used for applications where the system pressure is prevented from exceeding the safe operating limits specified by the manufacturer for the use of suitable safety pressure relief devices, for inert gas service and in environments where the possibility of mechanical damage is minimal.

Plastic piping can be used with inert gas (i.e. excluding flammable and oxygen) providing the following criteria can be met:

- There is a minimum ratio between the burst and the safe working pressure of 4:1;
- Design temperature is within the range -20oC to 50oC;
- The coefficient of expansion for the material is considered;
- Possible degradation due to UV light, along with considerations for operating pressures, temperatures and the operating environment is evaluated;
- Potential damage; as plastic is more prone to damage than steel or copper.
- If flexible piping is used, sufficient supports should be used to prevent sagging; and
- It is replaced with piping of the original specification.

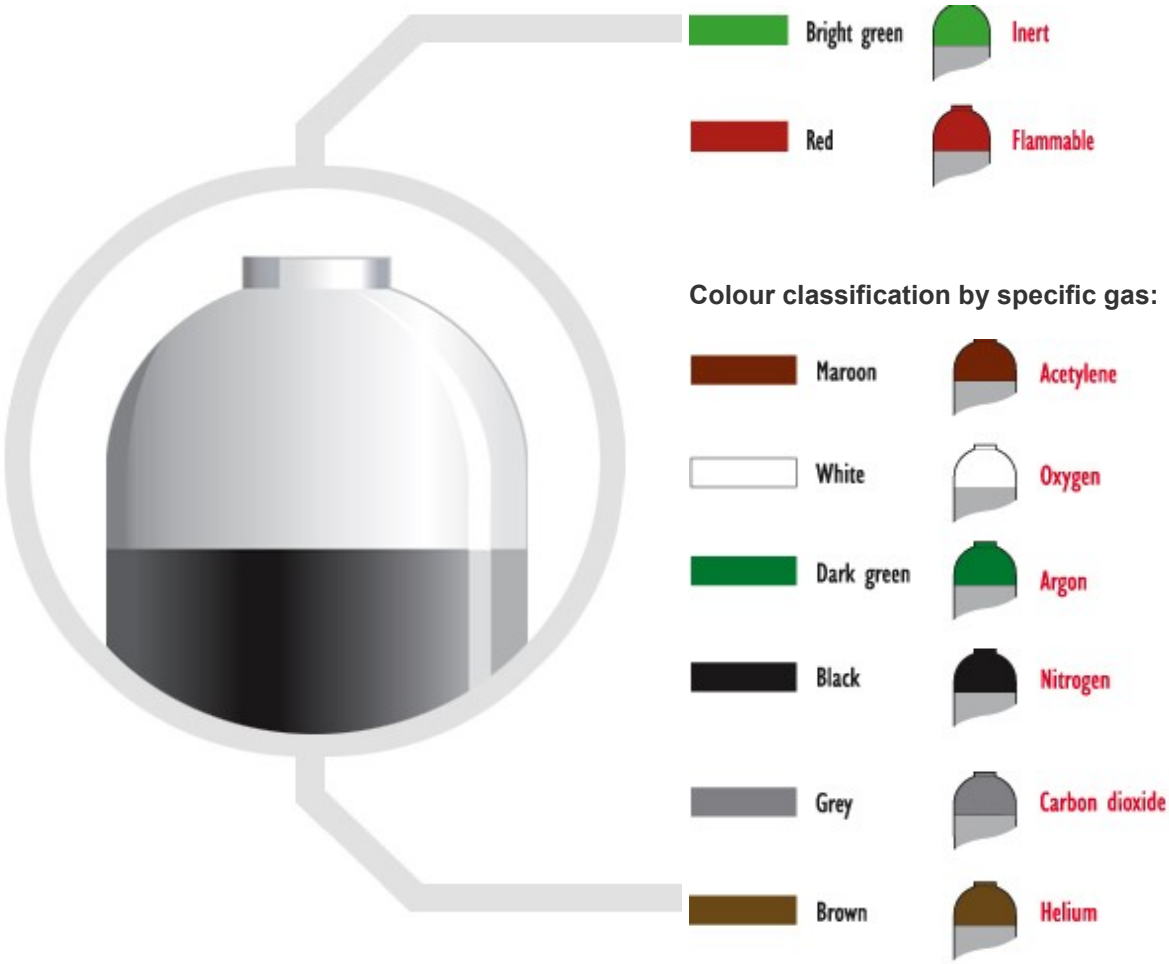
12.9 Piping Incompatibilities and Restrictions

- Make sure that all gas piping is compatible with the gases used and capable of withstanding full cylinder pressure;
- Do not use plastic piping in any portion of a high-pressure system;
- Do not use cast iron pipe for chlorine;
- Do not conceal distribution lines where a high concentration of a leaking hazardous gas can build up and cause an accident;
- Distribution lines and their outlets must be labelled clearly identifying the type of gas contained; and
- Where ferritic materials are used with oxygen note that there are limits of pressure and flow rate which must be applied

Piping systems should be inspected for leaks on a regular basis, preferably weekly. Special attention should be given to findings. More stringent joining and testing is required with primeval gases such as hydrogen and helium. In some cases a helium leak test may be appropriate.

Piped systems should be installed to a recognised standard e.g. as laid down within British Compressed Gases Association (BCGA) Code of Practice 4. Systems will vary in complexity, but whatever the case, they will require suitable maintenance.

Appendix 1 - Identifying BOC Gas Cylinders



Due to variation in monitor colour settings, the colours used for cylinder identification may not be accurate. Please contact BOC on 0800 111 333 if you have any queries.

Appendix 2 – Gas Safety Procedures

1. Storage

- Rotate stocks of gas cylinders to ensure first cylinder in, is the first cylinder used;
- Return corrosive gas cylinders to the gas supplier within one year, to avoid regulator and cylinder valve problems due to corrosion;
- Only purchase sufficient quantities of gas to cover short-term needs;
- Gas cylinders should not be stored for excessive periods of time;
- Ensure the cylinder valve is kept closed on empty cylinders to prevent contaminants getting in;
- Plastic caps used for valve protection should be kept on the cylinders at all times, except when the cylinder is actually being used;
- Empty cylinders should be clearly labelled or marked as “EMPTY”; and
- In cold weather particularly, cylinders should be allowed to warm up to room temperature before transportation to labs. This will avoid the cylinder warming up too quickly to room temperature before gas is taken off as this can result in a build-up of excess internal pressure.

2. Handling

- Wear appropriate personal protective equipment, such as safety shoes, safety glasses or goggles and gloves when handling gas cylinders and safety spectacles when using them;
- Damaged or leaking cylinders should be removed from service and tagged as "DAMAGED or DEFECTIVE" and reported to the supplier for uplift;
- NO gas cylinders may be cut, heated, welded or modified in any way;
- NO gas cylinder may be used for any purpose other than that for which it was designed; and
- The correct tools (e.g. appropriate sized cylinder keys) must be used to tighten cylinder connections and valves to avoid damage and over torque.

3. Visual Inspection

Users should be able to carry out an external visual inspection of the gas cylinder, and any attachments (e.g. valves, flashback arresters, and regulators), to determine whether they are damaged. Visible indicators may include dents, bulges, evidence of fire damage (scorch marks) and severe grinding marks, etc.

It is necessary to keep a record of any departmental annual and formal inspections; at departmental level these must be carried out by a suitably trained person who has been deemed competent to do this.

4. Emergency Procedures in the event of various incidents

a) In the event of Fire

- Operate the nearest available Fire Alarm Break Glass Call Point to raise the alarm;
- Dial 2222 from a safe place, giving details of incident and location to security control;
- Follow the Fire Evacuation Plan for the area/building concerned;
- If possible, isolate any piped supplies to the area affected, if safe to do so;
- Cylinders may burst, vent or explode when subjected to extreme temperatures, therefore avoid “first aid” fire fighting (e.g. using extinguishers) unless the fire is small and can be dealt with very quickly. If in any doubt, evacuate and leave to the professionals;
- DO NOT extinguish a flame involving a combustible gas until the source of gas has been shut off;

- On arrival, emergency services should be informed of the types of gases present in the area affected;
- It may be possible to cool cylinders with a hose from a safe distance – the emergency services will decide whether this is appropriate;
- Do not approach a cylinder that has been affected by fire. The emergency services and the supplier (e.g. BOC) will deal with matters when safe to do so and the supplier will recover the cylinder(s) for disposal; and
- Trip the remote emergency gas shutoff valve/button, if present.

b) Incident involving Acetylene

- Acetylene cylinders may react differently to other gas cylinders after exposure to fire due to a chemical reaction called decomposition. This reaction gives out a great deal of heat, which, if unchecked can cause the reaction to accelerate and the cylinders to rupture, even after the fire has been extinguished;
- Decomposition can be initiated from a flashback, by exposure to intense heat, or by shock to a warm fire-damaged cylinder;
- Acetylene cylinders are designed to minimise the risk if decomposition occurs. They contain a porous mass and a solvent in which the acetylene gas is dissolved. This mass acts as a stabiliser if decomposition was to start;
- The most effective way to control the reaction is to cool the cylinder by applying copious amounts of water to the exterior of the cylinder;
- If an acetylene cylinder has been involved in a fire: KEEP AWAY, do not approach or attempt to move the cylinder or open the valve;
- Operate the nearest available Fire Alarm Break Glass Call Point to raise the alarm;
- Dial 2222 from a safe place, giving details of incident and location to security control; and
- Follow the Fire Evacuation Plan for the area/building concerned.

c) Leakage from a Cylinder

- Supplies should be isolated if possible;
- If possible, increase ventilation by opening external windows, but only if safe to do so;
- Do not remove leaking cylinders from their ventilated enclosures until the leakage has stopped;
- Close the main cylinder valve if a leak is stopped or slow, hazardous gases are contained in their enclosure, and it is clearly safe to approach;
- Trip the remote emergency gas shutoff valve/button, if present; and
- Evacuate the laboratory/area and take steps to prevent re-entry until safe to do so, especially in cases of an oxygen depleted atmosphere.

d) Leakage from a CO2 Cylinder

In addition to being an asphyxiant CO_2 has a Workplace Exposure Limit (WEL) of 5000ppm (8hr TWA) and 15,000ppm (15mins STEL) (i.e. 1.5%). If the oxygen concentration drops to 19% v/v then the CO_2 concentration will increase to ~>or= 3% v/v. Exposure to this concentration of CO_2 would result in: headache (rise in blood pressure and pulse rate), breathing rate would double and hearing would be affected. If the assessment suggests that a CO_2 concentration of >10% v/v could arise then these concentrations would represent an immediate danger to life and health. Therefore in these circumstances fixed point CO_2 monitoring should be considered.

e) Suspected over-pressurisation of a CO_2 cylinder

Over-pressurisation will become apparent after attaching the regulator to the cylinder and opening the cylinder valve, so always check this carefully.

- If the pressure on the inlet gauge is in excess of the filled pressure, normally 50bar for CO_2, close the valve, remove the regulator, allow the cylinder to stand for a few more minutes and then reconnect and check pressure again;
- If the cylinder is still over pressure; close the valve, orientate the cylinder with the bursting disc facing away from any circulation route. Do not put the cylinder into service;
- Do not handle the cylinder further as movement may result in the bursting disc failing;
- On no account should the cylinder valve be used to 'throttle back' the inlet pressure;
- Evacuate the laboratory/area and contact the cylinder supply company immediately and ask them to remove the cylinder; and
- Report the incident to the Safety Services immediately and complete an S1 incident report form.

f) Rupture of Bursting Disc in Carbon Dioxide Gas Cylinder

Some cylinders such as carbon dioxide cylinders have bursting discs which operate if the pressure exceeds the maximum permissible service level (e.g. 50 bar). The bursting disc is designed to rupture at 180-200 bar - hence, if pressures approaching this value are noted when the regulator has been fitted, then rupture would appear to be imminent.

CO_2 is stored as a liquid under pressure however it is possible for solid CO_2 to form at the base of the cylinder and over-filling to occur. The bursting disc failure allows total loss of contents i.e. it does not relieve pressure and re-set, in the same manner as a pressure relief valve.

If the cylinder discharges into an unoccupied room, there is a risk to staff of asphyxiation from lack of oxygen. Risk assessments should take into account the amount of gas that could be released into the room and whether this may result in an unsafe atmosphere. Where it is possible that oxygen levels could be reduced to below 19%, oxygen depletion monitoring should be considered.

Fixed point CO_2 monitoring should be considered where there is a risk that the WEL for CO_2 may be exceeded. (See Appendix 4) Again, a risk assessment must be carried out to ascertain the circumstances and control measures which may be required to mitigate this risk.

g) Rupture of a bursting disc in any other cylinder.

- It will be immediately obvious to those present when a bursting disc ruptures, as gas will be emitted at very high pressure and velocity into the room.
- All personnel must immediately leave the laboratory and take steps to prevent re-entry until the full contents have been discharged and the oxygen levels within the room are safe (i.e. above 19%).
- If possible open any external windows, but only if safe to do so. This will assist in dispersing the gas and restoring oxygen to safe levels

Note: The above is aimed primarily at CO_2 cylinders, however all cylinders of compressed gas can be subject to over-pressurisation so the same principles should be applied, although there might be slightly different risks and calculations required depending on the actual gas in use. This must be considered as part of the department's risk assessment.

Appendix 3 - Gas Categories

Hazard	Description	Safety Precautions
Corrosive	Gases that corrode material or tissue with which they come in contact, or if in the presence of water. Can also be reactive and toxic and/or flammable or an oxidiser. Most are hazardous in low concentrations over long periods of time.	
Flammable **(e.g. acetylene, hydrogen, propane)**	These can be high-pressure, toxic, reactive and displace oxygen in air. A change in temperature, pressure or oxidant concentration may vary the flammability range considerably.	All possible sources of ignition must be eliminated through proper design of facilities and the restriction of smoking and open flames. Use a vent line made of stainless steel, purge with an inert gas and use a flashback arrester.
Inert **(e.g. Helium, Argon, Neon, Krypton, Xenon)**	Gases that do not react with other materials at ordinary temperature and pressure are classified as inert. They are colourless and odourless, as well as non-flammable and nontoxic. The primary hazard of these gases is pressure. These gases are often stored at pressures exceeding 138 bar. They can displace the oxygen levels when released in a confined place.	Use of adequate ventilation and monitoring of the oxygen content in confined places will minimise the danger of asphyxiation.
Oxidant **(e.g. Oxygen)**	Gases that do not burn but will support combustion are classified as oxidants. They can be high-pressure, toxic and reactive, and can displace breathing oxygen from air (except O_2 itself).	All possible sources of ignition must be eliminated when handling oxygen and other oxidants as they react rapidly and violently. Do not store combustible materials with oxidants. Do not allow oil, grease or other readily combustible materials to come in contact with the cylinder or equipment used for oxidant services. Use only equipment that is intended for this type of service. Materials and equipment must be scrupulously cleaned and degreased and jointing compounds or thread tapes be restricted to use on taper threads and PTFE must be of virgin, high density grade and grease-free (Often supplied in distinctive yellow packaging marked 'grease-free'.) Standard PTFE thread tape is NOT suitable.

Appendix 3 - Gas Categories (Contd.)

Hazard	Description	Safety Precautions
Cryogenic **(e.g. liquefied carbon dioxide)**	Gases with a boiling point below -90°C at atmospheric temperature are considered cryogenic gases. They are extremely cold and can produce intense burns and tissue necrosis may be even more severe. They can be non-flammable, flammable or oxidizing. Cryogenic liquids can build up intense pressures. At cryogenic temperatures, system components may become brittle and crack.	Never block a line filled with cryogenic liquid, as a slight increase in temperature can cause tremendous and dangerous build-up of pressure and cause the line to burst. The system should also be designed with a safety relief valve and, depending upon the gas, a vent line. Oxygen depletion monitoring should be considered as part of the risk assessment process. To protect from injury, wear gauntlet gloves to cover hands and arms. Take care to prevent liquids from getting trapped inside your shoes. Wear safety glasses and a face shield as cryogenic liquids tend to bounce upward when spilled. Materials and equipment must be scrupulously cleaned and degreased and jointing compounds or thread tapes be restricted to use on taper threads and PTFE must be of virgin, high density grade and grease-free (Often supplied in distinctive yellow packaging marked 'grease-free'.) Standard PTFE thread tape is NOT suitable.
Toxic or Poison	Gases that may produce lethal or other harmful effects on humans are classified as toxic or poison. They can be high pressure, reactive, non-flammable or flammable, and/or oxidizing in addition to their toxicity. The degree of toxicity and the effects will vary depending on the gas; however, death will occur when breathed in sufficient quantities.	Never work alone with toxic gases. Inspect the entire assembly or system that will contain the gas and thoroughly test it for leaks with an inert gas before use. Purge all lines with an inert gas before opening the cylinder valve or breaking connections. Use toxic gases in a well-ventilated area. For safety purposes and to minimise exposure, it is important to have gas detectors. Keep your inventory of toxic or poison gases to a minimum.

Appendix 4 - Gas Pressure Regulator Inspection Maintenance Checklist

Item Serial No.:				
Department:			**Location:**	
Regulator Type (one or two stage):			**Gas Type:**	
Date of Inspection:			**Inspected by:**	

No.	Item Check	Yes	No	Comments
1	Date codes and identified to BSEN ISO 2503			
2	Correctly labelled: max inlet and outlet pressure, name of gas and supplier			
3	Clean and free from contamination.			
4	Correct range of capacity for work in hand.			
5	Inlet in good condition.			
6	Outlet in good condition.			
7	Pressure adjustment screw captive.			
8	Pressure adjustment screw turns freely.			
9	Inlet pressure steady (inlet pressure gauge appears to be functional).			
10	Outlet pressure steady (outlet pressure gauge appears to be functional).			
11	Outboard gas leaks from regulator.			
12	Internal leakage from first to second stage.			
13	Outlet pressure creep.			
14	Safety pattern gauges fitted (e.g. gauges to EN 562)			
15	Gauges undamaged with no signs of zero error.			
	Summary of inspection assessment (including PASS or FAIL) Note: If a FAIL is determined, regulator should be removed from use.			

Appendix 5 - Legislation and Further Information

The main sets of Regulations referred to in this document are:

- The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 (SI 2007 No.1573).

- The Pressure Equipment Regulations 1999 (SI 1999/2001. T
  These cover within their scope the design, manufacture and initial integrity of cylinders used in breathing appliances and portable fire extinguishers, together with valves and other accessories used with these gas cylinders, which have a direct safety function

- Dangerous Substances and Explosive Atmospheres Regulations 2002 (SI 2776/2000)

- The Pressure Systems Safety Regulations 2000 (SI128/2000).

Health and Safety Executive

1. HSE Website
2. Safe Use of Gas Cylinders
3. Cylinder design standards
4. Safety of Pressure Systems, The Pressure Systems Safety Regulations 2000 Approved Code of Practice, L122
5. Welding, Flame Cutting and Allied Processes
6. DSEAR Approved Code of Practice L138

BCGA*

1. BCGA Website
2. Cylinder Identification. Colour Coding and Labelling Requirements
3. Handle Gas Cylinders Safely. Information for Customers Handling Gas Cylinders
4. Information for customers Collecting Gas Cylinders (Flammable, Inert and Oxidising Gases
5. BCGA Codes of Practice CP4 - Industrial Gas Cylinder Manifolds & Distribution Pipework / Pipelines (excluding acetylene). Revision 3: 2005
6. BCGA Guidance Note: GN2 - Guidance for the Storage of Transportable Gas Cylinders for Industrial Use. Revision 3: 2005
7. BCGA – Customer Leaflet: L6 Issue 2 2008

BOC

1. BOC Website
2. BOC safety data sheets
3.

Air Products

1. Air Products Website

*Publications by the British Compressed Gas Association can be obtained by contacting Safety Services.