Compressed Gas Safety Policy and Guidance

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Contents

1. Introduction

1.1 University Policy

It is the Policy of the London Metropolitan University to ensure 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, contractors and of members of the public who have access to University property.

It is recognised that some areas throughout the University use compressed gas cylinders and gas installations as a critical part of their function, supporting both teaching and research alike. It is therefore incumbent on those Schools, Professional Services and their departments to manage the use, maintenance and inspection of these systems to ensure the safety of all those working or conducting research 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.

This Guidance is aimed at all University staff and students using gas cylinders in their work, research and especially in areas where gas cylinders are used in Estates, eg in installation of compressed gas supply systems.

This guidance does not cover natural gas installations which is a scope of a separate policy.

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, students, researchers who transport compressed gas cylinders and the term **“users”** for those who use compressed gas cylinders.

2. Roles and Responsibilities

2.1 Heads of Schools/Departments

Heads are responsible for the day to day management of health and safety within their departments.

In the context of this document, Heads 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. They must also ensure that gas cylinders and components are supplied by a reputable supplier (e.g. BOC, Air Products etc.).

Heads must seek approval from Estates if any work on existing piped gas systems or installation of a new gas manifold is planned.

2.2 Local Managers

It is the responsibility of a Manager / Supervisor to ensure that:

1. Appropriate risk assessment/s for work with compressed gas systems and cylinders are made and recorded, and kept up to date by periodic review. See section 3 and 4 below and the Risk Assessment Policy for more details on risk assessment process.
2. Users/handlers of compressed gas systems and cylinders receive appropriate training (initial and refresher).
3. Any health monitoring and surveillance measures for users of compressed gas systems are identified in the risk assessment and implemented. Refer to Health Surveillance Policy.
4. Compressed gas hazard inventories are kept locally and regularly updated (when there is a change), and reviewed at least annually. They must be shared with the Fire Safety Advisor for updating the fire 'premisses information boxes'.
5. Local Managers must monitor the inspection regime (see section 7.2 and 10 and Appendix 2) of the gas cylinders and regulators, and replace gas regulators according to the manufacturer instructions.
6. Inform Estates on any piped installation so the service and maintenance could be arranged.

2.3 Handlers and users

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. Users and handlers must follow the safe operating procedures when working with gas cylinders described below in this Guidance. This includes carrying out inspections (Sections 10 and 11.3).
Users must report any defects with equipment or deficiencies in work practices to their Manager / Supervisor as soon as possible for remedial action.
Do not use failed or condemned equipment until they are repaired and fully fit for use.

2.4 Suppliers and Manufacturers

All gas cylinders must be designed and manufactured to an approved standard to withstand everyday use and to prevent danger. They must be initially inspected before they are put into service to ensure they conform to the approved standard and they must be periodically examined at appropriate intervals to ensure that they remain safe whilst in service. All gas cylinders should have details of the relevant inspection body stamped or etched onto the shoulder area of each gas cylinder itself (Fig. 1). 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.

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

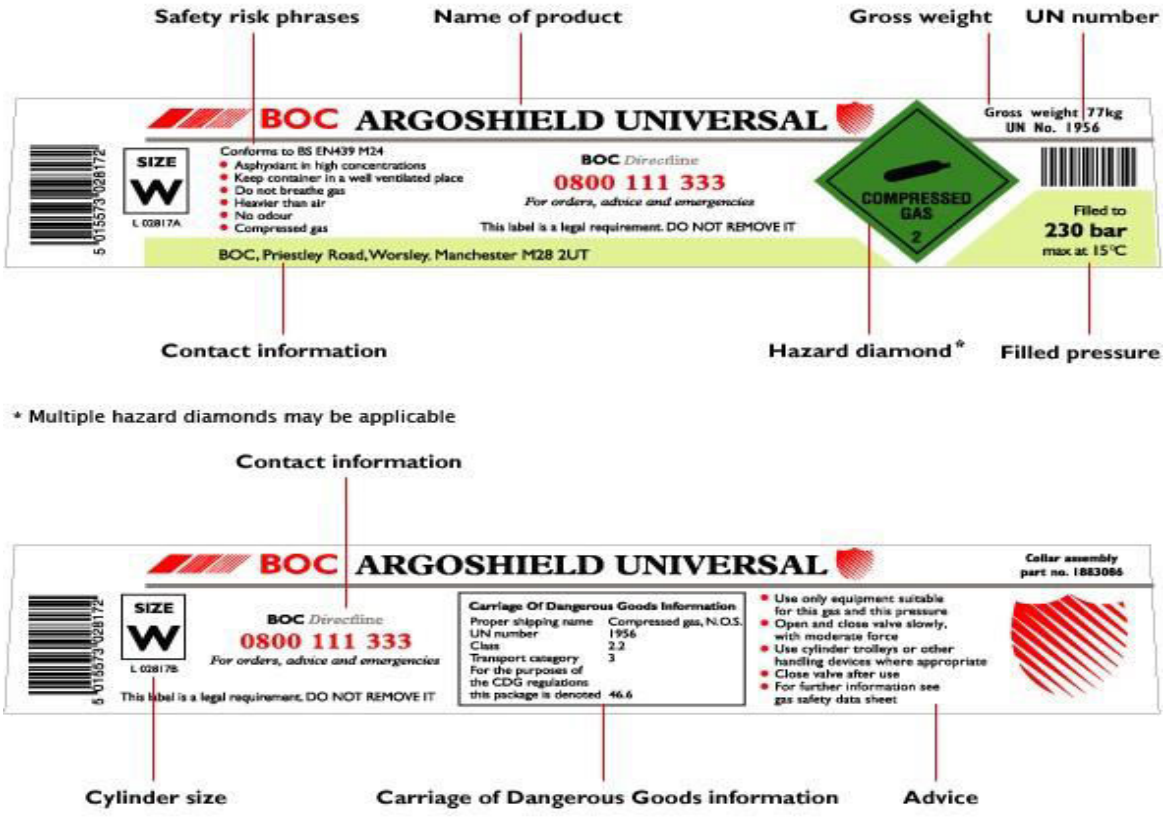

Fig. 1. Example of a Suppliers Label

It is the responsibility of compressed gas system suppliers to fully brief London Met client on the system safety and limitations.

2.5 Estates

It is responsibility of Estates to maintain and inspect gas manifolds and piped gas systems on University Premisses.

2.6 Health and Safety Team

The Safety Team exists to help all schools and departments effectively manage health and safety by providing advice and guidance on all workplace activities, including gas safety and gas supply installation.

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 resulting in cylinder rupture or explosion sending sharp metal pieces, like shrapnel, blasting through the area.

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

- 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);
- The weight of cylinders – as much as 80Kg.

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

- Inadequate training and supervision.
- Incorrect 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.
- 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.

4. 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. Normally this will be done using the University's standard risk assessment form. See Risk Assessment Policy for the details on the process. 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.

In 2016, an explosion of a pressure gauge during research work involving pressurised gases resulted in a PostDoc loosing her arm. It was identified, that the most likely immediate cause of the accident was an electrostatic discharge between the postdoctoral researcher and the gas storage tank which led to this laboratory explosion. This incident highlighted the importance of conducting adequate risk assessment for the whole process of use of gas, as well as the experiment environment.

5. 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!

6. Storing Cylinders

6.1 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. Examples of an bad and well-organised outside storage cage are shown in the Fig. 2.

Fig. 2. Examples of the incorrect and correct outside gas cylinder storage (correct storage must be locked when not in use).

Storage areas should be outside, otherwise they must be well ventilated, protected from any external heat source and away from sources of ignition or flammable materials. Where it is not possible to store them outside, 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.

6.2 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 (currently not present on the premises) 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

temporary 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 not designed for this purpose.

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

6.3 Signage

Cylinder storage areas must be identified with appropriately sized warning signs indicating the gas type(s) present along with any additional warnings (e.g. No Smoking) etc. Examples of signage are shown in Fig. 3.

Fig. 3. Example of storage signage.

7. 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.

7.1 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/supplier when not in regular use.

7.2 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.**

To prevent the interchange of fittings between cylinders containing combustible gases and non-combustible gases the cylinder valve outlets have different threads. Non-combustible gases, like oxygen, nitrogen, argon and air, all have right-hand threads. Combustible gases like acetylene, hydrogen, propane and mixtures containing fuel gas all have left-hand threads.

These precautions mean that oxygen and fuel gas regulators are not interchangeable. Spindle keys, however, are interchangeable.
The cylinder valves on all gas cylinders, whether they contain combustible or non-combustible gas, are opened by turning the spindle anti-clockwise and closed by turning the spindle clockwise (Fig. 4).

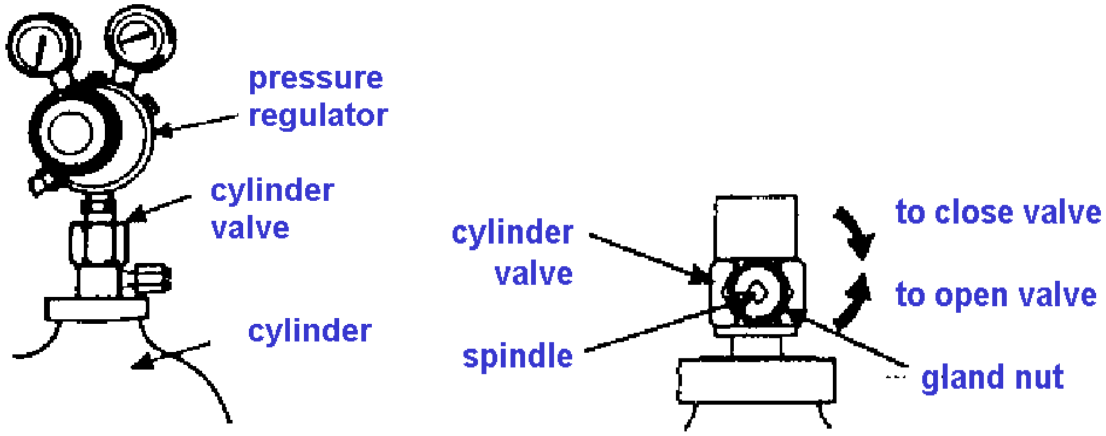

Fig. 4. Pressure regulator and cylinder valve.

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 get damaged and become detached and cause the cylinder to drop, possibly resulting in an explosion.

7.3 Regulators

Pressure-reducing regulators will always be required unless it can be proven that one is not required. 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 Section 10 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.

7.4 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. Follow the inspection and maintenance regimes specified in BCGA CP7 and GN7.
- Ensure the valves, regulators and flashback arrestors are clean and free from dirt or grease.
- Use 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 L137. Contact your gas suppliers for details on how to obtain these. Flashback arrestors should comply with BSEN 730.
- 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. **Refer to BCGA document CP7 for more information**.

8. Transporting and Movement of Cylinders within the University

Only suitably trained personnel using appropriate cylinder trolleys may transport cylinders (Fig. 5). 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.

Fig. 5. Trolleys suitable and not for transporting gas cylinders.

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.

9. 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.

- 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.
- 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.
- Gas Safety training is organised via CPED and includes gas safety awareness training, gas safety practical handling course and manual handling courses for all staff and students who handle and transport cylinders.

Unless included in the practical session, further specialist training is required for any member of staff who examines or inspects gas regulators as part of an annual maintenance programme (usually this would be local manager). Within departments this individual will be recognised as the “competent” person.

10. Maintenance and Inspection

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

Supplier:
All gas cylinders must be inspected on delivery by the supplier.
Supplier must collect cylinders for inspection at specified intervals indicated on the cylinder label (eg every 10 years).

Handler and user:
Visual inspection must be conducted at the point of use before use and thereafter periodically (weekly).

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.
Regular leak test with a specially designed inert leak test detergent is required before use.
Following checks must be done as a minimum:

1. Check visually that equipment is in good order, is being correctly used and all the required equipment is fitted.
2. Manifold, framework and chains are in good condition.
3. Pigtails and flexible hoses are not corroded or damaged.

4. Valves shut off and open correctly.
5. Regulators are identified as being suitable for the gas and pressures and are not damaged and are in date.
6. The system is operating normally, i.e. report to the local manager if the system is using more gas than normal, if there is an unusual drop in pressure or any indication of a malfunction or leak.
7. The manifold location is free from oil and combustible materials and the area is not used as a general storeroom.

Local manager:
In addition, all pressure systems must be examined, tested and certified by a competent person (usually this would be local manager) annually.
In addition to the aspect from weekly check above, following aspect need to be checked:

1. All repairs and modifications (including removals and additions of components) and extensions carried out conform to BCGA CP44.
2. Changes in the vicinity of the installation do not affect its operation or safety. Examples are location of heat sources or burners, moving of machines or work places, occurrence of vibrations, use of pipework as an electrical earth or as a support for other items, proximity to electrical installations and to other piping systems. There is adequate identification of above ground pipework and route markers for buried pipework.
3. The system is free from leaks by testing at the designated operating pressure.
4. Buried pipework is not visibly compromised in any obvious way.
5. Filters are in good condition and are not blocked and to clean or replace them where necessary.

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..

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.

11. Manifolds and Piped Supplies

Ducted gas supplies, such as those for incubators or compressed air units, are common across the University in laboratories 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/workshop. These installations are subject to testing and maintenance and are the responsibility of the Estates. It is responsibility of the Local manager to inform Estates of such installations.

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 Pressure Systems Safety Policy.

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. In accordance with University Control of Works Policy, all works concerning physical infrastructure, this will include amendments to the existing manifolds and installation of the new ones, and must be approved by Estates.

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 outlined in Section 12. 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 **Head of the department** responsibility to identify who in the department will take responsibility for these activity and ensure that safe operating limits and instructions are adhered to.

11.3 Maintenance of gas manifolds

Weekly checks will normally be carried out by a designated person within the department e.g. the laboratory technician (see Table 1 for an example of the check-list).

Annual checks should be carried out by a competent engineer or someone with the appropriate training, knowledge and experience (this is arranged via Estates).

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 if 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 tensions carried out conform to this Guidance. 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 be approved by Estates, 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.
- 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.
- 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/.

11.7 Keeping of Records

The owner of the installation/equipment must keep the 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.
- Details of any out of service periods and storage conditions.

12. Design and Installation Considerations

The BCGA Code of Practice (CP4) 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.
- Component materials which may be exposed to the gas stream should be compatible with the particular gas e.g. pipework.

12.2 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.
- 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 2)

Table 2. 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

12.3 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.
- 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 3)

Table 3. Component Parts for Gas Distribution Systems

Essential and/or recommended for all	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 cutoff valve

12.4 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. Identifying the gas conveyed.

12.5 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 -20^{o}C to 50^{o}C.
- 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.
- It is replaced with piping of the original specification.

12.6 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.
- 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.

13. 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.

13.1 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.
BCGA L6 Cylinders in Fire has more detailed information on managing cylinders involved in fire. Only trained staff should attempt to tackle a fire, all staff and students are expected to evacuate to avoid putting themselves at risk.

13.2 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 should be used to base the departmental procedure on.

14. 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). 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).
- Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2007 https://www.hse.gov.uk/cdg/index.htm

Health and Safety Executive

- HSE Website https://www.hse.gov.uk/
- Safe Use of Gas Cylinders http://www.bcga.co.uk/pages/index.cfm
- Cylinder design standards https://www.hse.gov.uk/cdg/stdcurr.htm

- Safety of Pressure Systems, The Pressure Systems Safety Regulations 2000
- Approved Code of Practice, L122 (HSE Books, ISBN 9780717617678)

BCGA

- BCGA Website http://www.bcga.co.uk/pages/index.cfm
- Cylinder Identification. Colour Coding and Labelling Requirements https://www.boconline.co.uk/en/
- Handle Gas Cylinders Safely. Information for Customers Handling Gas Cylinders https://www.boconline.co.uk/en/health-and-safety/safety-data-sheets/index.html
- Information for customers Collecting Gas Cylinders (Flammable, Inert and Oxidising Gases http://www.bcga.co.uk/pages/index.cfm
- BCGA Codes of Practice CP4 - Industrial Gas Cylinder Manifolds & Distribution Pipework / Pipelines (excluding acetylene). Revision 3: 2005
- BCGA Guidance Note: GN2 - Guidance for the Storage of Transportable Gas Cylinders for Industrial Use. Revision 3: 2005
- BCGA – Customer Leaflet: L6 Issue 2 2008

BOC

- BOC Website https://www.boconline.co.uk/en/index.html
- BOC safety data sheets https://www.boconline.co.uk/en/health-and-safety/safety-data-sheets/index.html

Air Products Website http://www.airproducts.co.uk

Appendix 1. 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.

Appendix 2. Gas Safety Procedures

A. 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.”
- on cold weather particularly, cylinders should be allowed to warm up to room temperatures 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.

B. 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.
- The correct tools (e.g. appropriate sized cylinder keys) must be used to tighten cylinder connections and valves to avoid damage and over torque.

C. 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.

D. Emergency Procedures in the event of various incidents

1. In the event of Fire

- **KEEP AWAY** – DO NOT approach or attempt to more the cylinder or operate the valve.
- Operate the nearest available Fire Alarm Call Point to raise the alarm and evacuate.
- Trip the remote emergency gas shutoff valve/button, if present.
- Dial 3333 (02073203333) from a safe place, giving details of incident (What gas, type, quantity? Where? What are other gases/hazards around?). Security will contact London Fire Brigade.
- If possible and safe to do so, isolate any piped supplies to the area affected.

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.

2. 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.
- Evacuate the laboratory/area and take steps to prevent re-entry until safe to do so, especially in cases of an oxygen depleted atmosphere.

3. Leakage from a CO2 Cylinder

In addition to being an asphyxiant CO_2 has a Workplace Exposure Limit (WEL) of 5000ppm (8hr TWA) and 15000ppm (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.

4. Suspected over-pressurisation of a CO2 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 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.
- Report the incident to the Safety Office immediately and complete an S1 incident report form.

5. 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 section 4 above). Again, a risk assessment must be carried out to ascertain the circumstances and control measures which may be required to mitigate this risk.

6. 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.