CODE OF PRACTICE 44

THE STORAGE OF GAS CYLINDERS

2016

British Compressed Gases Association

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PREFACE

The British Compressed Gases Association (BCGA) was established in l971, formed out of the British Acetylene Association, which existed since l901. BCGA members include gas producers, suppliers of gas handling equipment and users operating in the compressed gas field.

The main objectives of the Association are to further technology, to enhance safe practice, and to prioritise environmental protection in the supply and use of industrial, food and medical gases, and we produce a host of publications to this end. BCGA also provides advice and makes representations on behalf of its Members to regulatory bodies, including the UK Government.

Policy is determined by a Council elected from Member Companies, with detailed technical studies being undertaken by a Technical Committee and its specialist Sub-Committees appointed for this purpose.

BCGA makes strenuous efforts to ensure the accuracy and current relevance of its publications, which are intended for use by technically competent persons. However this does not remove the need for technical and managerial judgement in practical situations. Nor do they confer any immunity or exemption from relevant legal requirements, including by-laws.

For the assistance of users, references are given, either in the text or Appendices, to publications such as British, European and International Standards and Codes of Practice, and current legislation that may be applicable but no representation or warranty can be given that these references are complete or current.

BCGA publications are reviewed, and revised if necessary, at five-yearly intervals, or sooner where the need is recognised. Readers are advised to check the Association's website to ensure that the copy in their possession is the current version.

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* Throughout this publication the numbers in brackets refer to references in Section 11. Documents referenced are the edition current at the time of publication, unless otherwise stated.

TERMINOLOGY AND DEFINITIONS

Cylinders	For the purpose of this document cylinders refer to gas cylinders, bundles, packs and manifolded cylinder pallets (MCP).
May	Indicates an option available to the user of this Code of Practice.
Site	The premises of the organisation.
Store	A specific area dedicated to the storage of gas cylinders in-line with the requirements of this document.
Shall	Indicates a mandatory requirement for compliance with this Code of Practice and may also indicate a mandatory requirement within UK law.
Should	Indicates a preferred requirement but is not mandatory for compliance with this Code of Practice.
Vulnerable populations	Vulnerable populations include those who may not be easy to evacuate from premises because of, for example, age or infirmity, including schools, hospitals, old people's homes and other residential accommodation.

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THE STORAGE OF GAS CYLINDERS

1. INTRODUCTION

This Code of Practice provides advice and guidance for the safe storage of gas cylinders. It gives guidance on the construction and management of gas cylinder stores and provides information on the hazards likely to be encountered.

It shall be used when siting and constructing storage facilities or when reviewing the safety and suitability of existing storage facilities. It does not preclude the use of alternative designs, materials and methods, when they provide equivalent standards of safety.

The content of this publication is in line with advice from the Health and Safety Executive (HSE).

Where gas cylinders are stored in conjunction with other packaged dangerous substances additional guidance should be sought, refer to HSE HSG 71 (24). *Chemical warehousing*. *The storage of packaged dangerous substances.*

Gas cylinders are classed as hazardous substances and consequently gas cylinder stores will require relevant land use permission and may require planning permission from local authorities. Refer to Section 5.

2. SCOPE

This document defines the principles of safe practice for the storage of gas cylinders and gas cylinder bundles and outlines the relevant legal requirements in the UK.

Cylinders are never fully empty, unless a cylinder is new, de-valved, or following inspection and test where it has not yet been filled with a gas. Therefore, cylinders, containing a gas but regardless of the quantity of gas, shall all be treated in-line with this Code of Practice.

A gas cylinder(s) is deemed to be in storage when

- It is not in use; or
- It is not being transported.

Additional requirements for the storage of special gases, for example, very toxic or pyrophoric gases, are detailed in BCGA Code of Practice (CP) 18 (41), *The safe storage, handling and use of special gases*.

This Code shall be followed when storing gas cylinders and their associated gases with different hazard categories which are located within a common store(s). Where only liquefied petroleum gas (LPG) cylinders are stored in a dedicated LPG store refer to UKLPG CP 7 (60),

S*torage of full and empty LPG cylinders and cartridges*. Where a mixture of LPG (>400 kg) and other gas cylinders are stored then the applicable sections of UKLPG CP 7 (60) and this Code should be applied.

Exclusions from this Code of Practice are:

(i) Cylinders in use, i.e. connected to user equipment, or permanently connected for use; for example, fire protection systems and specifically sited emergency response equipment, such as, fire extinguishers and self-contained breathing apparatus. Refer to BCGA CP 4 (40), *Industrial gas cylinder manifolds and gas distribution pipework (excluding acetylene).*

(ii) Cylinders being processed for filling or for periodic inspection and test.

(iii) Medical cylinders in domiciliary use.

(iv) Gas cylinders during carriage by road, rail, air and sea.

(v) Cylinders permanently manifolded together to form part of a bulk gaseous hydrogen installation, refer to BCGA CP 33 (44), *The bulk storage of gaseous hydrogen at users' premises*.

(vi) Transportable vacuum insulated containers, for example, refer to BCGA CP 27 (43), *Transportable vacuum insulated containers of not more than 1000 litres volume*.

(vii) Containers (vessels) for cryogenic liquids. Refer to BCGA CP 26 (42), *Bulk liquid carbon dioxide storage at users' premises*, BCGA CP 36 (45), *Cryogenic liquid storage at users' premises*, and BCGA CP 46 (46), *Bulk storage of cryogenic flammable gases*.

(viii) Cylinders stored off-shore.

(ix) Aerosols.

3. GAS CYLINDER IDENTIFICATION

The cylinder label shall always be used as the primary means of identifying the contents of gas cylinders. The label will identify the product name and the class of hazard (Diamond Hazard Label(s)). Some gas cylinders may have this information stencilled on the body of the cylinder.

Colour coding is a secondary method of identifying certain gases or the properties of others, however colour coding is not mandatory for most gases but its use is supported by the majority of gas suppliers. Colour coding is typically applied to the shoulder, or curved part, at the top of the cylinder.

BCGA Technical Information Sheet (TIS) 6 (52), *Cylinder identification. Colour coding and labelling requirements*, provides comprehensive information on UK practice for cylinder labelling and colour coding.

Where the contents of a gas cylinder cannot be positively identified, the gas cylinder shall be quarantined and your gas supplier contacted for further advice. Refer to Section 10 for information on the return and disposal of cylinders.

4. POTENTIAL HAZARDS

Gas cylinders present a number of different hazards:

- Size, shape and weight - Manual handling, security.
- Pressure hazards.
- Product hazards.

As discussed below:

4.1 Size, shape and weight

Gas cylinders are generally heavy and are relatively unstable due to the base diameter to height ratio. Large cylinders can weigh over 100 kg when full and being tall and thin they are easily toppled over. Gas cylinders are awkward objects to move safely.

4.2 Pressure hazards

Cylinders contain gases stored under pressure and will have significant stored energy.

Any pressure above atmospheric released from a cylinder has the potential to cause injury to personnel, or damage to plant or property.

Pressure can be released by:

- Inadvertent operation of the outlet valve during handling.
- Deliberate operation of the outlet valve.
- Damage to the valve if cylinder topples or falls.
- Application of heat, for example, fire.
- Mechanical impact.
- Leaking valve.
- Operation of pressure relief devices.
- Unauthorised modification of the cylinder assembly.
- Failure of the cylinder wall, for example, from excessive internal and/or external corrosion (by reducing wall thickness).

4.3 Product hazards

All gases have different properties and each has its associated hazards.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (11) implement the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) (16), which provides a framework for dangerous goods to be carried internationally in road vehicles subject to compliance with standards for the packaging and labelling of the dangerous goods. Under ADR (16) gases are classified as Class 2 dangerous goods. Gases also require appropriate classification and labelling under the European Regulation on Classification, Labelling and Packaging of Substances and Mixtures (CLP) (14).

The classification of each gas is shown on the contents label. Full information will be shown in the individual product Safety Data Sheet.

A selection of the more common gas classifications are shown in Table 1. Further information is available in ADR (16) and EIGA Document 169 (37), *Classification and labelling guide*.

5. CYLINDER STORE – CONSTRUCTION AND GENERAL PRINCIPLES

5.1 Risk assessment

All gas cylinders contain gases under pressure and may present a risk of explosion if not safely handled and stored. UK legislation requires that a site specific risk assessment is required for each gas cylinder store, refer to *The Management of Health and Safety at Work Regulations* (6) and *The Dangerous Substances and Explosive Atmospheres Regulations* (DSEAR) (9). Every storage situation must be considered on its merits and special circumstances may necessitate variations on the recommended requirements.

The HSE provide a wide range of guidance on carrying out risk assessments on their website. www.hse.gov.uk/risk. Guidance on the preparation of Risk Assessments under DSEAR (9) is contained in BCGA Guidance Note (GN) 13 (49), *DSEAR Risk Assessment.*

5.2 Legal and permit requirements

The *Planning (Hazardous Substances) Regulations* (13) requires that consent from the local authority is obtained to store quantities of dangerous substances over certain thresholds. The regulations contain thresholds for both named substances, such as oxygen and hydrogen, and for generic categories of substances (flammable, toxic). For example the threshold for oxygen storage is 200 tonnes, for flammables 50 tonnes, but for hydrogen only 2 tonnes. In some cases the percentage / partial faction of thresholds (for example, flammables and oxidants) are additive when determining if consent is required.

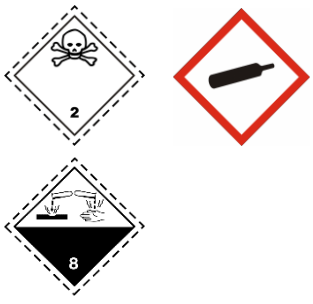
Category	Hazard pictograms	Signal word	Hazard statement Precautionary statement for storage	Notes
Class 2 Division 2.1 Flammable		Danger	Extremely flammable gas. Contains gas under pressure; may explode if heated. Store in a well-ventilated place.	Will burn if a source of ignition is present. Example: Hydrogen
Class 2 Division 2.2 Non-flammable Non-toxic Oxidizing		Danger	May cause or intensify fire; oxidizer. Contains gas under pressure; may explode if heated. Store in a well-ventilated place.	Strongly support combustion but do not, themselves burn. Example: Oxygen.
Class 2 Division 2.2 Non-flammable Non-toxic Asphyxiant		Warning	Asphyxiant in high concentrations. Contains gas under pressure; may explode if heated. Store in a well-ventilated place.	Do not in general react with other materials, but can cause asphyxiation by replacement of the oxygen in the atmosphere. Example: Nitrogen.
Class 2 Division 2.3 Toxic		Danger	Contains gas under pressure; may explode if heated. Toxic if inhaled. Store in a well-ventilated place. Store locked up.	Gases which, when inhaled, are known to produce injurious or fatal effects. Example: Hexafluoroisobutene
Class 2 Division 2.3 Corrosive		Danger	Contains gas under pressure; may explode if heated. Causes severe skin burns and eye damage. Toxic if inhaled. Corrosive to the respiratory tract. Store in a well-ventilated place. Store locked up.	Can cause severe burns to the skin and irritation to eyes and respiratory system. Example: Sulpher dioxide

Table 1: Gases classification.

It is unlikely that small quantities of cylinder gas storage will trigger these thresholds and there is a '*de minimus*' rule for small quantities (<2 % of the threshold). However as the thresholds include all dangerous substances held on the site, for example product, raw material or water treatment chemicals in bulk tanks, and as thresholds for toxic gases are lower, it is recommended that an evaluation is carried out to determinate if the site needs consent. For sites that currently have consent the addition of cylinder gases storage may require modification of the existing consent.

NOTE: Planning guidance can be found at:
http://planningguidance.planningportal.gov.uk/blog/guidance/hazardous-substances/when-is-consent-needed-for-the-storage-or-use-of-hazardous-substances/

Planning permission may be required for significant cylinder storage facilities under the *Town and Country Planning Act* (1). Contact your local authority for advice.

The *Control of Major Accident Hazards Regulations* (COMAH) (12) requires notification to the COMAH competent authority where a quantity of hazardous substances are stored above thresholds which are (with the exception of hydrogen at 5 tonnes) equivalent to the planning hazardous thresholds. There are additional requirements for upper tier sites.

The *Dangerous Substances (Notification and Marking of Sites) Regulations* (2) requires notification to the authorities where a total quantity of hazardous substances of 25 tonnes or more are stored, specific exemptions apply.

The storage, the location of the store and the use of gas cylinders may affect your insurance policy for the site. Check with your insurers that you have adequate cover.

5.3 Location of the storage area

The majority of gas cylinders are designed so that they can be stored in the open air and, as such, they will not be adversely affected by inclement weather.

Storage areas should be located in an external area where there is good natural ventilation. Adjacent buildings, structures and geographical features may adversely affect natural ventilation and their effect should be taken into account during the risk assessment, refer to Section 5.1 and Section 5.8. The store should not be located in low lying areas; where gases may accumulate.

Storage within a building is not recommended. Where storage indoors cannot be avoided, refer to Section 5.15.

The location of the store shall take account of the minimum recommended separation distances, refer to Section 5.4.1. Cylinder stores are to be located away from site designated emergency exits and escape routes.

Gas cylinder storage areas should be segregated from other stores. The risk assessment (refer to Section 5.1) shall take due regard of the potential hazards of the gases being stored and the risk from other hazardous processes or storage sites that may impact on a cylinder store. It shall also consider the potential for impact due to vehicle movements.

Storage locations should be sited at ground level. Where cylinders are stored at any other level this shall be specifically covered in the risk assessment (refer to Section 5.1). If the store is located at another level then consideration needs to be given to providing an area to allow vehicles to collect and deliver cylinders, cylinder movements between levels and the impact in the event of an incident for example, gas leakage, fire, access for emergency services, proximity to people, etc.

The risk assessment (refer to Section 5.1) shall take account of both underground and over-ground services. The location shall be chosen so that it is not directly beneath overhead power or other cables and where it will allow access for vehicles and other plant without the risk of them coming into contact with power or other cables.

Each storage area and its boundaries shall be well defined. The footprint of the store shall allow space for the expected quantity of gas cylinders being stored as well as for the safe movement and handling of the gas cylinders, including access for mechanical handling equipment. Refer to Section 5.4.

Appropriate access to the site will be required. This will include access for delivery vehicles and the emergency services.

The location of the storage area should consider the security of cylinders to avoid theft and to prevent tampering with the cylinders. Refer to Section 5.7.

5.4 Storage area layout and separation distances

The physical dimensions of the storage area shall take into account the storage requirements of Section 6.2, for example, grouping by hazard classification, full/empty or unserviceable cylinders and providing adequate space for access and egress, for safe manual handling operations and the use of mechanical handling equipment.

Means shall be provided to secure cylinders to prevent them falling over, for example, pallets, chains, lashing, etc.

5.4.1 Minimum recommended separation distances

Appendix 2 shows the minimum recommended separation distances between cylinders, the store(s) and other features.

Where there are space restraints a permanent physical partition may be used to help achieve the required minimum recommended separation distances. The height of the partition should be relevant to the hazard, however it should be not less than 2 metres high, unless for non-fire hazards a lower partition can be justified through risk assessment. The required minimum recommended separation distance can include the length of the sides of the partition, as shown in Figure 1. Such partitions should be imperforate and constructed of suitable materials, for example, solid masonry or concrete. Where protecting against fire hazards they should be constructed to achieve at least 30 minutes' fire-resistance. Refer to HSE L138 (22), *Dangerous substances and explosive atmospheres. Dangerous Substances and Explosives Atmospheres Regulations 2002. Approved Code of Practice and Guidance*, and BS 476 (27), *Fire tests on building materials and structures*.

Where the wall separates vulnerable populations from the cylinders (not including inert gases), the fire resistance provided should be a minimum of 60 minutes.

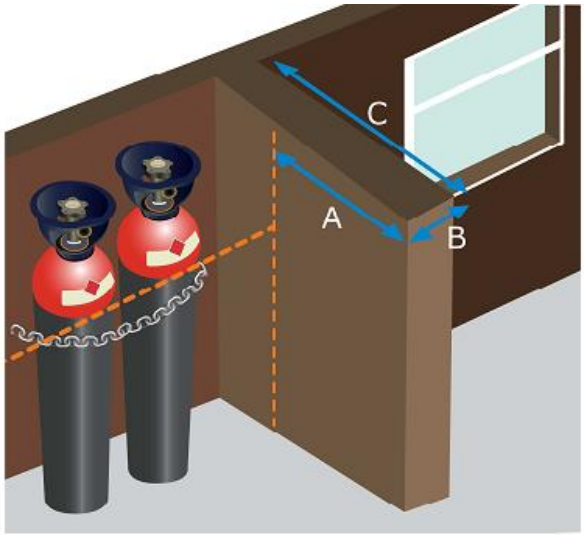


Figure 1: Use of a partition to achieve the minimum recommended separation distances

Within Figure 1 the minimum recommended separation distances may include the distance measured around the sides of the partition by determining the sum of A + B + C.

If flammable gas cylinders are stored against a building wall the area up to 2 m either side of the storage area and up to 9 m above ground should be imperforate and of a minimum of 30 minutes fire resisting construction.

When planning the gas cylinder storage facility, adequate handling space shall be allowed. The total amount of floor space required will depend on the quantity and the size of the cylinders; and the handling equipment to be used during their movement. Refer to Section 6 and Section 8.

5.5 Floor

The floor should be level and constructed of concrete or other non-combustible, non-porous material. A smooth concrete finish is preferred, is likely to have a longer life and is more practical for manual handling operations. All floor surfaces shall be constructed so that they can be maintained in a clean manner.

Obstacles such as expansion joints, steps and drainage systems, shall not impede cylinder handling operations.

The floor shall be of sufficient strength to support the weight of the gas cylinders / gas cylinder pallets, plus any mechanical handling aids employed on gas cylinder handling.

The floor should be laid to prevent the accumulation of water so that stored cylinders do not rest in standing water and risk being subjected to corrosion.

If drainage systems are required they shall be so designed as to prevent dense gases or cryogenic or liquefied gases entering any drainage system. As necessary a water trap should be considered.

5.6 Roof

Cylinders are designed for outdoor storage, however some applications require protected storage conditions for quality, hygiene and security reasons, for example, analytical and medical gases. Cylinders may also need additional protection from local environmental conditions.

Where required, the roofing shall be designed to prevent gas pockets accumulating, for example, gaps between the wall and sloping roof, natural ventilation in the roof apex etc.

5.7 General security

All stores containing gas cylinders shall be secure and access shall be restricted to authorised personnel. This may be achieved by securing the site with a boundary fence with lockable gates or by securing individual stores. Dependant on the site security requirements both conditions may be required.

Suitable security arrangements shall take into account the classification of the gases and the quantities being stored. The security arrangements shall include appropriate physical and management security controls to prevent unauthorised access, theft, tampering, arson, vandalism and to effectively monitor the usage of gases, as well as any specific local considerations. Keys for each store shall be kept in a secure location and only issued to authorised persons; a log should be kept.

Where electronic security systems, for example, alarms, are installed comply with the electrical requirements of Section 5.11.

The security perimeter shall meet the ventilation requirements of Section 5.8 and be not less than 1.8 metres high.

Where the gas cylinder store is enclosed, a suitable emergency exit(s) may be required dependant on the size and/or layout of the store. Refer to Section 5.9.

For the storage of small quantities of cylinders, refer to Section 5.14.

All persons handling gas cylinders shall have appropriate security training, as required by ADR (16), Chapter 1.3 and 1.10, commensurate with their responsibilities, refer to Section 7.

Where high consequence dangerous goods, such as toxic gases, are stored on site a security plan shall be drawn up and implemented in compliance with the security provisions of ADR (16), Chapter 1.10.

NOTE: The Department for Transport (DfT) operate a Dangerous Goods Security Compliance Team. Their role is to undertake security audits on sites where high consequence dangerous goods are stored. They will carry out checks, both physical and on documentation, to ensure your security plans are in place, are being applied and are affective. The DfT provide a template for a security plan on their website.

5.8 Ventilation

Ventilation is required to ensure that any small leakage of gas is adequately dispersed and will prevent a hazardous atmosphere being created. An outdoor store with open sides and without a roof is considered to provide adequate ventilation and is the preferred option.

Where a store may have restricted ventilation, due to, for example, adjacent buildings or a wall acting as a store boundary, it is necessary to ensure that there is through and thorough ventilation in all areas inside the store.

A semi-enclosed store maybe considered 'outdoors' if it consists of up to three adjacent solid sides, with a roof, provided at least 25 % of the perimeter is constructed to ensure that ventilation is not impaired, for example, meshed fencing.

Where the configuration of the store restricts air flow, the installation of high and low level vents should be considered to ensure a regular change of air. The design of a roof shall meet the ventilation requirements of Section 5.6. Minimum recommended separation distances, refer to Section 5.4.1, should be considered when locating vents.

A store with less than 25 % of the perimeter open is to be considered an indoor store. Refer to Section 5.15.

Examples of store designs are displayed in Appendix 3.

If a store is located against a building wall, then the risk assessment (refer to Section 5.1) shall take account of the likelihood of escaped gas entering the building, and the method of entry, for example, an overhanging roof, cellars, windows, air intakes, etc.

5.9 Access

The storage area should be located so that it is readily accessible for cylinder movements with manual handling distances kept to a minimum and clear access maintained at all times for deliveries and the emergency services.

Access to the delivery and storage area(s) is to be kept clear, with no parking allowed, except for the loading and unloading of cylinders. No vehicles are to be allowed within the minimum recommended separation distance referred to in Section 5.4.1.

Aisles should be provided to allow safe access to cylinders, to facilitate good housekeeping, stock control and for the ease of handling. They should be a minimum of 1 metre wide.

The layout of the storage area should allow for the safe movement of gas cylinder handling trolleys, fork lift trucks and any other powered vehicles. The layout shall take account of the separation of personnel and vehicles with appropriate traffic routes defined. Refer to HSE L24 (17), *Workplace health, safety and welfare. Workplace (Health, Safety and Welfare) Regulations 1992. Approved Code of Practice and guidance.*

Where the gas cylinder store is enclosed suitable access and egress shall be provided. The risk assessment (refer to Section 5.1) shall determine the maximum travel distance to enable escape and therefore identify the number of exits required.

Where installed, all designated emergency exits shall open in the direction of escape and shall be fitted with panic furniture of a type not requiring a key, card, or code to open. They are to provide an unobstructed means of escape and in operation shall not obstruct any other escape route. These exits shall be properly identified by signage, and maintained in a serviceable condition at all times. Ensure that emergency exits are secure and cannot be opened from the external side of the store (whist still allowing emergency escape from the inside of the store).

5.10 Lighting

The area should have adequate lighting to assist in providing a safe work environment, to allow the identification of the cylinder contents, signage and where necessary to assist with security. Where artificial lighting is used it shall give suitable colour rendering to enable colour labelling to be easily recognised by persons with normal colour vision.

Where required, emergency lighting shall be to the requirements of BS 5266 (28), *Emergency lighting. Code of practice for the emergency escape lighting of premises*.

For electrical safety refer to Section 5.11.

5.11 Electrical equipment

Only electrical equipment that is necessary for the safe and practical operation of the gas cylinder store shall be installed. As a minimum all electrical installations shall conform to BS 7671 (31), *Requirements for electrical installations. IET wiring regulations*. Where flammable or oxidising gases are stored the risk assessment (refer to Section 5.1) is to determine whether protected electrical equipment is required, if so refer to BS EN 60079, Part 14 (33), *Explosive atmospheres. Electrical installations, design, selection and erection.*

For the minimum recommended separation distance for unprotected electrical equipment refer to Section 5.4.1.

5.12 Fire safety requirements

A responsible person shall carry out a Fire Safety Risk Assessment on all gas cylinder storage areas to determine the hazard and the risk associated with a fire originating from a gas cylinder and / or a fire impacting on a gas cylinder(s). The findings from which are to be incorporated into the Site Fire Safety Management Plan that is to be implemented and maintained. As necessary, advice should be sought from the Fire and Rescue Service. The risk control measures identified shall be incorporated into the construction of the gas cylinder store(s).

The location of each gas cylinder store shall be recorded within the site's hazardous locations record. This record should include information on the products stored, their maximum quantities and their hazardous classification. This should be updated on a regular basis. This is to be made available to the emergency services in the event of an incident. Refer to The Regulatory Reform (Fire Safety) Order (10).

Appropriate emergency procedures shall be drawn up based on the Site Fire Safety Management Plan, these to include an evacuation plan covering all personnel likely to be on the site. For emergency procedures in the event of an incident, refer to Section 9.

It is good practice, especially where larger quantities of gas cylinders are stored, to invite the local Fire and Rescue Service to site so they are familiar with the location in the event of an incident.

Acetylene in cylinders react differently to other gases in cylinders after exposure to fire. Appropriate signs shall be posted outside all gas cylinder stores containing acetylene cylinders in order to alert the Fire and Rescue Services of their presence. Refer to Section 5.13. Refer also to BCGA Leaflet 6 (57), *Cylinders in fires*.

Adequate means of providing an alarm in the event of a fire shall be established. Where physical alarms are installed these should be clearly marked and suitably located, including at all emergency exit points. For electrical safety refer to Section 5.11.

The Site Fire Safety Management Plan will determine the appropriate fire equipment necessary, including the number and type of fire extinguishers to be provided, and their locations. Where fire extinguishers are required, they should be positioned in easily visible positions near entrances / exits, at the perimeter of the store and in safe positions in access routes between aisles.

Each gas cylinder store area shall be designated a '**NO SMOKING AREA**'. For the minimum recommended separation distances, refer to Section 5.4.1. Suitable signs are to be displayed. Refer to Section 5.13.

Wherever practicable, the cylinder storage infrastructure (walls, ceiling, floor) shall be constructed of non-combustible or fire-resistant materials. The construction materials will comply with the requirements of BS 476 (27), Parts 20 to 23. If the cylinder store is part of a larger building, it shall be of at least 30 minutes fire-resisting construction, preferably made of brick or concrete. Where vulnerable populations are housed, then it shall be of 60 minutes fire-resisting construction.

The Fire & Rescue Service may require a sufficient volume and pressure of water to be available to fight a fire in the vicinity of the gas cylinder store. Consultation with the Fire & Rescue Service is recommended. Refer to BS 5306, Part 0 (29), *Fire protection installations and equipment on premises. Guide for selection of installed systems and other fire equipment.*

5.13 Safety signs and warning notices

Individual gas cylinder stores shall have adequate signage to provide warnings and safety information on the hazardous products being stored.

Signage shall comply with:

- The Health and Safety (Safety Signs and Signals) Regulations (4).

- BS ISO 7010 (34), *Graphical symbols. Safety colours and safety signs. Registered safety signs*.

For additional advice refer to HSE L64 (19), *Safety signs and signals. The Health and Safety (Safety Signs and Signals) guidance on regulations*.

All signs shall be in the English language. Bilingual / multilingual signs may also be necessary.

Signs and pictograms shall be clearly visible from all angles of approach, preferably sited with the centre of the sign at the average eye level (between 1.5 and 1.7 m above the ground).

Signs for the following hazards should be displayed:

- NO SMOKING
- NO NAKED LIGHTS
- NO SOURCES OF IGNITION
- NO ACCESS FOR UNAUTHORISED PERSONS
- NO MOBILE PHONES OR OTHER ELECTRONIC DEVICES
- NO STORAGE OF OIL, GREASE OR COMBUSTIBLE MATERIALS

For inert gases, this additional sign should be displayed:

- ASPHYXIATION HAZARD

For flammable gases, these additional signs should be displayed:

- FLAMMABLE GAS
- ASPHYXIATION HAZARD

For oxidising gases, this additional sign should be displayed:

- OXIDISING GAS

With flammable and oxidising gases there is a risk of the development of an explosive atmosphere. In accordance with DSEAR (9) if an explosive atmosphere may exist display the explosive atmosphere "EX" sign.

For toxic gases, these additional signs should be displayed:

- TOXIC GAS
- ASPHYXIATION HAZARD

For corrosive gases, these additional signs should be displayed:

- CORROSIVE GAS
- ASPHYXIATION HAZARD

In addition a notice shall be displayed showing:

(i) Actions to take in the event of an emergency.

(ii) The site operator's routine contact details.

(iii) Emergency contact information including an emergency phone number, for example of the gas supplier and/or the site operator.

(iv) The emergency services phone number.

This information should also be available at a control point, for example the site control room or site security.

Examples of signs are provided in Appendix 4. Information on the actions to take in an emergency are detailed in Section 9.

5.13.1 Signage inside a gas cylinder store

Storage locations within the gas cylinder store shall be clearly identified by signage to show the condition and hazard classification of the gas cylinders. Refer to Section 6.2.

Consideration should be given to using the appropriate hazard 'diamond' label(s) for the gases stored, particularly when they are not in clear view.

Examples of signs are provided in Appendix 4.

5.14 Small quantity storage

A small quantity store for cylinders will be capable of holding up to a total quantity of 10 gas cylinders. Such an installation shall meet the requirements of this code, however alternative designs, such as a wire mesh enclosure, are acceptable, refer to Section 5.14.1.

The use of a gas cylinder storage cabinet is not recommended for general industrial gases but may be appropriate for some specialised gas uses. Refer to Appendix 1.

5.14.1 Storage in a cage

As an alternative to a store enclosed by an industrial-type fence, the store may be a bespoke wire mesh enclosure (cage).

- The cage is to be permanently secured to an adjoining wall or solid floor.
- The cage is to be lockable to prevent unauthorised access.

- The mesh on the cage is to be small enough to prevent any unauthorised tampering, for example, being able to operate a valve. The recommended size is 50 x 50 x 3 mm (10 swg) welded mesh.

- Means shall be provided to secure individual cylinders in their storage position and prevent them falling over, for example, chains, lashing, etc.

- The cage may contain both cylinders in use, i.e. connected to a manifold, as well as full and empty cylinders in storage.

- The cage may be used to store portable gas sets or trolleys complete with cylinders, for example, an oxygen cylinder and an acetylene cylinder mounted on a trolley.

An example of a cage is shown in Appendix 3.

5.15 Indoor storage

In addition to all the other requirements of Section 5, indoor storage requires the following measures to be taken.

5.15.1 Indoor store – justification

Internal storage is not recommended. Where it is unavoidable a documented justification process shall be undertaken to justify the need for indoor storage. Where indoor storage is the only option, then the type of store shall be in accordance with the location hierarchy, refer to Section 5.15.2. If a bespoke building cannot be utilised, then the use of a room inside a building shall be justified, documented and records retained.

5.15.2 Location hierarchy

Internal storage locations should be at ground level and in the following order of preference:

(i) A bespoke stand-alone dedicated, adequately naturally ventilated building.

(ii) A dedicated room sealed from the rest of the building, adequately naturally ventilated to the outside, only accessible from an external door(s).

(iii) A dedicated room, adjacent to an outside wall, inside a building, adequately naturally ventilated to the outside, sealed from other areas of normal occupancy.

(iv) A dedicated room, inside a building, with forced air ventilation, sealed from other areas of normal occupancy.

(v) In a building, as far as is practicable away from normal work locations.

5.15.3 Indoor storage risk assessment

In addition to the risk assessment required within Section 5.1, the chosen location will be subject to a risk assessment specific to the indoor store to confirm its suitability and the control measures required.

As a minimum, consideration shall be given to:

- The quantity of cylinders requiring to be stored. This should be kept to the minimum necessary.
- The hazard classification of the gases.
- The densities of gases stored.
- Fire,
    - originating from the cylinder store.
    - impacting on the cylinder store.
    - changes to the site Fire Safety Management Plan, refer to Section 5.12.
- Risk of explosion, especially from flammable gas release.

Indoors there is an increased risk, especially from flammable gases, of creating an explosive atmosphere. The DSEAR (9) risk assessment required in Section 5.1, shall include an assessment of this risk.

Where there is a risk of explosion the design of the building should ensure at least half of the longest wall or half of the roof area should be made of open mesh or lightweight materials to provide explosion relief. The relief should be designed and positioned such that any hazards are minimized in the event of an explosion.

- Leakage from valves or safety relief devices.
- Ventilation requirements, including ventilation intakes and exhausts, refer to Section 5.15.4.

NOTES: An indoor store may meet the criteria to be a confined space, where in the event of a release of gas the atmosphere would be affected sufficiently to represent a specific risk. In such cases a specific confined space risk assessment is required. Refer to HSE L101 (20), *Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice, Regulations and guidance.*

- Atmospheric monitoring and the use of gas detection equipment, refer to Section 5.15.5.

- Exposure of personnel to gas / gases.
- Access to and egress from the cylinder store.
- Movement and handling of cylinders to and from the store.
- Delivery and collection requirements, vehicle access.
- Other activities / processes taking place in the building.
- Other hazardous goods stored or used in the building.

Guidance on risk assessment is provided by BCGA GN 11 (48), *Reduced oxygen atmospheres. The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace.*

5.15.4 Indoor ventilation requirements

Ventilation is required to ensure that, in the event of a leak, the gas is adequately dispersed and will prevent a hazardous atmosphere being created. A specific risk assessment shall be conducted to determine the quantity of ventilation required. For additional guidance refer to Appendix 5.

Ventilation can be natural or provided by forced air ventilation.

Where natural ventilation is used the store should have ventilation openings with a minimum total area of 10 % of the ground area. A minimum of two permanent openings are required. The inlet and outlet openings shall be positioned diametrically across the store at high and low levels.

The type of forced air ventilation depends on a multitude of factors. The density of the gases being stored will determine the location of the forced air outlet openings i.e. at high levels for lighter than air gases, and at low level for heavier than air gases.

Where the store is part of an existing building, the forced air ventilation shall be arranged such that it is not directed into the building.

Ventilation openings shall take account of the minimum recommended separation distances, refer to Section 5.4.1. Ventilation openings shall discharge to a safe place in the open air. Ventilation openings in walls should not compromise any escape route.

Forced air ventilation systems shall be connected to suitable visual and audible alarm systems to provide a warning in the event that the ventilation system is not functioning correctly.

Warning signs shall be sited at each entrance so that they are clearly visible to personnel before entering the store.

5.15.5 Gas monitoring systems

Gas monitors shall be installed where ventilation arrangements are inadequate and it is not practical to increase natural ventilation or install forced air ventilation.

Gas detection systems shall incorporate an audio-visual warning alarm. The alarm shall be obvious in the store and also at all entrances to the store. Detector displays and warning signs shall be sited so that they are clearly visible to personnel before entering the store.

Alarm levels are to be set to activate at a limit that will still allow safe evacuation.

Detection equipment shall be installed, operated, maintained and tested in accordance with manufacturer's recommendations.

Where the store is part of an existing building then the Site Fire Safety Management Plan will determine if it is necessary to interface the gas detection system with the fire alarm system.

The gas detection system may interface with the forced air ventilation system.

For electrical safety refer to Section 5.11.

6. CYLINDER STORE MANAGEMENT

The site organisation shall appoint a person authorised to manage cylinder storage and operations on site.

6.1 Routine management checks

The person authorised to manage each cylinder store shall periodically check that:

- The minimum recommended separation distances are maintained, refer to Section 5.4.1.

- The fire control measures identified in the Site Fire Safety Management Plan have been implemented correctly and maintained, refer to Section 5.12.

To reduce the fire hazard to a minimum the area surrounding the storage site is to be kept clear. Long grass, weeds and any overhanging branches are to be removed. A minimum recommended separation distance of 3 m from the perimeter of the gas cylinder storage area is to be kept clear of all vegetation. Chemicals such as sodium chlorate and other oxidising agents which may cause a risk of fire shall not be used as a weed killer.

- Security arrangements are being upheld, refer to Section 5.7.

- All fire, safety signs and warning notices are displayed, refer to Section 5.13.

- All cylinders are stored in accordance with Section 6.2.

- All personnel accessing the store(s) are adequately trained, refer to Section 7.

- Where changes are made to the inventory or range of products being stored, the risk assessment for the store is updated, refer to Section 5.1, and personnel receive any additional training that may be necessary, refer to Section 7.

- All personnel handle gas cylinders safely, refer to Section 8.

- All emergency procedures are in place, refer to Section 9.

- Cylinders are not being subjected to adverse conditions.

- Stores are being kept clean and are subjected to regular housekeeping.

The only items to be stored in a gas cylinder storage compound are gas cylinders; their associated fittings, such as cylinder keys, valve caps, etc.; and associated mechanical handling aids, such as gas cylinder trolleys. Combustible stores of any description, for example, oils, greases, paints, fuels; excess packaging; other classes of Dangerous Goods; salt, or corrosive chemicals shall not be stored in the same store as gas cylinders. The store is not to be used as a lay-apart store or as a convenient storage area for other items.

Gas cylinders are to be stored in such a way as to prevent any accumulation of debris that may provide a refuge for pests. Particular care is required where food and medical gases are stored to prevent the spread of disease from contamination by animals, such as birds and rodents.

WARNING: Contact with oils, grease, hydrocarbons, tarry substances and many plastics carries the risk of spontaneous combustion, particularly with some high pressure gases.

6.2 Gas cylinder storage requirements

The gas cylinder store shall be arranged, and clearly identified by signage, according to the condition and hazard classification of the gas cylinders. Refer to Section 5.13, examples of signage are given in Appendix 4.

Where only small quantities of gas cylinders (a maximum of 10) are held in a small quantity store, refer to Section 5.14, it is not necessary to separate individual cylinders from each other.

Where more than 10 cylinders are stored then:

- The store is to be arranged such that there is adequate access to the cylinders, taking into account the use of mechanical handling equipment, and that escape routes remain clear and allow unimpeded escape in the event of an incident. Refer to Section 5.9.

- Gases with the same hazard category should be grouped together, the hazard categories being identified with signage.

- Full (including part-used) and empty cylinders should be segregated within the store, the areas being identified with signage.

Unserviceable cylinders, or those under quarantine, should be segregated from serviceable cylinders, the cylinders should be labelled as such and stored in a designated area. Such cylinders should be returned to the gas supplier as soon as practicable, refer to Section 10.

Medical gases are to be stored in a separate designated store. Refer to Section 6.4.

Toxic gases. Gas cylinders containing toxic gases are supplied with an additional valve outlet sealing plug or cap-nut that acts as a secondary seal. This should always be fitted when in storage. For additional information on toxic gases refer to BCGA CP 18 (41).

Corrosive gases. Corrosive gases will be subject to a 'return by' date. The cylinders are to be returned back to the gas supplier according to this date. Contact the supplier if this date is due or has passed. Refer to BCGA TIS 16 (55), *The storage of gas cylinders containing corrosive gas at users' premises*. For additional information on corrosive gases refer to BCGA CP 18 (41).

Pyrophoric gases. Pyrophoric gases spontaneously catch fire in air and shall only be stored in external gas cylinder stores. For additional information on pyrophoric gases refer to BCGA CP 18 (41).

Fluorinated Gases. Fluorinated Gases, for example, refrigerants, are subject to specific European regulation, refer to European Regulation No 517/2014 (15), *Regulation on fluorinated greenhouse gases*, EIGA Document 192 (38), *Fluorinated gases management*, provides additional information. Due to their effect on the environment the intentional release of fluorinated gases into the atmosphere is prohibited. Stock holdings are to be managed and measures to prevent and detect leakage implemented; these include routine leak checks and having standard operating procedures in place to deal with a leak. Refrigerant gases (CFCs, HCFCs and HFCs) returned as waste, are to be stored in accordance with the requirements of appropriate exemptions issued by your national environmental authority, for example, S2 in England.

Cylinders should be stored upright, when designed for this, using appropriate measures to prevent them toppling over, for example, secured by chains or lashings. Alternatively, they may be stored in specially designed pallets. Gas cylinders stored in a vertical position are to be stored no more than one cylinder high unless specifically designed for this purpose, for example, some LPG cylinders. Special arrangements may be required to secure small cylinders.

Where gas cylinders are stored horizontally, for example, round-bottomed cylinders, special arrangements will be required to secure them. Horizontally stored gas cylinders are not to rest directly on the floor. They should be suitably restrained to prevent movement. Particular care is to be taken to prevent the onset of external corrosion, for example, by ensuring gas cylinders do not rest in pools of water.

Gas cylinders, which are mounted within a gas cylinder trolley for movement and use, for example, a gas welding set, may be located within a designated area inside the store.

Avoid excessive levels of stock. Stock rotation should generally be controlled on a First In First Out (FIFO) basis. However, some gases are given a shelf life; it may be prudent to use those with the shortest life first, 'First-Expired First-Out' (FEFO). It is not recommended that these gases are used once this shelf life has expired; upon expiry the cylinder should be replaced. Specifically be aware of the dates on medical gases and corrosive gases. Excess stock of gas cylinders, empty gas cylinders or gas cylinders that are no longer required are to be returned to the owner (normally the gas supplier). As necessary, the owner is responsible for taking the appropriate disposal action. Refer to Section 10.

NOTE: All cylinders are required by law to have a periodic inspection and test to ensure the safety of the cylinder. Stamps on the shoulder identify the test date and the approved test authority. The use of cylinder test date rings between the cylinder and valve provide a quick visual reference to the next test date. Cylinders can continue to be used until nominally empty, but not refilled or transported (on the public highway) if the due date for inspection and re-test has passed.

When not in use cylinder valves shall always be closed. Where supplied, protective valve caps and covers should be fitted.

NOTE: Caps and covers help protect the valve and prevent contaminants, such as moisture and dirt, from gathering in the valve port(s).

Gas cylinders are not to be repainted, to have any markings obscured, labels removed or added, without the explicit consent of the owner. If the contents of a gas cylinder cannot be identified the gas cylinder is to be declared unserviceable and returned to the owner as soon as practicable. Refer to Section 3 and Section 10.

6.3 Management of stores for medical gas cylinders

As well as complying with Section 6.2, medical gas cylinders require additional measures to be taken when in storage. Reference should be made to the National Health Service (NHS) Protect document, *Guidance on the security and storage of medical gas cylinders* (63), and to HTM 02-01 (62), Part B, Section 8, *Medical gas pipeline systems*.

All medical gases are highly regulated by European Directives and UK legislation. The gases are classified as medicinal products for administration to a patient. As with all medicines they should be stored securely and out of the reach and sight of children.

The storage requirements of medicinal gases are covered within their individual Marketing Authorisation – product licence – and these have to be complied with. Each Marketing Authorisation will have agreed details for each company but the storage conditions will be summarised in the Summary of Product Characteristics.

As with all medicines, medical gases have a defined shelf life. Each cylinder will have a label that will show the expiry date as well as the batch number.

The following additional measures shall be taken:

- Medical gas cylinders shall be segregated from all other cylinders.

NOTE: Pathology gases are not classified as medical gases.

- Appropriate management controls should be implemented to prevent the theft of gas cylinders and to monitor the usage of gases. Particular care may be required for certain gases that are misused, for example as 'recreational drugs'. Refer to BCGA Leaflet 7 (58), *The dangers of industrial gas abuse*, and the NHS Protect document, *Guidance on the security and storage of medical gas cylinders* (63).

- Medical gas cylinders shall be stored in accordance with the Marketing Authorisation. This may include:

    - Storage under a weatherproof cover.

    - Kept dry.

    - Not subjected to extremes of temperature. This will maintain the quality of the product, for example by controlling temperature (for example, for gas mixtures where phase separation occurs on freezing) and/or humidity.

    - Kept clean. Particular care is required to prevent the spread of disease from contamination by animals, such as birds and rodents.

    NOTE: It is a requirement that medical gas cylinders are stored and managed in a manner that ensures that they will be delivered in a clean state, compatible with the environment in which they will be used.

    - Special storage conditions, where required these should be checked and monitored.

6.4 Delivery and collection of cylinders

All delivery and collection of cylinders is to be supervised with appropriate management controls in place to ensure:

- Clear access to and within the store, refer to Section 5.9.

- All vehicles have their engines turned off, with the handbrake applied, when cylinders are being loaded or unloaded.

- The movement of cylinders is only carried out by trained persons using appropriate equipment. Handling is only to be conducted following an appropriate assessment. Refer to Sections 7 & 8.

- Records of receipt into the store. Ensure each cylinder product is identified and a Safety Data Sheet is available.

- Records of issues from the store.

- The inventory account is managed.

- Each cylinder is positioned and secured in its designated area.

- Security of the store is managed, including control of access keys.

- Vehicle movements onto a site shall be managed. Some sites may require a specific delivery and collection point.

- The person collecting the gas cylinder is aware of their duties with regard to the carriage, handling, storage and safe use of the cylinder and its contents.

BCGA GN 27 (51), *Guidance for the carriage of gas cylinders on vehicles*, provides advice on the transportation of gas cylinders.

BCGA TIS 8 (53), *Information for customers collecting gas cylinders (flammable, inert and oxidising gases)*, provides useful safety information for those collecting gas cylinders.

BCGA TIS 15 (54), *Model risk assessment for the storage and use of oxyacetylene cylinders*, may be used to provide guidance for the storage of oxy / fuel-gas cylinders.

7. TRAINING

All personnel who are required to handle and store gas cylinders shall receive suitable information and instruction regarding the hazards associated with gas cylinders and the gases being stored, and provided with the necessary skills and knowledge to carry out their job safely.

It is the duty of the employer to ensure their persons are adequately trained and to establish competency. It is recommended that a training programme is carried out under a formalised system where an acceptable level of competency has to be achieved. Records shall be kept of the training provided and the competence level achieved. The training programme shall make provision for periodic re-training.

Recommendations for the training of personnel are described in EIGA Document 23 (35), *Safety training of employees*. BCGA GN 23 (50), *Identifying gas safety training requirements in the workplace*, provides information on the topics that should be covered when considering gases safety training.

Training should be reviewed and/or up-dated following:

- A related accident or incident.

- The receipt of gases which have not previously been used on site.

- Changes to guidance or information previously provided.

- The appointment of new and / or transferred employees.

All persons engaged in the storage of gas cylinders shall have training commensurate with their responsibilities and should include, but not be necessarily confined to the following subjects:

- Identification of the cylinder and its contents.
- Properties and hazards of gases, including pressure.
- Cylinder and valve types.
- Movement of cylinders, including local carriage.
- Stock management.
- Store management.
- Actions to be taken in an emergency situation.

Specific training and certification requirements are required for persons handling fluorinated gases.

8. THE SAFE HANDLING OF GAS CYLINDERS

8.1 Personal protective equipment

The minimum recommended Personal Protective Equipment (PPE) requirements for personnel engaged in the storage and handling of gas cylinders is:

- Protective gloves.
- Safety shoes, boots with metatarsal protection are strongly recommended.
- Safety glasses.

In certain locations, or site conditions, other additional PPE may be obligatory, for example, hard hats, ear defenders, breathing apparatus.

NOTE: All PPE is to be kept free of oil and grease. Contaminated PPE is to be replaced.

The work activity risk assessment will determine the requirement for the use of hazard controls, including PPE. PPE may only be considered as a control to achieve an acceptable level of residual risk after other levels of control have been addressed. Where PPE is required a PPE Assessment is to be carried out. PPE is to be provided as required by the Personal Protective Equipment Regulations (7). The PPE shall be selected for a particular task and location and must be appropriate and chosen to effectively reduce the overall risk. Thus there are different PPE requirements for differing products, different tasks and possibly different personnel. Due regard is to be given to the requirements of the Control of Substances Hazardous to Health Regulations (8), any relevant equipment publications, manufacturers information and the product Safety Data Sheet.

HSE L25 (18), *Personal Protective Equipment at Work*, provides guidance on the Personal Protective Equipment Regulations (7). EIGA Document 136 (36), *Selection of personal protective equipment*, provides guidance for selecting and using PPE at work.

8.2 Cylinder handling

The minimum recommended cylinder handling requirements for the storage of gas cylinders are:

- All personnel shall wear appropriate PPE, refer to Section 8.1.

- Mechanical handling equipment, such as serviceable purpose-designed trolleys, should be used for moving cylinders, wherever practicable.

- For moving over even floors and only for short distances (<5 m) the 'churning' method may be used.

- Cylinders shall not be rolled along the ground; this may damage or even open the valve and will also damage identifying labels, marks and symbols.

- A cylinder shall not be moved with the valve open.

- Where provided, valve protection caps are to be fitted before moving a cylinder.

- Do not lift single cylinders by using the valve protection device unless they have been designed for that purpose, refer to the gas supplier.

- Only use suitable cradles, platforms or trollies to hold individual cylinders for lifting. Refer to EIGA SI 25 (39), *Crane transport of cylinder packages*.

- Some cylinder bundles are designed to be lifted via their permanently attached pad-eyes or lifting eyes lugs. Some bundles can only be lifted using fork lift trucks. If you are not sure check with your gas supplier.

NOTE: When lifting, use only appropriate lifting accessories, such as serviceable, correctly rated and certified, ropes, chains or slings. For further information refer to HSE L113 (21), *Safe use of lifting equipment. Lifting Operations and Lifting Equipment Regulations 1998. Approved Code of Practice and guidance.*

- On fork lift trucks gas cylinders should be secured vertically within specially designed gas pallets using the affixed restraining straps. Gas cylinders shall not be lifted and moved directly on the forks of fork lift trucks.

Exceptionally gas cylinders may be palletised horizontally on wooden pallets. Only wooden pallets which are in a good condition, for example, no protruding nails, and which are free of contamination, for example, no oil, grease or tar contamination, are to be used. Gas cylinders that are laid flat on pallets shall be

smaller than the pallet used, not overhang the edges of the pallet and be adequately secured to the pallet.

- Bundles may be moved by fork lift truck where they are so designed.

NOTE: When moving gas cylinders, either in pallets or bundles, with fork lift trucks, the fork lift trucks shall be in a serviceable condition and will have the appropriate Lifting Operations and Lifting Equipment Regulations (LOLER) (5) certification. For further information refer to HSE L113 (21).

- When not being moved all cylinders shall be secured.

The Manual Handling Operations Regulations (3) require first that an assessment of manual handling operations is conducted. Following the assessments, training should take place. Where the assessment indicates that the work exceeds guideline limits, wherever practicable the operation should be mechanised or handling aids provided. BCGA Guidance Note 3 (47), *Safe cylinder handling and the application of the manual handling operations regulations to gas cylinders*, defines the principles of safe practice for handling and moving cylinders and provides a basic understanding of the Manual Handling Operations Regulations (3) relating to gas cylinders. BCGA TIS 17 (56), *Model risk assessment for manual handling activities in the industrial gas industry*, can be used to assist in developing a site risk assessment.

9. EMERGENCY PLANS

Cylinders handled and stored in a safe manner, as described in this document, should not give rise to an emergency situation. It is recognised, however, that they may occasionally become involved in an incident. This section is included to provide guidance on what action should be considered on such occasions, such as a fire or a gas leak.

Local management should carry out risk assessments to identify potential emergency situations. Emergency plans should then be established, and as necessary advice sought through liaison with the emergency services.

The emergency plan will identify:

- Potential emergency situations.

- Identification of gases held, approximate stock holdings and their hazard categories.

- Location of gas cylinder stores (and other hazardous goods stores).

- The procedures to be followed, for example, site evacuation, accounting of personnel.

- Responsibilities of key personnel, including the appointment of an incident controller. This shall be a trained person with adequate local site knowledge to take charge of the emergency and assist the emergency services as necessary.

- Access to and availability of emergency equipment and PPE. Further advice on fire-fighting equipment and fire precautions may be obtained from either the enforcing or fire authorities. Additional information is available in the product Safety Data Sheet, also refer to BCGA Leaflet 6 (57).

- Involvement of the emergency services.

- Contact details.

All personnel who are required to handle and store gas cylinders shall receive suitable information and instruction regarding the emergency plans.

Emergency plans should be reviewed or practiced on the following occasions:

- On a routine basis; at least annually.

- Whenever significant changes are made to the site.

- When there is a significant change in the quantity of gases held.

- There is an introduction of a different hazard category of gas, or the removal of a particular hazard category.

- An incident has occurred.

Any lessons learnt shall be incorporated back into the emergency plan.

The following initial actions should be considered as part of the emergency plan

9.1 Action in the event of a serious leakage

This is to be based on the extent of the leak and the hazard(s) and risk(s) associated with the leaking product.

(i) Raise the alarm.

(ii) Evacuate the immediate area.

(iii) Instigate the emergency plan.

Once initial control of the incident is established then, if it is safe to do so, an attempt should be made to stop the leak. Only people who have knowledge of gas properties, the hazards from the gas, who understand the risks involved and who have been trained to deal with gas emergencies, wearing appropriate PPE, should approach or handle leaking cylinders.

- Identify the gas concerned.

- Identify the source of the leak.

- Undertake the appropriate actions to make the gas cylinder safe. As necessary, consult the gas supplier for advice.

NOTE: Never attempt to dismantle or repair cylinder valves.

Once the cylinder has been made safe, quarantine the cylinder and make arrangements to return it to the owner (normally the gas supplier), refer to Section 10.

9.2 Action in the event of a fire involving or affecting a gas cylinder

(i) KEEP AWAY, do not approach or attempt to move the cylinder or open the valve.

(ii) Sound the alarm.

(iii) Evacuate the danger area.

(iv) Call the Fire and Rescue Service.

(v) Contact the gas supplier for advice on the gases or the gas cylinders involved in a fire. The gas supplier shall **ALWAYS** be notified of any cylinder involved in a fire.

Inform the Fire and Rescue Service immediately of the location, the products (by hazard classification) being stored and the quantities of any gas cylinders involved in the fire, as well as any other gas cylinder stores located on the site. Refer to Section 5.10.

NOTE: The Fire and Rescue Service have operational procedures in place for dealing with gas cylinders in a fire. Following a fire the Fire and Rescue Service will inform you when it is safe to handle a cylinder.

Do not use any fire-damaged cylinders. Quarantine any fire-damaged cylinders in a safe place. Mark, or label, fire-damaged cylinders to clearly show that they have been in a fire. After the fire is out, and the area has been declared safe by the Fire and Rescue Service, arrange collection of fire damaged gas cylinders with the gas supplier at a convenient date. Further information, including contact numbers, is available in BCGA Leaflet 6 (57).

10. CYLINDER RETURN AND DISPOSAL

The vast majority of gas cylinders in circulation in the UK are refillable cylinders which remain the property of the gas suppliers. They are supplied to gas users under a rental agreement, which requires the user to pay rental on the cylinder until its return. The simplest and best way to deal with these cylinders when they are empty or no longer required, is to identify the owner (usually the gas supplier) and request that they are collected. Even if the cylinders were not originally supplied to the premises where they are discovered, the gas supplier will make arrangements to collect them.

The details of the cylinder owner will be printed on the cylinder contents label (refer to Section 3) or other visual identification marks, such as stampmarking around the shoulder of the cylinder.

Detailed advice on the recovery and disposal of all types of gas cylinders is available on the BCGA website under 'Cylinder Recovery and Disposal'.

11. REFERENCES

	Document Number	Title
1		Town and Country Planning Act 1990
2	SI 1990 No. 304	The Dangerous Substances (Notification and Marking of Sites) Regulations 1990.
3	SI 1992 No. 2793	Manual Handling Operations Regulations 1992 (as amended).
4	SI 1996 No. 341	The Health and Safety (Safety Signs and Signals) Regulations 1996.
5	SI 1998 No. 2308	The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER).
6	SI 1999 No. 3242	The Management of Health and Safety at Work Regulations 1999.
7	SI 2002 No. 1144	Personal Protective Equipment Regulations 2002.
8	SI 2002 No. 2677	Control of Substances Hazardous to Health Regulations 2002 (COSHH).
9	SI 2002 No. 2776	Dangerous Substances and Explosives Atmospheres Regulations 2002 - (DSEAR).
10	SI 2005 No. 1541	The Regulatory Reform (Fire Safety) Order 2005.
11	SI 2009 No. 1348	The Carriage of Dangerous Goods and use of Transportable Pressure Equipment Regulations 2009 (as amended).
12	SI 2015 No. 483	The Control of Major Accident Hazards Regulations 2015 (COMAH).
13	SI 2015 No. 627	The Planning (Hazardous Substances) Regulations 2015.
14	European Regulation (EC) No 1272/2008	Classification, Labelling and Packaging of Substances and Mixtures (CLP Regulation).

	Document Number	Title
15	European Regulation (EC) No 517/2014	Regulation of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.
16	ECE/TRANS/242	European Agreement concerning the international carriage of dangerous goods by road (ADR) (as amended).
17	HSE L24	Workplace health, safety and welfare. Workplace (Health, Safety and Welfare) Regulations 1992. Approved Code of Practice and guidance.
18	HSE L25	Personal Protective Equipment at Work.
19	HSE L64	Safety signs and signals. The Health and Safety (Safety Signs and Signals) guidance on regulations.
20	HSE L101	Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice, Regulations and guidance.
21	HSE L113	Safe use of lifting equipment. Lifting Operations and Lifting Equipment Regulations 1998. Approved Code of Practice and guidance.
22	HSE L138	Dangerous substances and explosive atmospheres. Dangerous Substances and Explosives Atmospheres Regulations 2002. Approved Code of Practice and Guidance.
23	HSE HS(G) 51	The storage of flammable liquids in containers.
24	HSE HS(G) 71	Chemical warehousing. The storage of packaged dangerous substances.
25	HSE HS(G) 176	The storage of flammable liquids in tanks.
26	HSE EH 40	Workplace exposure limits.
27	BS 476 Parts 20 to 23	Fire tests on building materials and structures.
28	BS 5266	Emergency lighting. Code of practice for the emergency escape lighting of premises.
29	BS 5306 Part 0	Fire protection installations and equipment on premises. Guide for selection of installed systems and other fire equipment.

	Document Number	Title
30	BS 5925	Code of Practice for ventilation principles and designing for natural ventilation.
31	BS 7671	Requirements for electrical installations. IET wiring regulations.
32	BS EN 14470 Part 2	Fire safety storage cabinets. Safety cabinets for pressurised gas cylinders.
33	BS EN 60079 Part 14	Explosive atmospheres. Electrical installations, design, selection and erection.
34	BS ISO 7010	Graphical symbols. Safety colours and safety signs. Registered safety signs.
35	EIGA IGC Document 23	Safety training of employees.
36	EIGA IGC Document 136	Selection of personal protective equipment.
37	EIGA SAC Document 169	Classification, and labelling guide in accordance with EC Regulation 1272/2008 (CLP Regulation).
38	EIGA IGC Document 192	Fluorinated gases management.
39	EIGA Safety Information 25	Crane transport of cylinder packages.
40	BCGA Code of Practice 4	Industrial gas cylinder manifolds and gas distribution pipework (excluding acetylene).
41	BCGA Code of Practice 18	The safe storage, handling and use of special gases.
42	BCGA Code of Practice 26	Bulk liquid carbon dioxide storage at users' premises.
43	BCGA Code of Practice 27	Transportable vacuum insulated containers of not more than 1000 litres volume.
44	BCGA Code of Practice 33	The bulk storage of gaseous hydrogen at users' premises.
45	BCGA Code of Practice 36	Cryogenic liquid storage at users' premises.

	Document Number	Title
46	BCGA Code of Practice 46	Bulk storage of cryogenic flammable gases.
47	BCGA Guidance Note 3	Safe cylinder handling and the application of the manual handling operations regulations to gas cylinders.
48	BCGA Guidance Note 11	Reduced oxygen atmospheres. The management of risks associated with reduced oxygen atmospheres resulting from the use of gases in the workplace.
49	BCGA Guidance Note 13	DSEAR Risk Assessment.
50	BCGA Guidance Note 23	Identifying gas safety training requirements in the workplace.
51	BCGA Guidance Note 27	Guidance for the carriage of gas cylinders on vehicles.
52	BCGA Technical Information Sheet 6	Cylinder identification colour coding and labelling requirements.
53	BCGA Technical Information Sheet 8	Information for Customers Collecting Gas Cylinders (Flammable, Inert and Oxidising Gases).
54	BCGA Technical Information Sheet 15	Model risk assessment for the storage and use of oxyacetylene cylinders.
55	BCGA Technical Information Sheet 16	The storage of gas cylinders containing corrosive gas at users' premises.
56	BCGA Technical Information Sheet 17	Model risk assessment for manual handling activities in the industrial gas industry.
57	BCGA Leaflet 6	Cylinders in fires.
58	BCGA Leaflet 7	The dangers of industrial gas abuse.
59	UKLPG Code of Practice 1, Part 1	Bulk LPG storage at fixed installations: Design, installation and operation of vessels located above ground.

	Document Number	Title
60	UKLPG Code of Practice 7	Storage of full and empty LPG cylinders and cartridges.
61	UKLPG Code of Practice 24	Use of LPG cylinders. Part 1: Use of LPG cylinders at residential and similar premises. Part 5: The storage and use of LPG on construction sites.
62	Department of Health. Health Technical Memorandum 02-01 Part B	Medical gas pipeline systems. Part B: Operational management.
63	NHS Protect	Guidance on the security and storage of medical gas cylinders.

Further information can be obtained from:

UK Legislation	www.legislation.gov.uk
Health and Safety Executive (HSE)	www.hse.gov.uk
International Organization for Standardization (ISO)	www.iso.org
British Standards Institute (BSI)	www.bsigroup.co.uk
European Industrial Gases Association (EIGA)	www.eiga.eu
British Compressed Gases Association (BCGA)	www.bcga.co.uk
The UK LPG trade association (UKLPG)	www.uklpg.org
National Health Service (NHS) – Business Services Authority - Protect	www.nhsbsa.nhs.uk

BCGA POSITION REGARDING THE USE OF GAS CYLINDER STORAGE CABINETS

A European standard, BS EN 14470, Part 2 (32), *Fire safety storage cabinets. Safety cabinets for pressurised gas cylinders*, exists for gas cylinder storage cabinets, though BCGA was not involved in the creation of that standard.

BCGA advice generally is to recommend external (outdoor) storage of gas cylinders in well secured compounds or cages and piping into buildings where needed. But we acknowledge that internal storage is sometimes necessary where the above is not suitable / practicable or does not suit the gas product or process (see below). In that case our recommendation is a well signed dedicated store room.

The Fire & Rescue Service view is unambiguous. They do not like to encounter gas cylinders in cabinets at all, regardless of the nature of hazard of the gas, or its potential contribution to fire load (all gas cylinders, even those containing inert gases will ultimately rupture if exposed to fire). If the contents are a fuel gas or oxygen then the fire load will be significantly increased.

Firefighters want to be able to see and apply cooling water to cylinders from a distance in a fire, but they also want cylinders secured against theft, so external storage in locked cages is very much their preference.

Whether a cabinet has 30 or 90 minutes fire resistance makes little difference to Firefighters, since they won't likely know where they are on that timescale in a real fire scenario. But even with the higher fire rating it is questionable whether such cabinets would keep cylinders below the 60 °C temperature norm, which guides the maximum developed pressure most cylinders are designed for.

HOWEVER, we also recognise that in some specialised gas uses, storage in suitable extraction cabinets may have merit:

a) Where there is a personal safety or process quality consideration, for example, toxic or ultra high purity gases are needed, for example in the electronics industry.

b) Where gases / mixtures require to be temperature controlled for process reasons.

In such cases cabinets should only be used for cylinders which are connected and in current use and not for storage of full inventory or ‘empty’ cylinders awaiting return, both of which should be held in secure external storage.

Where cylinders are held in cabinets, prominent and fire resistant signage should be visible on the outside of storage cabinets and on the buildings/rooms which house them and consideration should be given to notifying the local Fire and Rescue Service of the existence and whereabouts of gas cylinders in buildings.

The placing of cylinders into cabinets and their removal also presents manual handling risks, for which suitable training should be given. Refer to Section 8.

MINIMUM RECOMMENDED SEPARATION DISTANCES

The recommended separation distance is to provide a minimum separation which will mitigate the effect of any likely event and prevent it from escalating into a larger incident. The minimum recommended separation distance will also provide protection for the gas cylinder from foreseeable external impacts (for example, vehicles) or activities outside the control of the operation (for example, plant or customer station boundary).

The minimum recommended separation distances may be used as guidance for cylinders that are in-use subject to appropriate risk assessment.

To assist in the control of separation distances external to the store, the use of painted hatched lines is an option.

When siting cylinders near another hazard, check that there is no specific legislation concerning that hazard which requires measures beyond those stated.

Cylinder stores should not be located next to other stores containing combustible materials or products. Stores are to be located away from any potential source of excessive heat or ignition. Where significant quantities are present or there is uncertainty about arrangements it is recommended that the Fire and Rescue Service is consulted.

In some cases physical partitions or barriers may be used to reduce the required separation distances. A suitably constructed firewall may eliminate or reduce the separation distance. Refer to Section 5.4.1.

Where gas cylinders are kept in a store and are connected into a distribution system, additional information is available in BCGA CP 4 (40).

LPG. Where only LPG is stored, or for quantities above 400 kg and for additional information on the storage of LPG cylinders in other circumstances, for example, domestic and retail, refer to publications from the UKLPG, for example, UKLPG CP 7 (60), and UKLPG CP 24 (61), *Use of LPG cylinders*.

Minimum recommended separation distance from the gas store to other classes of packaged dangerous substances

The separation distance is measured from the boundary of each store, or for individual cylinder packages, their outer edge, where they are not located in a store.

For additional advice, refer to HSE HSG 71 (24), and for flammable liquids <1000 L, HSE HSG 51 (23), *The storage of flammable liquids in containers*.

Minimum recommended separation distance from the gas store to other classes of bulk dangerous substances

The distances from bulk storage are to be taken from the skin of the tank or any potential release points, for example, filling lines, vents, vaporiser.

Where dangerous goods are stored in bulk close to a gas store an additional risk assessment shall be carried out to determine the minimum recommended separation distances as they may need to be greater than those used for packaged dangerous goods.

For additional advice and examples, refer to UKLPG CP 1 (59), Part 1, *Bulk LPG Storage at Fixed Installations : Design, Installation and Operation of Vessels Located Above Ground*, and HSG 176 (25), *The storage of flammable liquids in tanks.*

TABLE A2-1: Minimum recommended separation distance from the gas store to specific hazards, processes and articles.

Image	Descriptors	Hazard	Inert	Flammable	Oxidiser	Toxic / Corrosive
	Wooden structures, site huts, work sheds etc. NOTE 2.	Thermal radiation from fire.	1	3	3	3
	Combustible material, paper, cardboard boxes, etc. Excessive vegetation.	Thermal radiation from fire.	1	3	3	3
	Plant, ventilation and conditioning. Intakes Exhausts NOTES 7, 8, 9.	Intake – Suction of gas into machinery. Hazardous gas properties creating danger to personnel and equipment such as, oxygen depletion, explosion and / or fire risk. Exhaust – Heat and properties / quality of the air (gas) being exhausted. Potential harmful effects on the condition of a cylinder.	3 1	3 3	3 3	3 3

	Fuel gas vent pipes. NOTE 8.	Ignition of leaking product. Thermal radiation from fire.	0	3		3	3
	Overground services	Ignition of leaking product. Damage caused by electric arcing.	1	< 1 kV	1.5	1	1
				≥1 kV	10		
			Not to be located directly underneath electrical power cables, this includes telephone cables.				
	Process equipment & machinery which is not a part of the storage installation. NOTE 7.	Ignition of leaking product from the process equipment. Thermal radiation from heat generated by normal operation.	0	3		1	1
	Unprotected electrical equipment NOTE 7.	Source of ignition.	1	3		1	1
	Medium Voltage (MV) and High Voltage (HV) sub-stations. NOTE 7.	Ignition of leaking product. Thermal radiation from fire.	Undesirable to locate near. Requires a specific risk assessment and specialist advice.				

	Openings, windows and escape routes from buildings.	Hazardous gas properties creating danger to personnel and equipment such as, oxygen depletion, fire risk.	1	2	1	3
	Vulnerable populations.		8	8	8	8
	Places where people assemble or have public access.	Hazardous gas properties creating danger to people and equipment such as, oxygen depletion, fire risk.	1	3	1	3
	Where naked flames, smoking, welding etc. may be present.	Increased fire risk, danger to personnel.	1	NOTE 4 3	1	3
	Railway tracks (on railway property).	Hazardous gas properties creating danger to people and equipment such as, oxygen depletion, fire risk.	Undesirable to locate near. Requires a specific risk assessment and specialist advice. Do not locate flammable gas cylinder stores underneath a bridge supporting a railway.			
	Public roads.	Hazardous gas properties creating danger to people and equipment such as, oxygen depletion, fire risk.	Undesirable to locate near. Requires a specific risk assessment and specialist advice. Do not locate flammable gas cylinder stores underneath a bridge supporting a public road.			

	Site boundaries NOTE 3.	Hazardous gas properties creating danger to people and equipment such as, oxygen depletion, fire risk.	1	3	1	3
	Vehicle(s). Parking areas. The store shall have adequate protection against vehicle impact.	Hazardous gas properties creating danger to people and equipment. Potential of vehicle to act as an ignition source.	0	3	1	3
	Pits, ducts & surface water drains (untrapped). Openings of systems below ground level.	Liquefied and heavier-than-air gases are likely to accumulate below ground causing oxygen deficient or flammable atmospheres.	0	2	0	0
	Cryogenic storage tank NOTES 5, 6.	Embrittlement from extreme cold.	1	From inert cryogen = 1 From oxidant cryogen = <2000 L = 5 >2000 L = 8	1	1

TABLE A2-1: NOTES:

1. All distances are in metres (m).

2. The separation distance is measured from:
   - For individual cylinders, the separation distance is to be measured from the external shell of the cylinder to the external boundary of the specific hazard; or
   - Where multiple cylinders are kept in a store with a fence, for all hazards external to the store the fence-line may be taken as the starting point to measure a separation distance.

3. Where the store boundary also acts as a site boundary – the values quoted are the distance between the cylinder and the site boundary.

4. LPG cylinders. <400 kg = 1 m; >400 kg = 3 m.

5. For all bulk dangerous substances a risk assessment shall be carried out to establish the safe separation distance.

6. The distances from bulk storage are to be taken from the skin of the tank or any potential release points, for example, filling lines, vents, vaporiser.

7. The risk assessment (refer to Section 5.1) may identify a need for protected electrical equipment or may justify a change to the separation distance for un-protected electrical equipment.

8. The store shall not be directly below an air intake. Exhaust gases should be directed away from cylinders.

9. Consideration should be given to the density of the gases being stored, i.e. lighter or heavier than air. Take into account air intakes, doors, windows and other openings close to the storage area. This may require an increased separation distance.

EXAMPLES OF STORE DESIGN

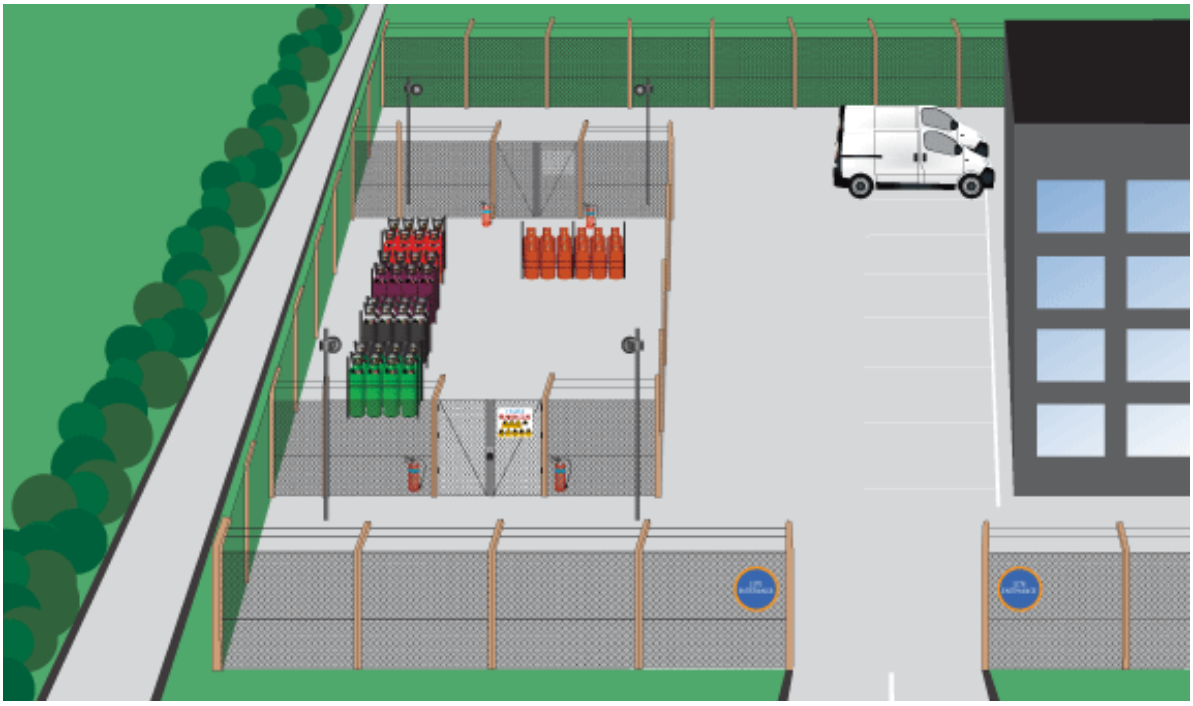


Figure A3–1: Example of an outdoor store. On a site, against a boundary fence.

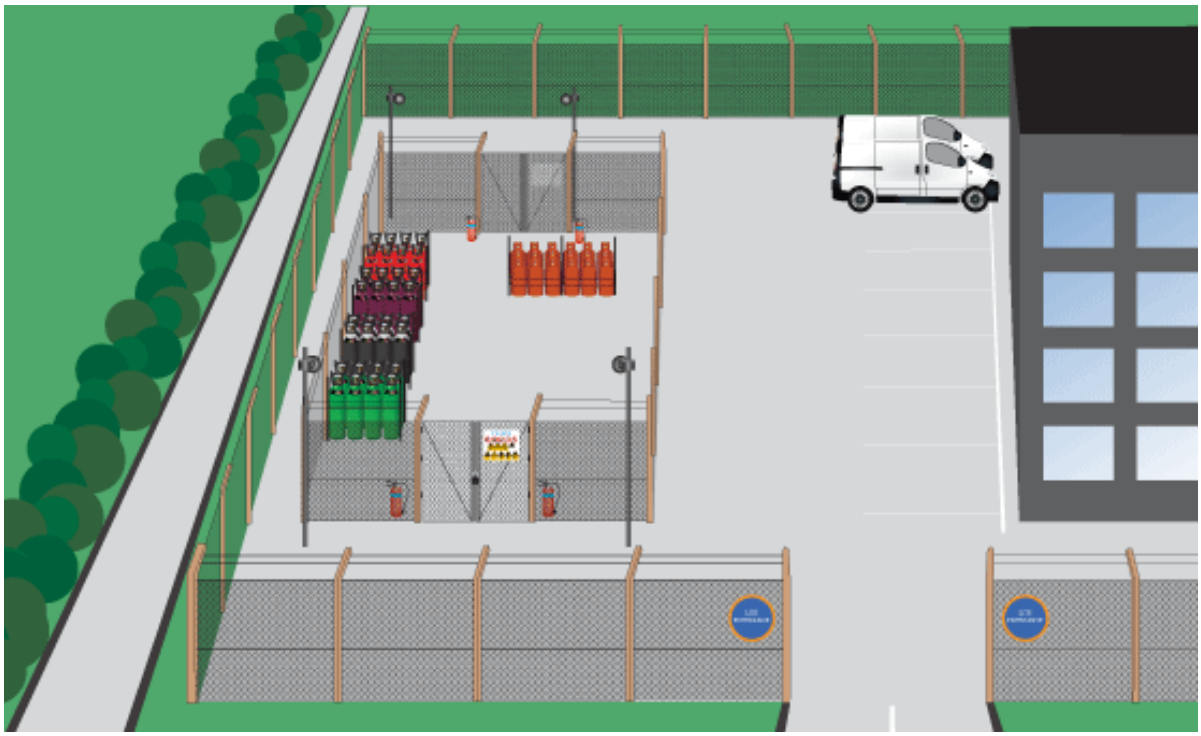


Figure A3-2: Example of an outdoor store. Inside a site.

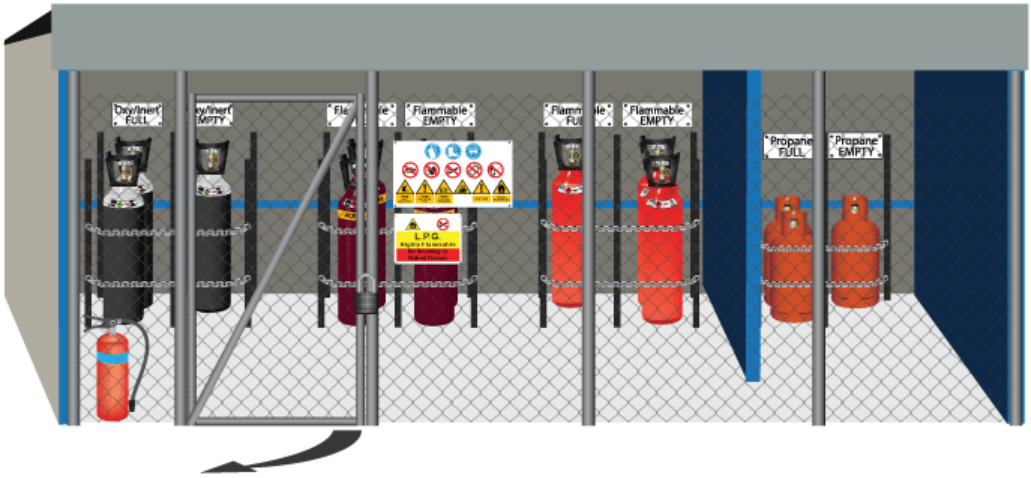


Figure A3-3: Example of a standalone outdoor store

Figure A3-4: Example of an outdoor store. Located inside a secure site.

Figure A3-5: Example of a gas cylinder storage cage

GAS CYLINDER STORE - EXMPLES OF SIGNAGE

Examples of signage that may be used on the site and the external area of a gas cylinder store.

General:

No source of ignition

No smoking

No unauthorised access

No mobile phones

Potential asphyxiating atmosphere

Gas cylinder store

Explosive Atmosphere

No oil or grease

Safety gloves must be worn

Safety boots must be worn

Eye protection must be worn

Industrial vehicles

Gases:

Flammable gas

Acetylene

Oxidising gas

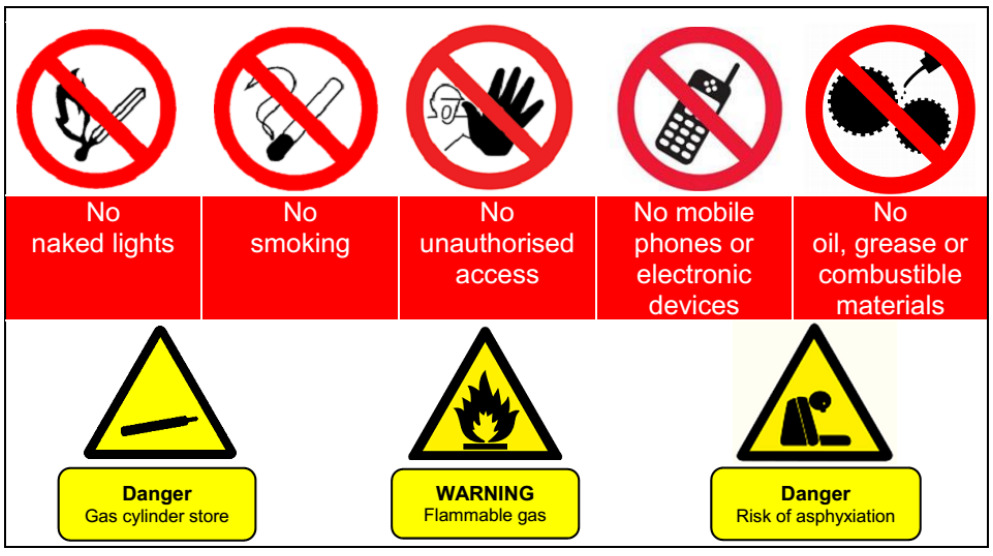
Corrosive gas

Toxic gas

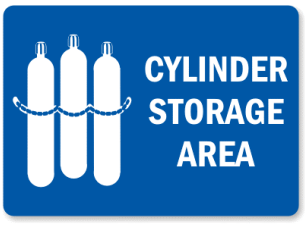
Example combination signs:

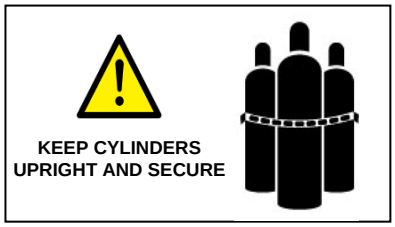
1. Inert gas

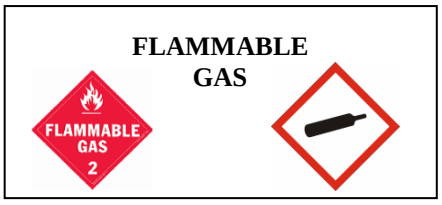
2. Flammable gas

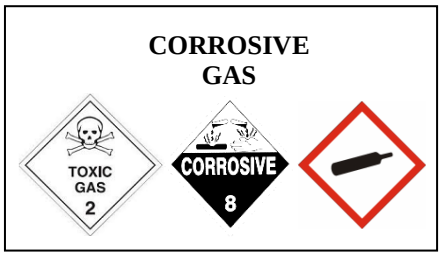


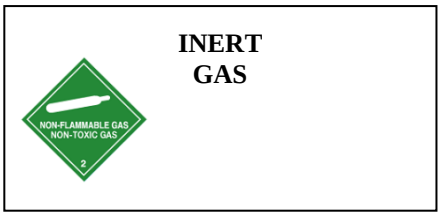
Examples of signage for the inside of a gas cylinder store:

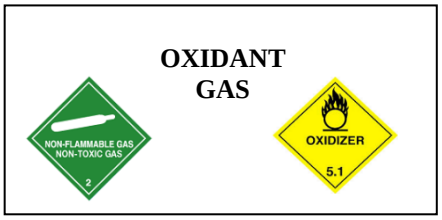












GUIDANCE FOR ASSESSMENT OF VENTILATION REQUIREMENTS

Where gas cylinders are stored in an indoor store, refer to Section 5.15.4, ventilation is required to ensure that, in the event of a leak, the gas is adequately dispersed and will prevent a hazardous atmosphere being created. The type of ventilation depends on a multitude of factors such as the design of the store, its location, the properties of the gas(es) being stored, the quantity and size of cylinders, activities which take place inside or close to the store etc.

Additional information is available in BS 5925 (30), *Code of Practice for ventilation principles and designing for natural ventilation*. HSE provide guidance on workplace exposure limits in HSE EH 40 (26), *Workplace exposure limits*.

Ventilation can be natural or provided by forced ventilation. The design criterion is the number of air changes per hour that will prevent gases accumulating to the point where they become a hazard, for example, the atmosphere becomes asphyxiant, oxidant, toxic or exceeds the gas lower flammability limits in air.

In locations above ground level with no special ventilation openings, natural ventilation provides typically 1 change per hour. This is not the case of buildings with windows sealed with tight seals. For underground rooms with small windows 0.4 changes per hour can be considered as an average value.

If natural ventilation is insufficient, such as where more than 1 change per hour is required, a forced ventilation system is necessary.

An indoor location should have ventilation openings with a minimum area of 10 % of the ground area. The inlet and outlet openings shall be positioned diametrically across the store at high and low levels. The density of the gases being stored will determine the location of the forced air outlet openings i.e. at high levels for lighter than air gases, and at low level for heavier than air gases.

Where the gas has several hazardous properties, for example, toxic, intoxicating or flammable, as well as the potential to result in an oxygen deficient atmosphere, the resulting concentration of the gas and the various properties from a release should be established, the risk from the hazards assessed, and action taken to ensure each property is appropriately managed safely.

The accepted limits of oxygen concentration in the atmosphere for normal working are above 19.5 % and below 23.5 %. Where oxygen deficiency or enrichment is the overriding hazard the oxygen concentration from a release can be calculated assuming a certain leakage rate and a homogeneous distribution of gas.

For short periods of time taking the number of air changes into consideration:

$$C_t = 0.21 + \left[\frac{0.21n}{\left(\frac{L+n}{Vr} \right)} - 0.21 \right] \left[1 - e^{-t/m} \right]$$

For long periods taking the number of air changes into consideration (t tending to infinity):

$$C_\infty = \frac{Vr \times 0.21 \times n}{L + (Vr \times n)} \quad \text{approximately}$$

For long periods of time NOT taking the number of air changes into consideration (this formula may be used for a quick assessment):

$$C_{ox} = \frac{100\, V_o}{V_r}$$

Where the toxic, intoxicating or flammable properties of the gas is the overriding hazard, the gas concentration resulting from a release can be calculated assuming a certain leakage rate and a homogeneous distribution of gas, using the following formula:

For long periods taking the number of air changes into consideration: (t tending to infinity):

$$C_{ac} = \frac{Vr \times n}{L + (Vr \times n)} \quad \text{approximately}$$

For long periods of time NOT taking the number of air changes into consideration (this formula may be used for a quick assessment):

$$C_{nac} = 100 \frac{V_g}{V_r}$$

Where:

C_{ac}	=	Gas concentration after long periods (days)
C_{nac}	=	Resulting gas concentration with no air changes
Ct	=	Oxygen concentration after defined time
C_∞	=	Oxygen concentration after long periods (days)
C_{ox}	=	Oxygen concentration
L	=	Gas release rate, m^3/h

V_g = maximum gas release m^3

V_o = 0. 21 (V_r - V_g) for argon, nitrogen, helium, nitrous oxide and carbon dioxide

V_o = 0. 21 (V_r - V_g) + V_g for oxygen

V_r = The volume of free air in the room, m^3

n = The number of air changes per hour

t = Time gas has flowed in hours

e = 2.72

$$m = \frac{Vr}{L + n\,Vr}$$

Example calculations

Example calculation A5-1 (Oxygen deficiency)

One nitrogen 50 litre cylinder charged to 200 bar in a store with a free air volume of 75 m^3.

Using: $$C_{ox} = \frac{100\,V_o}{V_r}$$

Vr = 75 m^3

$$\text{Volume of gas in cylinder} = \frac{50 \times 200}{1000} = 10\ m^3$$

$$Vo = 0.21(75 - 10) = 13.65\ m^3$$

$$\text{Resulting oxygen concentration } (C_{ox}) = \frac{100 \times 13.65}{75} = 18.2\ \%$$

This oxygen concentration is below the minimum workplace concentration for normal working. However, the instantaneous release of the whole contents of a compressed gas cylinder is an almost inconceivable event, and not foreseeable as part of normal working. Thus specific preventative measures are unlikely to be required in this case.

Example calculation A5-2 (Oxygen deficiency)

An inert gas is being used in a work place with a free air volume of 18 m^3, the gas flow rate is 1.1 m^3/h, the air changes are 0.4 per hour and the time taken to complete the job is 2 hours.

To establish the effect of this activity on the workplace atmosphere after 2 hours the following formula is used:

Using: $$C_t = 0.21 + \left[\frac{0.21n}{\left(\frac{L+n}{Vr} \right)} - 0.21 \right] \left[1 - e^{-t/m} \right]$$

Where:

C_t = oxygen concentration at time t, which can be multiplied by 100 to give the % concentration

L = 1.1

Vr = 18

n = 0.4

t = 2

$$m = \frac{Vr}{L + nVr} = 2.17$$

Ct = 0.193 = 19.3 %

This is the concentration of the oxygen in the air.

This oxygen concentration is below the minimum workplace concentration for normal working (19.5 %), therefore preventative measures such as increasing ventilation will need to be taken.

Example calculation A5-3 (Intoxication)

One 6.35 kg (14 lb) carbon dioxide cylinder in a store with a free air volume of 75 m^3.

Using: $$C_{nac} = 100 \frac{V_g}{V_r}$$

Where:

V_g = Volume of gas in cylinder $= \frac{6.35 \times 535}{1000}$ = 3.4 m^3

NOTE: 535 is the conversion figure for CO_2 when changing from a liquid to gas.

Vr = 75 m^3

Resulting carbon dioxide concentration (C_{nac}) = (100 x 3.4)/75 = 4.5 %

Carbon dioxide is an intoxicant and therefore the HSE have defined a workplace exposure limit of 0.5 % averaged over 8 hours, with a maximum exposure of 1.5 % for short periods of 15 minutes, refer to HSE EH 40 (26). In this example the carbon dioxide concentration is above the workplace exposure limit. Measures should be taken to reduce the risk as carbon dioxide cylinders are fitted with rupture discs which, when operate, release of the whole contents of the gas cylinder.

Example calculation A5-4 – (Flammable)

Consider a 50 litre, 200 bar cylinder of hydrogen in a room of internal volume 75 m^3. The volume of gas contained in the cylinder is 8.796 m^3, measured at 1.013 bar and 15 °C.

The concentration of hydrogen in the room if it is released is thus:

Using: $C_{nac} = 100 \frac{V_g}{V_r}$

Where:

V_g = 8.796 m^3

Vr = 75 m^3

Resulting gas concentration (C_{nac}) = (100 x 8.796)/75 = 11.7 %

The instantaneous release of the complete contents of the cylinder is not normally a reasonably foreseeable event, however the result is over 10 times the suggested maximum acceptable gas concentration (25 % of LEL, which is for hydrogen in air 4 %, giving a maximum allowable concentration of 1 %). There is therefore sufficient gas to create a hazardous situation and preventive measures should be considered.

British Compressed Gases Association

www.bcga.co.uk