BCGA CODE OF PRACTICE CP 26

LIQUID CARBON DIOXIDE STORAGE AT USERS' PREMISES

Revision 3: 2012

British Compressed Gases Association

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ISSN 0260 - 4809

PREFACE

The British Compressed Gases Association (BCGA) was established in 1971, formed out of the British Acetylene Association, which existed since 1901. 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 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.

This document has been prepared by BCGA Technical Sub-Committee 1. This document replaces BCGA CP 26: Revision 2. It was approved for publication at BCGA Technical Committee 143. This document was first published on 13/06/2012. For comments on this document contact the Association via the website www.bcga.co.uk.

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TERMINOLOGY AND DEFINITIONS

System **Relevant Fluid** **Danger** **Examination** **User** **Protective Device** **Owner**	These terms are defined in the Pressure Systems Safety Regulations (5).
Access Apron	Indicates an area between the tank and a tanker where the process operating controls on both tank and tanker are accessible to the operator during filling/discharging.
Competent Person	The competent person should have such practical and theoretical knowledge and actual experience of the type of plant which he has to examine as will enable him to detect defects or weaknesses, which it is the purpose of the examination to discover, and to assess their importance in relation to the strength and function of the plant. Equivalent levels of knowledge and experience are also required for competent persons engaged in the writing or certifying of Written Schemes of Examination.
Designer	Any person responsible for the design or specification of carbon dioxide systems or any part thereof.
Liquid Transfer Area	Indicates an area adjacent to the tank which surrounds the tanker, when the latter is in the filling/discharging position, and which includes the access apron.
May	Indicates an option available to the user of this Code of Practice.
Outer Jacket	The insulation container.
Pressure	Pressures are gauge pressures unless stated otherwise.
Pressure relief devices	A single or combination of relief valves or discs designed to relieve a specified flow rate at a defined pressure.
Shall	Indicates a mandatory requirement for compliance with this Code of Practice.
Should	Indicates a preferred requirement but is not mandatory for compliance with this Code of Practice.
Tank	Indicates an assembly, complete with a piping system, of an inner vessel and an outer jacket to contain insulation. The insulation space may be subject to a vacuum.
Vessel	Indicates a pressure vessel which may or may not be insulated.

BCGA CODE OF PRACTICE 26

Bulk liquid carbon dioxide storage at users' premises

INTRODUCTION

This BCGA document is intended as a Code of Practice for the guidance of UK companies directly associated with the installation, operation and maintenance of liquid carbon dioxide storage installations at users' premises. As such, it is complementary to similar documents published by the BCGA, such as Code of Practice 36 (20), covering installations for other common liquefied gases, including oxygen, argon and nitrogen.

This document is not a Design Code. The user of this Code of Practice shall make reference where applicable to UK legislation and internationally recognised Standards where these apply to liquid carbon dioxide systems and to take into account the specific practices of the UK Industrial Gases companies.

BCGA is grateful for the help and co-operation of the Health and Safety Executive, who provided comments on the text of the document.

Carbon dioxide is widely used in industry in gaseous, liquid and solid states. The storage of liquid carbon dioxide at sub-ambient temperatures and moderate pressures in insulated pressure vessels at users' premises not only provides an efficient way of storing gas, but improves safety when used in conjunction with a piped distribution system by eliminating the need for cylinder, or other container, handling.

However, the particular properties of carbon dioxide necessitate certain precautions to be taken and certain rules to be followed.

As part of the continual effort to promote a high standards of safety, the scope of this document has been revised to include liquid carbon dioxide tanks previously covered by BCGA Code of Practice 28 (19) which has been withdrawn.

All new storage installations at users' premises, including a change of vessel size, shall comply with this Code of Practice.

SCOPE

A liquid carbon dioxide storage installation on a user's premises is defined for the purposes of this Code of Practice as the installed static insulated liquid storage vessel, or storage tank, together with the control equipment and safety devices, vaporising and pumping equipment, the liquid storage enclosure and the liquid transfer area. Storage tanks for liquid carbon dioxide are insulated either by conventional, typically polyurethane, materials or by the use of a vacuum jacket.

This Code of Practice applies to static, conventional or vacuum insulated, tank installations with an individual water capacity up to 250,000 litres designed to store liquid carbon dioxide.

Transportable pressure vessels (such as small portable tanks, road and rail tankers, shipboard vessels), and vessels on plants which produce or recover carbon dioxide are specifically excluded from this Code of Practice.

Where the carbon dioxide installation is part of a multiple gas installation, the BCGA have published the following Codes of Practice. Due consideration shall be given to these when designing such installations.

(i) CP 36 (20) Bulk cryogenic liquid storage at users' premises.

(ii) CP 27 (18) Transportable vacuum insulated containers of not more than 1000 litres volume.

Codes produced by other associations should be consulted for installations that include gases not covered by the scope of this document nor detailed in the above references. Examples include LPG and Hydrogen.

1. GENERAL DESIGN CONSIDERATIONS

1.1 Properties of carbon dioxide

At normal temperature and pressure, carbon dioxide is classified as a non toxic, non flammable gas but it does start to affect breathing at concentrations at about 1% with effects becoming more serious with increasing concentration. Carbon dioxide is a colourless odourless gas with a characteristic taste and pungency at higher concentrations. It does not support life or combustion. It is approximately 1.5 times as heavy as air, with a density, at 1.013 bar absolute, 15 °C, of 1.87 kg/m³. It is usually transported and stored in bulk as a liquefied gas, at a temperature of approximately minus 17 °C and a pressure of 20.7 bar.

Carbon dioxide cannot exist as a liquid at atmospheric pressure. When the liquid under pressure is released to the atmosphere, a dense white cloud is formed, containing cold gas, solid carbon dioxide particles and condensed moisture from the air. The solid carbon dioxide, at minus 78.4 °C, may settle on adjacent surfaces before subliming to produce more cold gas. As the gas is heavier than air, it will spread along the ground and accumulate in low lying areas such as pits and trenches.

Carbon dioxide will dissolve in water to a limited extent to form a weak acid, but it is generally un-reactive.

1.2 Precautions

1.2.1 Physiological and asphyxiation hazards

Carbon dioxide is normally present in atmospheric air at a level of approximately 0.03 % (300 ppm). As a normal product of human and animal metabolism, it plays an important role in the control of several vital functions, but is toxic in high concentrations.

The Health and Safety Executive (HSE) Guidance Note EH 40 (7) on occupational exposure limits gives a workplace exposure limit (WEL) for the concentration of carbon dioxide in the air of 0.5 % by volume (5000 ppm), calculated as an 8-hour time-weighted average. A short term exposure limit (STEL) of 1.5 % by volume (15000 ppm), calculated as a 15 minute time weighted average concentration, is also given.

The effects of inhaling varying concentrations of carbon dioxide are given in Table 1, but it should be appreciated that the reactions of some individuals can be very different from those shown.

CO_2 Concentration Vol %	**Effects and Symptoms**
1	Slight and unnoticeable increase in breathing rate.
2	Breathing becomes deeper, rate increases to 50 % above normal. Prolonged exposure (several hours) may cause headache and feeling of exhaustion.
3	Breathing becomes laboured, rate increases to twice the normal. Hearing ability reduced, headache experienced with increase in blood pressure and pulse rate.
4 - 5	Breathing laboured at four times the normal rate. Symptoms as above, with signs of intoxication after ½ hour exposure and slight choking feeling.
5 - 10	Characteristic pungent odour noticeable. Breathing very laboured, leading to physical exhaustion. Headache, visual disturbance, ringing in the ears, confusion probably leading to loss of consciousness within minutes.
10 - 100	Loss of consciousness more rapid, with risk of death from respiratory failure. Hazard to life increased with concentration, even if no oxygen depletion.

Table 1: The effects of inhaling varying concentrations of carbon dioxide.

The effects of carbon dioxide are entirely independent of the effects of oxygen deficiency. The oxygen content in the atmosphere is therefore not an effective indication of the danger. For example, a potentially fatal carbon dioxide concentration of 14 % can exist with a normal oxygen content.

Oxygen depletion monitors do not provide protection for monitoring atmospheres where carbon dioxide may be present.

Attempts to rescue persons from confined spaces or where high concentration carbon dioxide atmospheres may be present should be made only by persons trained in the use of air-supplied breathing apparatus and confined space entry procedures. Filter respirators give **NO PROTECTION** in atmospheres containing dangerous concentrations of carbon dioxide.

Further information on the physiological effects of carbon dioxide is given in EIGA Safety Information 24/11 (28) and EIGA IGC Document 164/10 (26).

1.2.2 Embrittlement of materials

Many materials, such as certain steels and plastics, become brittle at low temperatures and the use of appropriate materials, for the service conditions prevailing, is essential.

Materials suitable for liquid carbon dioxide service include austenitic stainless steels, copper and its alloys, and aluminium alloys. Fine grained, low carbon steels, with high toughness at low temperatures, are the most widely used materials of construction for liquid carbon dioxide vessels and pipework, but they should only be used within the guidelines laid down in internationally recognised standards or codes. These normally require the specification of a minimum design temperature for the vessel or piping and restrict the pressure permitted within it when its temperature is below this or a related level.

Where materials that may become brittle are used it is essential that procedures and protection mechanisms are in place to prevent catastrophic failure. If the pressure in a liquid carbon dioxide vessel falls significantly below the normal operating range, owing to excessive draw-off or venting, its temperature will fall correspondingly. Under these circumstances, the user shall not attempt to re-pressurise or re-commission the vessel, which may contain solid CO_2, but shall contact the Competent Person, (see Section 4.4 (ix)).

Solid carbon dioxide formed during a low temperature excursion is denser than liquid carbon dioxide and will accumulate and remain at the bottom of the tank. It can stay in this condition even if the tank is re pressurised to normal operating pressure. This can result in localised low temperatures beyond the safe operating range which could result in catastrophic failure.

1.2.3 Risk of blockage

Liquid carbon dioxide will change to a solid when its pressure falls below 4.18 bar. This must be considered in the design and operation of the installation, particularly fill and vent lines. Due consideration shall be given to cross connections between gas and liquid lines to allow liquid lines to be pre pressurised and safely purged prior to the introduction of liquid.

1.2.4 Cold burns

Severe damage to the skin may be caused by contact with solid or cold gaseous carbon dioxide, or with uninsulated pipes or receptacles containing cold liquid carbon dioxide. For this reason, appropriate Personal Protective Equipment, including gloves and eye protection shall be worn when handling equipment in bulk liquid carbon dioxide service. Further information on cold burns and their treatment is given in Appendix 1.

1.3 Regulations and codes

This BCGA Code of Practice describes minimum requirements. It is not to be considered as a definitive Design Code. It is the responsibility of the Designer to ensure that all relevant Statutory regulations are applied and relevant Codes of Practice, standards and specifications taken into account in the designs and installations covered by this Code of Practice. Section 7 gives a list of directly relevant documents but is not intended to be exhaustive.

2. LAYOUT AND DESIGN FEATURES

2.1 General

The installation shall be sited to minimise risk to personnel, local population and property. Consideration should be given to the location of any potentially hazardous processes in the vicinity, which could jeopardise the integrity of the storage installation.

An installation may, because of its size or strategic location, come within the scope of specific legislation for planning control. If so, the siting of any proposed installation should be discussed and agreed with the local authority and appropriate sections of the Health and Safety Executive.

2.2 Design and manufacture of the installation

The complete installation shall be designed, manufactured and installed in accordance with recognised pressure vessel, storage tank and piping codes that meet the requirements of the Pressure Equipment Regulations (4).

Where appropriate, tanks and other equipment shall be designed to withstand windloads in accordance with the appropriate design codes and with BS EN 1991-1-4 (14) or equivalent.

The backfeed category of risk and protection required shall be assessed in accordance with the requirements of BCGA Guidance Note 10 (23). The system shall incorporate the identified preventative measure according to the risk category determined.

A full system process and instrumentation diagram and design dossier shall be produced and maintained by the owner of the system for the life of the system.

2.2.1 Materials

All components shall be constructed from materials compatible with carbon dioxide, and with the temperature and pressure conditions to which they will be subjected.

These considerations shall be also taken into account when designing pipework systems and their accessories connected to the tank, for example fill, product withdrawal and vent lines.

2.2.2 Tank pressure relief devices

Each tank shall have pressure relief devices fitted to the pressure vessel (inner vessel) and to the outer jacket of vacuum insulated tanks to ensure safe operating limits are not exceeded.

Inner vessels shall be protected by at least two independent pressure relief devices. Both shall be on line at all times during normal operating conditions. Combinations of smaller capacity pressure relief valves can be used to achieve the required rate of a pressure relief device. Pressure relief devices shall comply with the requirements for safety accessories as defined within the Pressure Equipment Regulations (4).

For sizing the relieving capacity of pressure relief devices all operational conditions shall be considered including:

(i) Boil off rate (including a safety factor) in case of insufficient insulation or loss of vacuum.

(ii) Filling operations.

(iii) Malfunction of control in pressure raising systems.

(iv) Any other foreseeable source of energy input into the vessel for example pump recycle systems.

(v) Failure of the refrigeration unit.

(vi) Reasonably foreseeable combinations of the above.

Consideration may also be given (when sizing pressure relief devices), to the possibility of complete or partial fire engulfment of the vessel or tank if required by the design code or site specific risk assessment.

The installation should be designed to facilitate the regular inspection, testing and maintenance of the pressure relief devices.

Bursting discs are not recommended for protecting the pressure vessel as their rupture leads to complete de-pressurisation and solidification of the tank contents. Furthermore, any existing installations fitted with bursting discs should have these replaced with relief valves at the first practical opportunity. This statement is not applicable to the protection of the outer jacket of double skinned tanks where it is standard practice to fit a bursting disc.

It shall not be possible to isolate a combination of relief devices which could result in a reduced relieving capacity below the calculated requirement.

If a three-way valve is installed to accommodate two pressure relief devices operating either simultaneously or alternatively, then the size of the three-way valve and the inlet pipework shall be such that the vessel is always adequately protected. Where a tank is only protected by two pressure relief devices, one either side of a three way valve the default position of the valve shall be with both pressure relief devices on line. Isolation of a pressure relief device shall only be carried out under controlled maintenance operations.

If the outlet of a relief valve is connected to any pipework, nozzle, elbow or relief valve header, any imposed back pressure shall be included in the relief valve sizing calculation.

The pressure relieving devices shall be designed to operate effectively across the full-range of working temperatures.

All pressure relief devices shall be orientated in such a manner as to prevent the accumulation of water or other contamination, which could result in incorrect operation.

Installation and orientation of the relief device shall be in accordance with manufacturers recommendations. Consideration shall be given to the thrust resulting from operation of the relief device and the effect on the device, pipework and vessel nozzle. Provision of additional supports may be required to control imposed thrust forces.

Due consideration shall be given to the direction of any relief device vent so that it does not affect the safety of personnel or equipment. Consideration shall also be given to the ease of access to the three way change over valves for operation when a relief device is discharging.

Outer jackets need not be designed to a pressure vessel design standard, but they shall be capable of withstanding full vacuum.

The outer jackets of vacuum insulated tanks shall be fitted with a device to relieve pressure increase in the event of a leak from the inner vessel or interspace pipework. The device shall be set to open at a pressure of not more than 0.5 bar. The discharge area of the pressure relief device shall be not less than 0.34 mm^2 per litre capacity of the inner vessel but not less than 10 mm diameter.

2.2.3 Markings

The tank and other equipment as appropriate shall be marked in accordance with the requirements set out in paragraph 3.3 of schedule 2 of the Pressure Equipment Regulations (4) and or other applicable Regulations. The safe operating limits should be readily accessible.

2.3 Safety distances

Safety distances are defined as the distance from the exposure or item to be protected to the nearest of the following:

(i) Any point on the storage system where in normal operation leakage or discharge can occur (e.g. hose couplings, including those on extended fill lines, relief valve vents etc.), or

(ii) The vessel insulation cladding or tank outer jacket, or

(iii) The vessel/tank nozzles.

Safety distances are intended to:

(iv) Protect personnel from exposure to hazardous atmospheres.

(v) Protect the installation from the effects of thermal radiation or jet flame impingement from fire hazards.

The safety distances given in this Code of Practice are based on experience and calculations of minor release. They are not intended to protect against catastrophic failure of the liquid storage vessel. Previous operating history, the protective devices fitted, material properties and the mode of vessel construction support this philosophy.

The distances given in Appendix 2 are intended to protect the storage installation as well as personnel and the environment. They are considered to give protection against risks involved in the normal operation of liquid storage installations covered by this Code of Practice.

These distances correspond to well established practice and are derived from operational experience within Europe and the USA. They relate to over hundreds of thousands of tank years in service.

Shorter distances may be used if a site specific risk assessment in line with EIGA IGC Document 75/07 (27) methodology (using HSE fatality rates) indicates an acceptable level of risk.

The safety distances may be reduced by the provision of impervious fire resisting walls of concrete, masonry, or similar construction, (see BS 476 ‘Fire Tests on Building Materials and Structures’ (12)) to a minimum height of 2.5 m.

The distance between the installation and the exposure around the ends of the segregation walls should be equal to or greater than the separation distance given in Appendix 3.

Care must be taken to ensure that good ventilation is retained and a minimum clearance between the barrier or wall and the installation shall be 0.6 metres to allow free access to and escape from the enclosure. It is recommended that walls should not be constructed on more than two sides of the installation. Where this is unavoidable a risk assessment shall be conducted.

2.4 Location of installation

Consideration shall be given to the consequences of any release from the tank and resultant vapour clouds when choosing a location for the tank.

When gas is not being withdrawn, pressure within the tank will gradually increase to the point where the relief valve will lift if a refrigeration unit is not fitted or has failed. Although the rate of gas discharge is small, precautions shall be taken to avoid the creation of dangerous atmospheres from vented gases.

Storage installations should be situated in the open air in a well-ventilated position and where there is no risk of damage by passing vehicles.

Storage tanks should be at the same level as the tanker parking area to enable the operator / driver to control the transfer operations.

Tanks below 2,000 litres may be installed internally provided that:

(i) The exhaust of the vessel pressure relief devices and the vents are piped away to a fixed safe external location, or

(ii) The installation is within an enclosed space of adequate size such that using the calculation in Appendix 6 of this Code, the release of gas will not result in an atmosphere with a carbon dioxide concentration exceeding 1.5 %

Consideration shall be given for the tank to be vented in an emergency and during filling. This may be achieved by the use of the try-cock/vent exhaust in which case they shall be piped away to a fixed safe external location that is visible from the fill connection.

Note: 2.4 (i) and (ii) only provide protection against risks presented by releases from the tank and not through the use of the product.

A road tanker, when in position for filling from or discharging to the fill connection, should be in the open air. Tanker operators shall have easy access to and from the fill connection.

The formula in Appendix 3 of this Code may still be used to calculate the effects of minor leakages, e.g. from try-cock or thermal relief valves.

Consideration shall also be given to the use of carbon dioxide detectors where ventilation arrangements are poor and it is not practical to increase natural ventilation or install forced ventilation.

When installed internally, locations should be chosen in the following order of preference:

(iii) In a ventilated room sealed from other areas of normal occupancy.

(iv) At or above ground level adjacent to an outside wall as far as is practicable away from normal work locations.

(v) At or above ground level, as far as is practicable away from normal work locations.

(vi) Below ground level as far as is practicable away from normal work locations.

Tanks of a capacity greater than 2,000 litres shall not be located where natural air ventilation is inhibited, unless they are subjected to a suitable and sufficient risk assessment. Examples of locations where such risk assessments are required are:-

(vii) inside structures with two or more sides and a roof

(viii) enclosed on three or more sides

(ix) below ground level or where there are pits, ditches and other ground depressions.

Appendix 4 provides additional guidance for the indoor installation of storage vessels.

2.4.1 Gas detection

Carbon dioxide rich atmospheres are created when gas or liquid is released and the local ventilation is not sufficient to prevent a dangerous gas concentration accumulating. The best precaution against this situation arising is to increase the ventilation level. If it is not reasonably practicable to provide additional ventilation, appropriate gas detection equipment that incorporates a warning alarm shall be considered. The following provides some guidance on the selection of appropriate equipment.

Before detector equipment is specified the intended location shall be assessed to establish persons at risk, what gases present a risk, where the gases may accumulate (taking into consideration the properties of the gas) and an appropriate location for the detector measurement head.

A safe system of work, which may include carbon dioxide monitoring, shall be in place where there is a risk of carbon dioxide levels exceeding 1.5 %.

Gas detection alarms, displays and warning signs shall be sited so that they are clearly visible or audible to personnel before entering and once within the affected area.

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

Guidance on assessing ventilation requirements is given in Appendix 3.

2.4.2 Protection against electrical hazards and lightning

The location shall be chosen so that damage to the installation by electric arcing from overhead or other cables cannot occur. Protection against lightning is not normally required, but may be necessary to comply with local conditions or site regulations. Any necessary lightning protection should be installed in accordance with BS EN 62305 (17).

Flame proof, explosion proof, or other forms of hazardous area classified electrical equipment are not necessary for carbon dioxide systems since the product is not classified as a flammable gas according to BS EN 60079 (15). Where applicable, electrical equipment, which is necessary for the installation shall be in accordance with BS EN 60529 (16), protection class IP54 or better. For more severe environmental conditions protection class IP55 (designed to protect against water jets) should be used. Consideration should be given to earth bonding of the installation and pipework. All electrical installation shall comply with current electrical legislation.

2.4.3 Installation level and slope

The installation should not be located below ground level and should be sited away from pits, ducts, un-trapped drains, cellars and other ground depressions (see Appendix 2 for safety distances).

The slope of the ground shall be such as to allow surface water runoff.

2.4.4 Position of gas vents

Vents, including those of safety relief devices, shall discharge to a safe place in the open and comply with the safety distances shown in Appendix 2. They shall be directed so as not to impinge on personnel, occupied buildings and structural steelwork.

Consideration shall be given to the risk of blockage by solid CO_2, ice, organic matter or debris and the prevention of accumulation of water, including that from condensation, in vent outlets. For the separation distance from any flammable gas vents see Appendix 2.

All vent systems shall be adequately supported to cope with loads created during discharge.

2.4.5 Vapour clouds

Vapour clouds may be formed during normal operation of a storage system for example from vaporisers, from venting during liquid transfer or from the operation of protective devices. The extent of the visible vapour cloud resulting from product release should not be relied upon to indicate the limit of a carbon dioxide enriched atmosphere.

Vapour clouds created by product releases are generally low lying (typically below waist height). Such vapour clouds may be quite extensive depending on weather conditions and therefore persons working below ground or at low level in the vicinity may be put at risk.

When siting an installation, due consideration shall be given to the possibility of the movement of vapour clouds, originating from spillage or venting, which could be a hazard from carbon dioxide enrichment or decreased visibility. The prevailing wind direction and the topography shall be taken into account.

2.4.6 Location of transfer area

The liquid transfer area should be designated a ‘No Parking’ area and should be level.

A road tanker, when in position for filling from or discharging to the installation, shall be in the open air and not a confined area from which the escape of vapour is restricted. Tankers should have easy access to and from the installation at all times. The installation shall be protected from vehicular damage that could result in product release.

The liquid transfer area should normally be located adjacent to the fill coupling of the installation and be positioned in such a way that it facilitates the movement of the tanker in the case of an emergency.

Extended fill lines should be avoided if possible. Unless the tank is specifically designed for remote filling, suitable ‘repeater’ gauges and valves should be installed at the extended fill point. The length of extended filling lines should be kept to a minimum.

Transfer of liquid with the tanker standing on public property is not recommended. However, if this cannot be avoided, the hazard area shall be clearly defined, using suitable notices during the transfer period. Access to this area during transfer shall be strictly controlled.

2.4.7 Ventilation of ancillary equipment enclosure

Where pumps, vaporising or ancillary equipment are located in enclosures, these shall be properly ventilated. A safe system of work, which may include carbon dioxide monitoring, shall be in place where there is a risk of carbon dioxide levels exceeding 1.5 %.

2.4.8 Equipment layout

The equipment shall be installed so as to provide for easy access, operation and maintenance. Consideration should be given to the location of valves, pipework and controls to ensure these are easily accessible. Equipment, pipework and cables should be installed so as to minimise hazards from, for example, tripping and allow safe access and egress to the installation.

2.4.9 Pressure relief devices

Pressure relief devices shall be provided to prevent over pressure, where this can occur, including situations where liquid can be trapped.

Consideration shall also be given in the design of the installation to facilitate the periodic testing or replacement of the pressure relief devices (see Section 4.1.2).

Installation design shall ensure that the risk of pressure relief and vent line blockage is minimised, and that intended purge and vent operations can be safely and effectively carried out.

The outlet of relief valves shall not be reduced.

2.4.10 Isolation valves

Any primary process isolation valve shall be located as close as practical to the vessel itself and be easily accessible. Protection against over pressure shall be installed between any two isolation valves where liquid or cold vapour can be trapped and the position of isolation valves should be such that they can be afforded adequate protection against damage from external sources.

2.4.11 Secondary isolation

A secondary means of isolation should be provided to prevent any large release or to enable maintenance operations should the primary isolating valve fail.

The secondary means of isolation, where provided, may be achieved for example, by the installation of a second valve or a suitable cap or plug rated for the duty temperature and pressure.

Suitable means shall be provided for preventing the build-up of pressure of any trapped liquid.

2.4.12 Couplings

Users shall not modify the fill couplings provided by the gas company.

Fill and balance line couplings used for transfer of liquid carbon dioxide shall be non-interchangeable with each other and with those used for other products.

2.4.13 Backflow prevention

The installation shall be in accordance with BCGA Guidance Note 10 (23).

2.4.14 Fencing

Fencing is required to prevent access of unauthorised persons, where other means are not provided.

On controlled sites with sufficient supervision fencing is optional.

Where fencing is provided and access around the tank is required for maintenance, the minimum clearance between the fence and the installation shall be 0.6 m to allow free access and escape from inside the enclosure.

For ‘open’ fences, the safety distances given in Appendix 2 will apply regardless of the position of the fence.

The height of the fence should be at least 1.8 m.

Any gates should be outward opening and wide enough to provide for easy access and exit of personnel. Consideration should also be given for routine maintenance access.

Gates shall be locked during normal operation. Consideration should be given to the provision of an additional emergency exit where the size of fenced area or equipment location necessitates this. Any emergency exit gate should be at least 0.8 m wide.

2.4.15 Vaporisers

Vaporisers may be an integral part of the tank assembly, or may be added as part of the installation.

Vaporisers shall be adequately sized for the off-take rate specified by the customer. Where necessary a device to restrict the flow to the maximum flow capacity of the vaporisers shall be installed.

Measures shall be taken to prevent the system temperature downstream of the vaporiser dropping to a value which could cause damage to pipework or other equipment.

Ambient vaporisers should be positioned to ensure free movement of air to prevent a drop off in performance.

2.4.16 Foundations

The tank supplier will provide indicative foundation requirements but it is the responsibility of the user to ensure the tank foundation is designed to safely withstand the weight of the tank and its contents plus other possible loads caused by wind, snow or earthquake.

Accumulation of water shall be avoided.

2.4.17 Bolting down

Many factors determine whether a tank needs to be bolted down, for example:

(i) Seismic activity

(ii) Wind speed

(iii) Topography (nature of surrounding terrain)

(iv) Tank shape factor (L/D ratio, attachments to tank)

The principles of BS EN 1991-1-4 (14) or equivalent shall be followed to determine bolting down requirements.

The tank supplier shall take these factors into account in deciding whether bolting-down is necessary. Where a horizontal vessel is secured by bolts, allowance must be made for expansion/contraction of the vessel as a result of changes of contents pressure and temperature.

2.4.18 Other requirements

The location chosen for the installation shall be acceptable to both the gas supplier and the user and shall be exclusively reserved for the storage of carbon dioxide.

Any modifications shall be carried out in accordance with the applicable design code and in consultation with the gas supplier. Particular attention shall be given to any change that will alter the validity of the BCGA Guidance Note 10 (23) risk assessment.

2.4.19 Pipework

Pipework shall be identified and valves marked for function where appropriate.

2.4.20 Refrigeration system

The refrigeration system, where fitted, shall be designed, manufactured and installed in accordance with all relevant regulations and industry Codes of Practice, for example BS EN 378 (11).

2.4.21 Ancillary equipment

Some installations feature pumps, refrigeration systems, compressors and other rotating machinery which shall be designed in accordance with the requirements of the Machinery Directive (10).

2.4.22 Tank instrumentation and gauging

Tanks manufactured from materials with a minimum design temperature above minus 80 °C shall be fitted with an alarm to warn of low pressure in the vessel. The alarm should be set well above the triple point of CO_2 (4.18 bar) to allow intervention before the formation of solid CO_2 in the tank. Operator procedures shall specify the necessary actions to take in the event of an alarm. A high pressure alarm set before the tank relief valve set pressure is reached is also desirable.

Each vessel shall be fitted with the following:

(i) A maximum level indicator (for example, dip pipe at the vessel termination of the vapour balance line, trycock).

(ii) An independent liquid contents gauge.

(iii) A pressure gauge connected to the vapour space.

3. ACCESS TO THE INSTALLATION

3.1 Means of escape

Consideration should be given to the provision of an emergency exit where there is a risk of persons becoming trapped by a release of product.

3.2 Personnel

The installation shall be so designed that authorised persons shall have easy access to and exit from the operating area of the installation at all times. Access to the installation shall be forbidden to all unauthorised persons. Warning notices shall support this.

3.3 Access to installation controls

Filling connections and equipment controls shall be located in such a way that easy access to them is provided.

Filling connections and equipment controls should be located in close proximity to each other and in such a way that tanker controls and indicators are visible and easily accessible from the tanker operator's position.

3.4 Notices and instructions

3.4.1 General precautions

Notices shall be clearly displayed, to be visible at all times on or near the tank, particularly at access points, to indicate the following:

(i) Liquid Carbon Dioxide

(ii) No access for Unauthorised Persons

(iii) Asphyxiation Hazard.

(iv) Smoking and Naked Flames Forbidden

Symbols should be used instead of written notices wherever possible, for example:

Potential Asphyxiating Atmosphere

Cold burn risk

No naked flames

No Smoking

No Unauthorised Access

These signs shall comply with The Health and Safety (Safety Signs and Signals) Regulations (2) and with BS 5499, Safety signs, including fire safety signs. (13).

A sign shall be displayed showing:

(v) Gas supplier's name and local address

(vi) Gas supplier's emergency phone number

This information should also be available at a control point.

3.4.2 Identification of contents

The storage tank should be clearly labelled "LIQUID CARBON DIOXIDE".

The storage tank or compound should be clearly labelled with the UN product identification number.

The connection fittings of multi-storage installations or long filling lines shall be clearly marked with the gas name or the symbol in order to avoid confusion.

3.4.3 Legibility of notices

All displayed warning signs and labels shall be legible, visible and up-to-date at all times.

3.4.4 Labelling – food regulations

Where the gas in the tank is used either as packaging or propellant gas for foodstuffs or beverages, the tank shall also be labelled in accordance with the Food Additives Labelling Regulations (1). These regulations require the following information additional to the above:

(i) The product name shall be followed by E290.

(ii) The statement "for use in food", or another statement referring more specifically to the use for food for which the packaging or propellant gas is used.

(iii) A mark identifying the batch or lot from which the gas came. The letter "L" shall precede this mark, unless it is clearly distinguishable from other markings. Alternatively this number may be incorporated in normal product delivery documentation.

3.4.5 Operating and emergency instructions

Operating and emergency instructions shall be provided by the carbon dioxide supplier and shall be available and understood by the user before commissioning the installation (see also Section 5.1.2). These instructions shall be kept legible and up-to-date.

4. TESTING AND COMMISSIONING

4.1 Testing of the installation

Prior to commissioning the following tests shall be carried out by the supplier or his representative in accordance, with established procedures.

4.1.1 Pressure test

Works manufactured storage tanks and pressure vessels of the installation will already have been tested / inspected in compliance with the relevant Pressure Vessel Code in the manufacturer's workshop prior to the first installation. This should be verified from the name plate on the vessel. Further pressure tests shall not be carried out on the vessel without reference to the vessel design documents and tank history.

In order to ensure the integrity of the installation, a pressure test shall be carried out on site-erected piping / systems in accordance with design codes and appropriate standards. Precautions shall be taken to prevent excessive pressure in the system during the test. Following any hydraulic test, the system / equipment shall be drained, thoroughly dried out and checked for moisture content.

Where a pneumatic pressure test is specified, nitrogen or dry oil-free air shall be used as the test medium. The pressure in the system shall be increased gradually up to the test pressure. Pneumatic pressure testing is potentially hazardous and should be carried out in accordance with HSE Guidance Note GS4 (8).

Any defects found during the testing shall be rectified in an approved manner and the system then retested.

A leak and function test shall be carried out in accordance with HSE Guidance Note GS4 (8) and at a pressure in accordance with the applicable code or regulation.

Pressure tests / leak tests shall be witnessed by a competent person and a test certificate signed and issued. Such certificates shall be kept for future reference.

4.1.2 Pressure relief devices

A check shall be made to ensure that all transport locking devices have been removed from pressure relief devices of the inner vessel, outer jacket and piping systems and that the devices are undamaged and in working order. The relief device set pressure (stamped on or attached to each device) shall be checked to see it is in accordance with the maximum permissible operating pressure of the system.

Relief valves must have a valid test certificate or be covered by an appropriate batch test certificate or be subjected to a successful functional test the results of which shall be recorded.

Where relief devices are adjustable, tamper proof tags or locking devices shall be fitted.

4.2 Adjustment of controlling devices

The controlling devices of, for example, refrigeration, alarm systems, pressure regulators, low temperature shut down systems, shall be adjusted to the required operating conditions of the system and be subjected to a functional test.

4.3 Posting of notices

Notices (see Section 3.4) shall be posted before putting the installation into service.

4.4 Commissioning

Prior to first fill, checks shall be carried out to ensure the suitability of the installation for commissioning.

Commissioning shall only be carried out by experienced personnel and in accordance with a written procedure which ensure that:

(i) The appropriate pressure and leak tests have been carried out and documented.

(ii) A check has been made that the installation conforms to the process and instrumentation diagram.

(iii) A functional check has been made to ensure that back-feed from the system into the tank, for example from high-pressure gas cylinders, is not possible.

(iv) A check has been made that liquefied gas cannot become trapped in any part of the system not protected by thermal relief devices or reach parts of the system not designed for low temperature service.

(v) A check has been made that the correct safety devices are fitted.

(vi) If fitted, refrigeration and alarm systems shall be checked for correct operation.

(vii) A check has been made that all warning and identification labels are clearly displayed and that they are correct for the product being stored.

(viii) An ageing pressure equipment assessment in accordance with BCGA CP 39 (21) has been conducted to identify the in-service requirements.

(ix) A written scheme of examination for the entire system, in accordance with the Pressure Systems Safety Regulations (5) has been drawn up by a competent person. The responsibility for providing and complying with this scheme lies with the user. Where systems are leased or hired the user may transfer his responsibility to the owner by written agreement (in accordance with the Pressure Systems Safety Regulations, Schedule 2 (5)).

(x) An initial examination has been completed if required by the above written scheme.

(xi) Thermal shock and rapid pressure rise are taken into account.

(xii) Noise management is in place.

(xiii) Product release is minimised and controlled as far as is practicable.

(xiv) Confirm that electrical equipment associated with the installation has been installed, tested, and as required certified by a competent person.

(xv) Confirm with the user that down stream pipework and equipment is compatible with the default supply temperature and pressure conditions.

(xvi) Establish and agree with the user procedures for the safe filling of the tank.

4.5 Handover

The owner or the installer shall be responsible for the handover to the user.

The handover shall include:

(i) A demonstration of the correct operation of the equipment.

(ii) Training of user personnel in accordance with Section 6.

(iii) The provision of a contact address and telephone number should the user have any questions about his installation.

(iv) An emergency telephone number.

(v) A check to ensure that the user understands his responsibilities under the Pressure Systems Safety Regulations (5) and has made arrangements for them to be fulfilled.

Handover documents shall include a minimum of:

(vi) A manual covering safe operation of the installation.

(vii) An appropriate Safety Data Sheet, which gives information in accordance with the requirements of the CHIP Regulations (6) and the REACH Regulations (9). Safety Data Sheets provide information on hazardous substances to help users conduct risk assessments. They describe the hazards the product presents, and give information on handling, storage and emergency measures in case of accident.

5 OPERATION AND MAINTENANCE

5.1 Operation of the installation

5.1.1 Putting into service (first filling)

The gas supplier shall confirm all the commissioning checks in Section 4.4 and the handover in Section 4.5 have been completed and the system is safe to operate.

The system should be purged to ensure any debris is removed prior to the system entering service. This can be done using the residual pressure held in the system from testing.

The tank shall be cooled down and filled according to the manufacturer's recommendations. Ensure that any pressure rise due to rapid liquid evaporation is controlled.

Measuring and control devices shall be checked for correct operation and adjusted where appropriate.

A check should be made for leaks on all pipework and fittings and remedial action taken where necessary.

5.1.2 Operating personnel and procedures

Only authorised and trained persons should operate the installation. Operating instructions shall be supplied to operating personnel.

The instructions shall define the safe operating limits of the system and include the necessary safety information relating to the product and the installation.

In general such instructions should be written and presented in a clear concise format.

For the convenience of the operator the supplier may colour code or identify by other means the hand wheels of those valves which are to be shut in an emergency. These valves should normally be:

(i) Feed and return valves to and from the pressure build up vaporiser.

(ii) Feed valve to the product vaporiser.

(iii) Customer supply line isolation valve.

(iv) Any withdrawal valve.

The number of valves will vary, depending on the type of the installation.

Operating instructions should include the daily safety checks detailed within BCGA Leaflet 11 (25).

5.1.3 Operating difficulty or emergency

Any excursion outside the normal safe operating limits of the system shall be reported to the gas supply company and equipment owner immediately. Examples of unsafe conditions include over pressure, under pressure, rapid temperature or pressure change and mechanical damage.

The competent person who prepared the written scheme of examination for the system shall also be informed so that a decision about the continued safe use of the system can be made. When continued use is deemed unsafe, the system shall be taken out of service. The system may only be put back into service following a programme of inspection that satisfies the competent person's requirements.

Where the equipment is user or third party owned the gas supply company shall suspend deliveries until the user's competent person is satisfied that the system is safe for continued service.

Reduction of tank pressure below the range specified in the operating procedures will reduce the temperature of the stored product. This may take the tank below its minimum design temperature. In some cases this could lead to catastrophic failure of the tank. It is therefore essential that the tank is not re pressurised except under the supervision of the supplier. The gas supplier must immediately be informed of such a pressure reduction. Further detailed guidance can be obtained in EIGA IGC Document 164/10 (26).

Any operating difficulty or emergency, concerning the installation that does not respond to measures covered by the instructions, shall be referred to the gas supplier.

5.2 In service inspection and maintenance

The user is responsible for ensuring the installation is maintained and examined in accordance with the Pressure Systems Safety Regulations (5).

All aspects of in service inspections and maintenance are addressed in BCGA CP 39 (21) and the details for carbon dioxide systems are contained in BCGA CP 39, Module 2 (22).

6 TRAINING AND PROTECTION OF PERSONNEL

6.1 Training of personnel

All personnel directly involved in the commissioning, operation and maintenance of carbon dioxide storage systems shall be fully informed regarding the hazards associated with carbon dioxide and have appropriate training.

Training shall be arranged to cover those aspects and potential hazards that the particular operator is likely to encounter.

It should cover, but not necessarily be confined to the following subjects:

(i) Potential hazards of the gas.

(ii) Site safety regulations.

(iii) Emergency procedures.

(iv) Use of protective clothing/ apparatus including breathing sets where appropriate.

(v) First aid treatment for cold burns and gas exposure

In addition individuals shall receive specific training in the activities for which they are employed.

It is recommended that the training be carried out under a formalised system and that records be kept of the training given and, where possible, some indication of the results obtained, in order to show if further training is required.

The training programme should make provision for refresher courses on a periodic basis.

6.2 Emergency procedures

Emergency procedures shall be prepared by the user to cover the eventuality of a release of carbon dioxides so that persons likely to be affected shall know the actions required to minimise the adverse effects of such release.

Consideration should be given to the carrying out of practical exercises.

The following are guidelines which may be used for formulating emergency procedures:

(i) Raise the alarm.

(ii) Summon help and emergency services.

(iii) Notify the gas supplier.

(iv) Isolate the source of gases, if appropriate and where safely possible.

(v) Evacuate all persons from the affected area and seal it off.

(vi) Alert the public to possible hazards from vapour clouds and evacuate when necessary.

After the release has been isolated, carbon dioxide concentration checks should be carried out in any enclosed areas where the vapour cloud may have entered. This includes basements, pits and confined spaces.

7. REFERENCES

1. SI 1992 No. 1978 — The Food Additives Labelling Regulations 1992.

2. SI 1996 No. 341 — The Health and Safety (Safety Signs and Signals) Regulations 1996.

3. SI 1997 No. 1713 — The Confined Spaces Regulations 1997.

4. SI 1999 No. 2001 — The Pressure Equipment Regulations 1999.

5. SI 2000 No. 128 — The Pressure Systems Safety Regulations 2000.

6. SI 2009 No. 716 — The Chemicals (Hazard Information and Packaging for Supply) Regulations 2009 (CHIP Regulations).

7. HSE EH 40 — Workplace exposure limits.

8. HSE Guidance Note GS4 — Safety in pressure testing 1998.

9. Regulation (EC) No 1907/2006 — European Commission - Registration, Evaluation, Authorisation and restriction of Chemicals. (REACH), as amended.

10. 2006/42/EC — European Commission - Machinery Directive.

11. BS EN 378 — Refrigerating systems and heat pumps.

12. BS 476 — Fire tests on building materials and structures.

13. BS 5499 — Safety signs, including fire safety signs.

14. BS EN 1991-1-4 — Eurocode 1. Actions on structures. General actions. Wind actions.

15. BS EN 60079 — Explosive atmospheres.

16. BS EN 60529 — Specification for degrees of protection provided by enclosures (IP Code).

17. BS EN 62305 — Protection against lightning.

18. BCGA Code of Practice 27 — Transportable vacuum insulated containers of not more than 1000 litres volume.

19. BCGA Code of Practice 28 — Vacuum Insulated Tanks of not more than 1000 litres volume which are static installations at user premises.
Note: Obsolete publication

20. BCGA Code of Practice 36 — Cryogenic liquid storage at users premises.

21. BCGA Code of Practice 39 — In-service requirements of pressure equipment installed at user premises.

22. BCGA Code of Practice 39, Module 2 — In-service requirements of CO_2 / N_20 refrigerated storage system at user premises.

23. BCGA Guidance Note 10 — Implementation of EIGA carbon dioxide standards.

24. BCGA Guidance Note 11 — Use of gases in the workplace. The management of risks associated with reduced oxygen atmospheres.

25. BCGA Leaflet 11 — Safety checks for vacuum insulated storage tanks.

26. EIGA IGC Document 164/10 — Safe handling of liquid carbon dioxide containers that have lost pressure.

27. EIGA IGC Document 75/07 — Determination of safety distances.

28. EIGA Safety Information 24/11 — Carbon Dioxide Physiological Hazards “Not just an asphyxiant!”.

"BURNS" DUE TO VERY COLD LIQUEFIED GASES

The temperature of liquefied gases varies. The approximate boiling points, i.e. the temperatures at which the liquefied gas vaporises at atmospheric pressure, of some common industrial gases are as follows:

Helium	–268 °C	
Nitrogen	–195 °C	
Argon	–185 °C	
Oxygen	–183 °C	
Ethylene	–103 °C	
Carbon dioxide	–78 °C	At atmospheric pressure, carbon dioxide is a solid which sublimes directly to gas
Propane	–42 °C	

General effect on tissue

The effect of extreme cold on tissue is to destroy it, a similar end result to that of heat exposure, and in like fashion the amount of cold and the duration of contact is crucial.

The destruction of tissue is not so immediately obvious as in the case of burns, since pain is absent in the frozen stage, and the tissue, although rigid, keeps its normal shape and is not obviously destroyed. Pain and destruction become more apparent as thawing occurs. Those who have had mild frostbite of fingers or toes will have some idea of the pain on re-warming.

Prevention of contact with very cold fluids and surfaces is quite vital and those who work in this field must be aware of the hazard.

Skin effects

Liquid, vapour, or low-temperature gas can produce effects on the skin which will vary in severity with temperature and the length of exposure. Naked or insufficiently protected parts of the body coming into contact with un-insulated pipes or vessels may stick fast by virtue of the freezing of moisture, and flesh may be torn in removal. The wearing of wet clothing should be avoided.

Continued exposure of naked flesh to cold atmospheres can result in frostbite. Usually there is sufficient warning by local pain whilst the freezing action is taking place. Re-warming with lukewarm water (42 °C to 44 °C, or 107 °F to 111 °F) is generally a sufficient safeguard against injury.

Effect of cold on lungs

Whilst transient and short exposure produces discomfort in breathing, prolonged inhalation of vapour or cold gas, whether respirable or not, can produce serious effects on the lungs.

First Aid Treatment of cold Burns

Flush the affected areas of skin with copious quantities of tepid water, but do not apply any form of direct heat, e.g. hot water, room heaters etc. Move casualty to a warm place (about 22 °C; 72 °F). If medical attention is not immediately available, arrange for the casualty to be transported to hospital without delay.

While waiting for transport:

(i) Loosen any restrictive clothing.

(ii) Continue to flush the affected areas of skin with copious quantities of tepid water.

(iii) Protect frozen parts with bulky, dry, sterile dressings. Do not apply too tightly so as to cause restriction of blood circulation.

(iv) Keep the patient warm and at rest.

(v) Ensure ambulance crew or hospital is advised of details of accident and first aid treatment already administered.

(vi) Smoking and alcoholic beverages reduce the blood supply to the affected part and should be avoided.

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SAFETY DISTANCES

Explanatory Notes

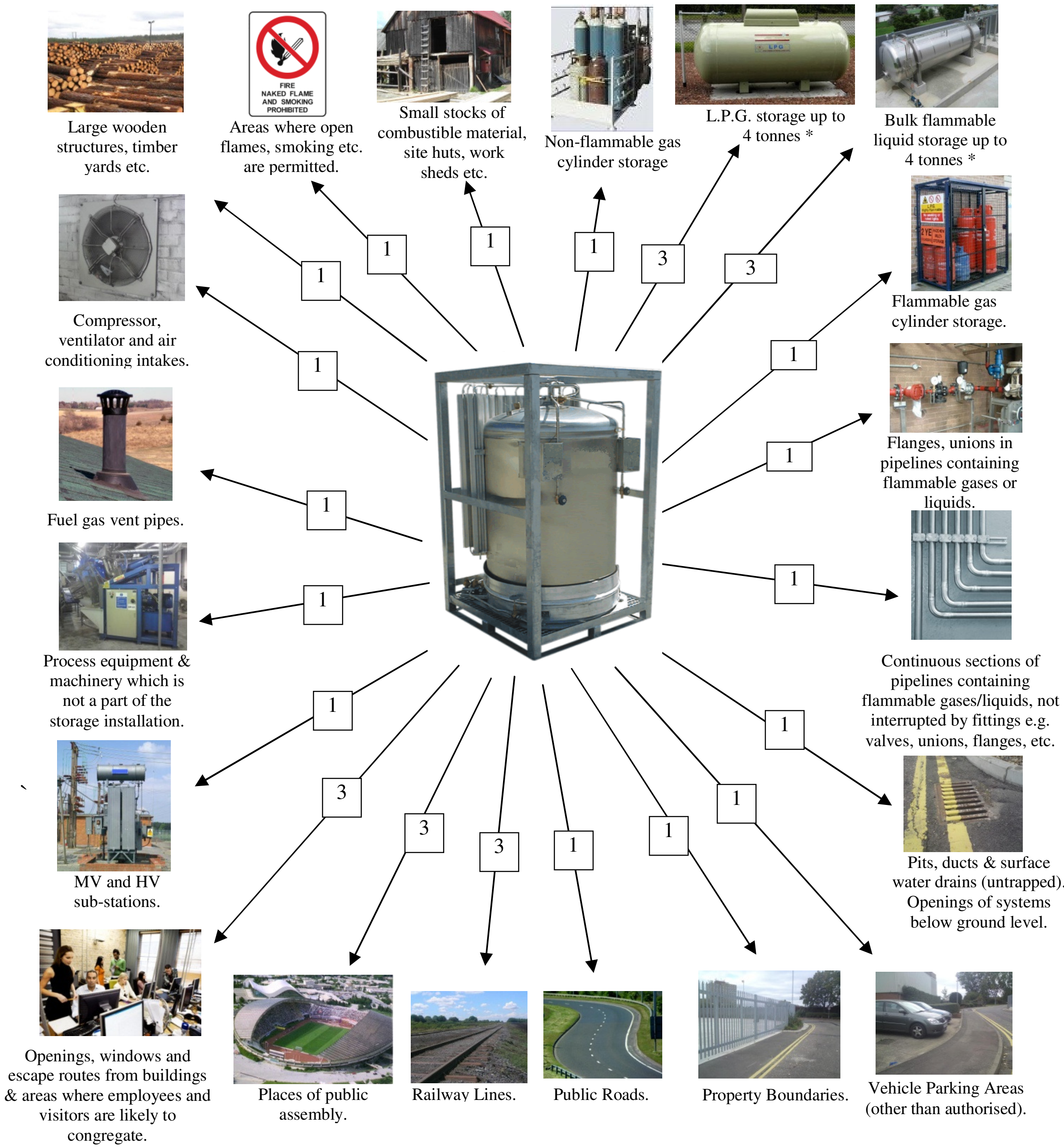
The following descriptors are used in the safety distance diagrams (Diagrams 1 & 2), with examples of the risks.

DESCRIPTORS	RISK
Large wooden structures, timber yards etc.	Thermal radiation from fire.
Compressor, ventilator and air conditioning intakes.	Ventilator and air conditioning intakes –carbon dioxide enriched atmosphere from leaking product and danger to personnel. Embrittlement of equipment.
Fuel gas vent pipes.	Thermal radiation from fire.
Process equipment & machinery which is not a part of the storage installation.	Embrittlement of equipment. Malfunction / contamination from leaking product entering process equipment.
MV and HV sub-stations.	Embrittlement of equipment. Thermal radiation from fire.
Openings, windows and escape routes from buildings & areas where employees and visitors are likely to congregate.	Carbon dioxide enriched atmosphere from leaking product, danger to personnel. Thermal radiation from fire.
Places of public assembly.	Carbon dioxide enriched atmosphere from leaking product, danger to personnel.
Railway lines.	Carbon dioxide enriched atmosphere from leaking product. Embrittlement of equipment.
Public roads.	Carbon dioxide enriched atmosphere from leaking product, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release.
Property boundaries	Carbon dioxide enriched atmosphere from leaking product, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release.
Vehicle parking areas.	Ventilator and air conditioning intakes – carbon dioxide enriched atmosphere from leaking product, danger to personnel. Embrittlement of equipment. Reduced visibility from major product release. Accessibility to the tank controls.

DESCRIPTORS	RISK
Pits, ducts & surface water drains (untrapped). Openings of systems below ground level.	Carbon dioxide enriched atmosphere from leaking product, danger to personnel. Embrittlement of equipment.
Continuous sections of pipelines containing flammable gases / liquids, not interrupted by fittings e.g. valves, unions, flanges, etc.	Embrittlement of equipment.
Flanges, unions in pipelines containing flammable gases or liquids.	Thermal radiation from fire. Embrittlement of equipment.
Flammable gas cylinder storage.	Thermal radiation from fire. Embrittlement of equipment.
Bulk flammable liquid storage up to 4 tonnes *	Thermal radiation from fire. Embrittlement of equipment.
L.P.G. storage up to 4 tonnes *	Thermal radiation from fire. Embrittlement of equipment.
Non-flammable gas cylinder storage.	Embrittlement of equipment.
Small stocks of combustible material, site huts, work sheds etc.	Thermal radiation from fire.
Areas where open flames, smoking etc are permitted.	Carbon dioxide enriched atmosphere from leaking product, danger to personnel.

Diagram 1: Distance between carbon dioxide tanks up to 2,000 litres water capacity and typical hazards.

Distances in metres

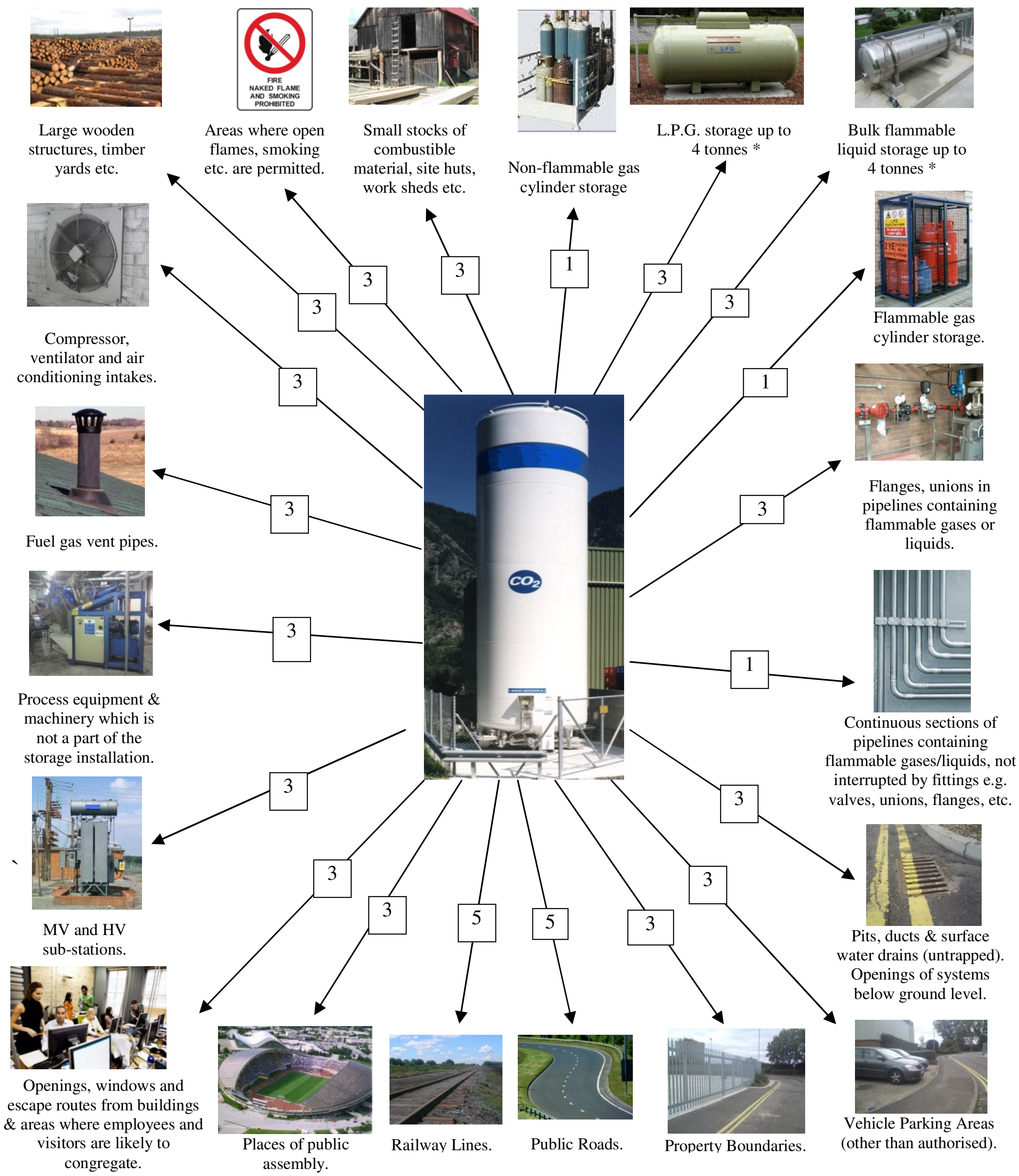


NOTE: Assumed maximum carbon dioxide liquid phase pipework diameter DN 15 (½″ nominal bore) and flammable gas/liquid pipe up to DN25 (1″ nominal bore).

* For LPG or flammable liquid tanks above 4 tonnes a risk assessment shall be carried out to establish the safe separation distance.

Diagram 2: Distance between carbon dioxide tanks from 2,000 litres to 250,000 litres water capacity and typical hazards.

Distances in metres



NOTE: Assumed maximum carbon dioxide liquid phase pipework diameter DN 50 (2˝ nominal bore) and flammable gas / liquid pipe up to DN25 (1˝ nominal bore).
* For LPG or flammable liquid tanks above 4 tonnes a risk assessment shall be carried out to establish the safe separation distance.

GUIDANCE FOR ASSESSMENT OF VENTILATION REQUIREMENTS

The type of ventilation depends on a multitude of factors such as type of location, gas type, possible leaks and process application.

Ventilation can be natural or forced. The design criterion is the number of air changes per hour.

In locations above ground level with no special ventilation openings, natural ventilation provides typically 1 change per hour. This is not the case for 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.

For handling (storing, filling, withdrawal, etc.) cryogenic vessels with non flammable, non toxic contents in locations above ground level, natural ventilation is generally sufficient provided that the room is large enough or that the outdoor area is not enclosed by walls or other obstructions. An assessment should be conducted to confirm the ventilation is adequate.

An indoor location should have ventilation openings with a total area of 1 % of the ground area. The openings should be positioned diagonally across the room with the main opening at ground level.

For more than 2 changes per hour a forced ventilation system is necessary. The specific requirement for air changes per hour will depend on the process, the working environment and local regulations.

In typical situations the number of air changes can be calculated assuming a certain leakage rate from the vessel pipework and a homogeneous distribution of gas, using the following formula:

$$C_t = 100 - \left[\frac{Vr \times n}{L + (Vr \times n)} \times 100 \right] \left[1 - e^{-t/m} \right]$$

where:

C_t = concentration at time t
L = gas release m^3/h
V_r = room volume m^3
n = air changes per hour
t = time gas has flowed in hours
m = $\frac{Vr}{L + n\,Vr}$

For long periods (t tending to infinity):

$$C_\infty = 100 - \left[\frac{Vr \times n}{L + (Vr \times n)} \times 100 \right] \text{ approximately}$$

CALCULATION FOR SITING TANKS IN BUILDINGS

This appendix considers the "worst case" scenario where the entire contents of the vessel are lost to the room immediately. The resulting CO_2 concentration in the room may then be calculated from the following formula:

$$CCO_2 = \frac{Vo}{V_R} \times 100$$

where:

CCO_2 = Resulting carbon dioxide concentration %
Vo = Maximum gas release m³ of CO_2
= Liquid volume capacity of the vessel (m³) x 543 (gas expansion factor fg)
V_R = Room volume m³

Worked Example

To calculate the CO_2 concentration resulting from a release of 50 litres of liquid carbon dioxide into a room of 300 m^3 volume:

V_R = Room volume = 300 m^3

Vo = Gas release from vaporised liquid = $\frac{50}{1000}$ x 543 = 27 m^3

$$CCO_2 = \frac{27}{300} \times 100 = 9\ \%$$

This carbon dioxide concentration is close to life threatening levels. As carbon dioxide is mildly toxic, the HSE have defined an occupational exposure limit of 0.5 % averaged over 8 hours, with a maximum exposure of 1.5 % for short periods of 15 minutes. Additional precautions such as increased ventilation and gas detection would be required to increase the safety of such an installation.

INDOOR INSTALLATION

Precautions for indoor siting

When the storage vessel is to be sited in a room within a building, the following precautions shall be taken.

(i) The room shall normally be unoccupied, locked and should be completely and permanently sealed off from any other parts of the building.

(ii) The room must be provided with suitable means of exit (at least 2 at widely separated positions) and adequate ventilation. Methods of calculating the requirements for ventilation are detailed in Appendix 3 and in BCGA Guidance Note 11 (24). The exits shall be provided with doors which open outwards to the open air.

(iii) The liquid CO_2 filling and gaseous CO_2 balance connections shall be piped to a suitable open-air loading point. The vessel pressure and level indications should be duplicated at the fill connections.

(iv) The outlets from each relief valve must also be piped to a safe discharge point in the open air and should incorporate the safety considerations specified in Section 2.4.4. Vent lines shall be properly designed and sized taking account of anticipated back-pressure so that the pressure relief device can vent the vessel or piping safely.

(v) An indoor storage room is always considered to be subject to a risk of an atmosphere containing above 1.5 % carbon dioxide thus monitoring will be required in accordance with Section 2.4.1.

Duties of users

Before allowing anyone to enter the CO_2 tank room, the user shall comply with all of the Confined Spaces Regulations (3). This places a statutory duty on users to define a system of operation which renders such entry safe and without risks to health.

PLAN VIEW OF TYPICAL LIQUID TRANSFER AREA ACCESS APRON AND TANKER STANDING AREA

1. All distances "A" to be minimum of 1 metre.
2. All distances "B" to be minimum of 2 metres.
3. Apron to be of concrete or other load bearing material.